TESTING AGRICULTURAL and VEGETABLE SEEDS

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Manual for

TESTING AGRICULTURAL AND VEGETABLE SEEDS

UNITED STATES DEPARTMENT OF AGRICULTURE

Production and Marketing Administration
in cooperation with the Bureau of
Plant Industry, Soils, and Agricultural Engineering

Most of the work on this manual was
performed under a project authorized by the
Research and Marketing Act of 1946

AGRICULTURE HANDBOOK No. 30

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The original drawings of seeds were done by F. H. Hillman, the late Helen H. Henry, and Regina O. Hughes. The following contributed to the preparation of the manual by writing one or more sections: Alice M. Andersen, Harriet Cull, Vera C. Drake, Frieda L. Wertman, Bruce Caldwell, Charles A. Kent, Jr., and Lawrence Zeleny. Magdalene Brummit, Mary Haferkamp, Constance Sleeper, Lillian Wessel, and other members of the Seed Act Division, assisted with the preparation of the manuscript. W. A. Davidson and R. H. Black reviewed it and offered helpful suggestions.

Acknowledgment is made to numerous workers in Federal, State, Canadian, commercial, and private seed-testing laboratories. Their contributions have been of inestimable value in the preparation of this manual. Credit is also due certain firms that manufacture or handle seed-testing equipment for supplying some of the photographs of equipment.

Most of the work on this manual was performed under a project authorized by the Agricultural Marketing Act of 1946 (RMA, Title II).

PREFACE

In the field of seed technology there is a wealth of technical information that has never been brought together in a form immediately available to laboratory workers. Some of this information has been published in journals and proceedings of associations and societies of widely differing interests, and in mimeographed form, whereas some has never been published. In order that much of the practical information may be readily available to seed technologists, instructions for conducting laboratory tests and pertinent background information are set forth in this publication.

With respect to the results obtainable in seed testing there are two principal requirements: (1) The results should indicate, as nearly as possible, the actual planting quality of the seed lot; and (2) the tests should be made in such a manner that the results can be reproduced within calculated limits. During the last 50 years seed testing in the United States has developed to the extent that rather specific rules or instructions for carrying out the tests have been devised and published. These rules are the basic guides for officially testing seed in the administration of Federal and State seed laws and are generally followed by private and commercial technologists as well. In spite of these specific rules, however, wide variations frequently exist among laboratories, with respect to test results on seeds of the same quality. One of the principal reasons for these variations is the lack of detailed instructions for the application of the rules for seed testing.

This manual has been prepared primarily as a working tool to be used for instruction purposes aimed at reducing the variations in test results. If used by seed technologists generally, the manual can serve as an important instrument in standardizing procedures, equipment, and interpretations with the result that these variations should decrease. It may also serve temporarily as an instruction manual in agricultural colleges and provide the necessary incentive to encourage additional colleges to offer instruction in seed technology, thus alleviating the present critical personnel situation.

Seed technology covers a broad field. It includes a knowledge of seeds of agricultural, vegetable, flower, herb, orchard, and forest plants as well as of equipment and supplies essential to testing. Owing to the fact that this manual has been prepared primarily for technologists working on those kinds of commercial seeds which are subject to Federal and State regulation, the information contained herein is limited to agricultural and vegetable seeds, domestic or imported.

An attempt has been made to present the information in the most usable arrangement without undue repetition. To accomplish this it seemed necessary to include in certain sections information applicable to many or all kinds of seeds and in other sections information applicable to smaller but related groups of seeds. Those workers and students who may be interested in more basic information pertaining to seeds will find three brief treatments near the back of the

manual under the headings: "Development, Structure, and Hereditary Characteristics of Seeds," "Physiology of Seeds," and "Pathological Considerations in Seed Testing." In order to present the information in a concise manner it was necessary to use certain technical and infrequently used common terms. Thus, a glossary of terms has been provided for the reader on pages 319 to 327.

This manual supersedes Miscellaneous Publication No. 437, *Testing Farm Seeds in Home and School*, published in 1942.

CONTENTS

	Page
Introduction	1
Rules for testing seed	1
Federal Seed Act	3
State seed laws	3
Seed-testing laboratories in the United States	4
Seed sampling and testing equipment	5
Sampling equipment	5
Air blast for cleaning seed dividers	12
Equipment for purity testing	12
Equipment for germination testing	21
Greenhouse	35
Filing cabinets	36
Obtaining the seed sample	37
Sampling the seed lot	37
Reducing the sample in the laboratory	39
Care of samples	40
Procedures for determining purity composition	42
Accommodations	42
The use of equipment	42
The purity separation	46
Separating seeds of similar kinds and varieties	47
Interpretation of crop seed	47
Interpretation of weed seed	49
Special tests and procedures	52
Application of purity procedures to specific groups of seeds	54
Gramineae (grass family)	55
Leguminosae (legume or pea family)	73
Valerianaceae (valerian family)	80
Umbelliferae (carrot family)	80
Solanaceae (nightshade family)	80
Polygonaceae (buckwheat family)	81
Malvaceae (mallow family)	81
Linaceae (flax family)	81
Liliaceae (lily family)	82
Geraniaceae (geranium family)	82
Cucurbitaceae (cucurbit family)	82
Cruciferae (mustard family)	83
Compositae (composite family)	84
Chenopodiaceae, Cannabinaceae, and Aizoaceae (goosefoot, hemp, and carpetweed families)	84
Procedures for determining germination	86
Definition and object	86
The kinds and use of substrata	86
Preparing the test	92
Provision and maintenance of environmental conditions	94
Interpretation of the germination test	96
Methods of overcoming dormancy	101
Special procedures	103
Application of germination procedures to specific groups	107
Aizoaceae (carpetweed family) and Chenopodiaceae (goosefoot family)	107
Compositae (composite or sunflower family)	113
Cruciferae (mustard family)	119
Cucurbitaceae (cucurbit family)	124
Gramineae (grass family)	126
Leguminosae (legume or pea family)	142
Liliaceae (lily family)	160
Linaceae (flax family)	162
Malvaceae (mallow family)	164
Polygonaceae (knotweed family), Solanaceae (nightshade family), Umbelliferae (carrot family), and miscellaneous kinds in other families	167
Examination for noxious-weed seeds	172
Object and nature of test	172
State and regional lists of noxious-weed seeds	172
Size of sample	172
Conducting the examination	173
Interpretation of seeds	174
Expressing the rate of occurrence	174
Origin of seeds	175
Importance of origin determination	175
Size of sample for origin determination	175
Evaluation of impurities	175
Major seed-producing regions	176
List of seed impurities available	177

	Page
Testing for trueness of variety	178
Scope of variety testing	178
Purpose of variety testing	178
Authentic samples for controls	178
Number of plants to grow	178
Testing in the field	179
Testing in the greenhouse	180
Judging the crop	181
Testing for moisture	183
Basic methods	183
Practical methods	185
Tolerances	187
Definition and necessity of tolerances	187
Probability or degree of certainty	188
Pure-seed tolerances	188
Germination tolerances	189
Noxious-weed seed tolerances	189
Tolerances for fluorescence tests and other 400- to 1,000-seed separations	189
Application of tolerances	190
Calculations, records, and reports	191
Calculation of laboratory test results	191
Laboratory records	193
Reporting the results of tests	193
Identification of seeds	194
(Also see List of Plant Names for Others Which Are Illustrated Only)	
Gramineae (grass family)	195
Caryophyllaceae (pink family)	232
Cruciferae (mustard family)	233
Leguminosae (legume or pea family)	237
Convolvulaceae (morning-glory family)	258
Development, structure, and hereditary characteristics of seeds	263
The flower	263
Development of the ovule	263
Development of the pollen grain and the generative cells	264
Fertilization	264
Types of ovules	264
Development of the seed in monocotyledonous plants	265
Development of the seed in dicotyledonous plants	269
The seed	271
Hereditary qualities of the seed	271

	Page
Physiology of seeds	273
The resting seed	273
The process of germination	273
Environmental conditions affecting germination	275
Physiology of dormancy	278
Retention of viability in seeds	281
Duration of viability	282
Mechanics of germination	283
Pathological considerations in seed testing	284
Seeds as hosts and carriers of organisms causing disease and injury	284
How seed-borne organisms are carried	285
Relation of host and parasite	285
Effect upon the host seed	286
Methods	292
Partial list of pests and injury conditions	293
Literature cited	297
Selected references	300
Purity determination	300
Physiology and germination	302
Identification of seeds	310
Testing for variety	312
Pathological considerations	312
Morphology	313
Sampling	314
Tolerances and statistics	315
Equipment	315
Origin	316
General	316
Available publications on seed testing	318
Glossary	319
Appendix	328
Rules for testing seeds	328
Sample record and report forms	369
List of botanical names	373
Index for identification, purity, and germination	373
List of plant names	395
Index for identification, purity, and germination	395
List of botanical and common names	417
Index	425

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Bureau of Plant Industry, Soils, and Agricultural Engineering
Agricultural Research Administration

INTRODUCTION

SEED is both an important item in commerce and a basic commodity in agriculture, being essential for the propagation of crops and perpetuation of germ plasm. It is of extreme importance that the grower know something of the quality of the seeds he plants. However, it is not possible for the average person interested in seeds to learn much of their quality by visual examination. Thus, the responsibility of providing information pertaining to seed quality has been placed upon the seed merchant, and State and Federal governments are charged with the responsibility of checking to determine whether the requirements are carried out.

To meet these responsibilities, the seed must be tested (1) by the seed merchant in order to label it properly, and (2) by the seed control official to determine whether it is correctly labeled when offered for sale. The primary objective in seed testing is to obtain accurate and reproducible results regarding the purity composition, rate of occurrence of noxious-weed seeds, and percentage of seeds that can be expected to produce normal plants under favorable conditions. In some instances such additional information as presence of seed-borne fungi, origin, or varietal purity, is desired. Thus, seed testing provides information for: (1) Planting purposes; (2) labeling purposes; (3) establishing prices; and (4) seed control work.

RULES FOR TESTING SEED

The result of a test on a seed sample should be a fair measure of its quality and the test should be made by such methods that the results can be reproduced by other laboratories testing like samples. To make the latter possible, rules for seed testing have been developed and published. The present rules are rather specific in their require-

ments, which is essential if uniform test results are to be expected. Although specific rules are desired, caution must be observed in developing them so as not to exclude the proper testing of seed stocks which do not respond to the usual testing conditions for the kinds under consideration. Frequently, seed lots of a given kind differ in their germination requirements, the difference depending on such factors as: (1) Length of time between harvest and test date; (2) conditions during seed maturation; and (3) storage conditions subsequent to harvest.

The rules for seed testing must be practical and capable of application. Owing to the large number of samples that laboratories are expected to test, the methods must permit testing with a minimum of effort and time on the part of the analyst, and the demands for early test results usually require that the tests be completed within the least number of days possible. Formerly, the work load in many laboratories was not heavy and many samples could be handled as minor research problems, but that is not possible in the average laboratory today.

The earliest rules for seed testing in the United States were published as Circular No. 34 of the Office of Experiment Stations, United States Department of Agriculture, in 1897, under the title "Rules and Apparatus for Seed Testing." There have been numerous revisions and improvements in the rules since that time, some revisions having been published by the United States Department of Agriculture and some by the Association of Official Seed Analysts. Two sets of Rules for Seed Testing are in use in the United States. These have been developed jointly by the U. S. Department of Agriculture and the Association of Official Seed Analysts and are published separately by each (*48*, *6*).[1] Owing to the close cooperation in developing the rules there are only a few minor differences in the two sets of rules. Hence, the expressions "Rules for Seed Testing" or "rules" as used in this publication will refer to both sets of rules. These can be found on pages 328 to 368 in this manual.

Seed-testing stations in other countries have their own rules for seed testing. The Scandinavian countries have developed a set of rules to be used in Denmark, Norway, and Sweden. The International Seed Testing Association has had a set of international rules in effect since 1934. These rules are rather general but are currently being revised along the lines of the American and Canadian rules.

Improvement in the methods of testing seed is highly desirable. It may include: (1) Reducing the total amount of effort required in making the tests; (2) completing tests within a shorter period of time; (3) obtaining more accurate and uniform results than present methods permit; (4) new kinds of agricultural and vegetable seeds; and (5) additional groups of seeds such as flower seeds and tree seeds. There are two means of obtaining data for improving the methods of testing: (1) By accumulation of results from routine testing, particularly when more than one method is employed; and (2) through research designed to solve specific problems. Both methods have been important in developing the present rules but most improvements in technique at present result from research. This will probably continue to be the case in the future.

[1] Italic numbers in parentheses refer to Literature Cited, pp. 297 to 299.

FEDERAL SEED ACT

It is not within the scope of this manual to set out the complete details of Federal and State laws and regulations relating to the sale, transportation, and distribution of seed. The Federal Seed Act, enacted by the United States Congress in 1939, applies to imported seed and to seed in interstate commerce.

IMPORTED SEED

Agricultural and vegetable seeds imported into the United States must meet minimum standards for pure-live seeds, must not contain more than 2 percent by weight of weed seeds, and must not contain designated noxious-weed seeds in excess of the number specified in the act. Imported alfalfa and red clover seeds must be stained to indicate origin. Imported seed is not required to be labeled but if labeled the information must not be false or misleading in any respect.

SEED IN INTERSTATE COMMERCE

Agricultural seed moving in interstate commerce is required to be truthfully labeled to show: (1) The name of each kind, kind and variety, or kind and type of agricultural seed present in excess of 5 percent; (2) percentages of pure seed, other crop seed, weed seed, inert matter, germination, and hard seeds, when present; (3) the name and rate of occurrence for each secondary or permissible noxious-weed seed and otherwise to comply with the noxious-weed seed requirements of the State into which the seed is shipped; (4) the date the test was made to determine the percentages of germination and hard seeds shown on the label, and the test is required to have been made within a 5-month period prior to shipment; (5) lot designation; and (6) name and address of shipper or name and address of consignee together with the shipper's code designation.

Vegetable seed is required to be labeled to show: (1) The name of the kind and variety; and (2) name and address of shipper or name and address of the consignee together with the shipper's code designation. Vegetable seed must meet the minimum germination standards established under the Federal Seed Act, or, if below standard, must be labeled to show the percentage of germination, the percentage of hard seed when present, the date of test, and the words "Below Standard."

STATE SEED LAWS

The interstate section of the Federal Seed Act is frequently referred to as a Truth-in-Labeling Law and represents the pattern of the State seed laws. However, there is considerable variation in detail among the State seed laws. For example, a few States require that the name of the variety be given on the label for agricultural seeds. Some require that the germination test shall not have been made more than 6 months prior to the date the seed is sold whereas other States permit as much as 12 months to elapse after the test and before sale, and a few do not make any reference to the date of test.

The State seed laws differ more in their noxious-weed seed requirements than in any other respect. This difference applies to both the manner in which the amounts of noxious-weed seeds are expressed and in the species considered noxious. Although each State has its indi-

vidual list of noxious-weed seeds some measure of success has been attained with respect to establishing noxious-weed lists on a regional basis.

Most States have a list of noxious-weed seeds which are prohibited, and another list of seeds which are permitted up to an established maximum provided the name and rate of occurrence of each kind appear on the label. In some States the former are referred to as "Prohibited Weeds" and in other States as "Primary Noxious Weeds." Weeds falling into the second list are usually referred to as "Secondary Noxious Weeds." The early seed laws were enacted to protect the consumer, but more recently it has become evident that good seed laws coupled with good administration offer protection to the scrupulous seedsman as well as to his ultimate customer.

SEED-TESTING LABORATORIES IN THE UNITED STATES

In order to carry out the intent of the laws pertaining to seeds, each State or Federal agency charged with administering such laws must have means of testing seed samples. The seed laws in most States are administered by the State departments of agriculture, although in a few States administration of such laws is the responsibility of the State colleges of agriculture or experiment stations. In approximately one-half of the States the official seed-testing laboratories are located in the State departments of agriculture, whereas in approximately 20 States they are located at the State colleges of agriculture or experiment stations. In 4 States other provisions are made for testing.

The Federal Seed Act is administered by the Grain Branch, Production and Marketing Administration, U. S. Department of Agriculture. All testing incident to the administration of the act is carried out by the Grain Branch, except that a few samples are tested annually by the seed laboratory of the Board of Commissioners of Agriculture and Marketing, Honolulu, T. H. Federal stations are located at Beltsville, Md., New Brunswick, N. J., Minneapolis, Minn., Montgomery, Ala., and Kansas City, Mo. Federal-State cooperative stations are located at Sacramento, Calif., and Corvallis, Oreg.

The Federal seed laboratories do not conduct service tests for the general public but most State laboratories perform this service insofar as their personnel and facilities permit. In some States, service testing is limited to residents of the State but in other States there are no such restrictions. A high percentage of the seed in commercial channels is tested by commercial and private technologists. Commercial laboratories are operated on a fee basis to serve the general public, particularly such groups as seedsmen and farmers. Private laboratories are operated by seed firms, solely or principally for their own use. Since the test results obtained by commercial and private analysts are ordinarily used for labeling seed in commercial channels, such analysts find it necessary to follow the official rules for seed testing.

SEED SAMPLING AND TESTING EQUIPMENT

SAMPLING EQUIPMENT

TRIERS OR SAMPLERS

Triers are commonly used in sampling seeds in bags and bins. The most commonly used instrument is known as a sleeve-type trier which consists of a hollow brass tube inside a closely fitting outer shell or sleeve. The tube and sleeve have open slots in their walls so that when the tube is turned until the slots in the tube and sleeve are in line, seeds can flow into the cavity of the tube, and when the tube is given a half turn the openings are closed. The tubes vary in length and diameter, being designed for different kinds of seed and sizes of bags. In sampling seed in bags the following sizes of triers have been found suitable: For clovers and other small, free-flowing seed, 30-inch trier with outside diameter of ½ inch and 9 slots; for cereals, 30-inch trier with outside diameter of 1 inch and 6 slots. The 11-inch bag trier which is only ⅜ inch in diameter may be used to advantage in sampling small bags of clover and similar seeds. It is a sleeve-type trier with a single slot in the outer casing near the pointed end. Seed is admitted into the tube by withdrawing the tube past the slot. This trier makes a very small hole which is important in sampling seed in cotton bags; however, it should not be used in sampling large bags as the trier is not long enough to reach the most distant parts.

Bin samplers are constructed on the same principle as seed triers but are much larger, ranging up to 63 inches in length and 1½ inches in diameter with 6 or 9 slots. Many seed inspectors use a 6-, 9-, or 12-inch thief-type trier. This trier is not described because its construction and size do not permit sampling in accordance with the rules. Different types of triers are illustrated in figure 1.

DIVIDERS

Soil divider.—Perhaps the most simply constructed divider suitable for seed-testing work is the soil sampler which consists of a hopper with attached channels or ducts, a frame to hold the hopper, two receiving pans and a pouring pan (fig. 2). Ducts or channels, ½ inch wide, lead from the hopper to the collecting pans. There are 18 of these channels, alternate ones leading to opposite sides. The maximum dimensions are: 14 inches long; 10 inches wide; and 11 inches high. In using the divider the seed is scattered fairly evenly in a pouring pan the length of the hopper and poured in at approximately equal rates along the entire length of the hopper. This sampler is used in dividing samples of large seeds and chaffy grass seeds.

Boerner dividers.—The most commonly used mechanical seed dividers at the present time are the Boerner dividers. There are two dividers which differ in size, but which are made on the same plan. The essential parts consist of a hopper, inverted cone, and a series of baffles directing the seed into two spouts. The baffles form alternate

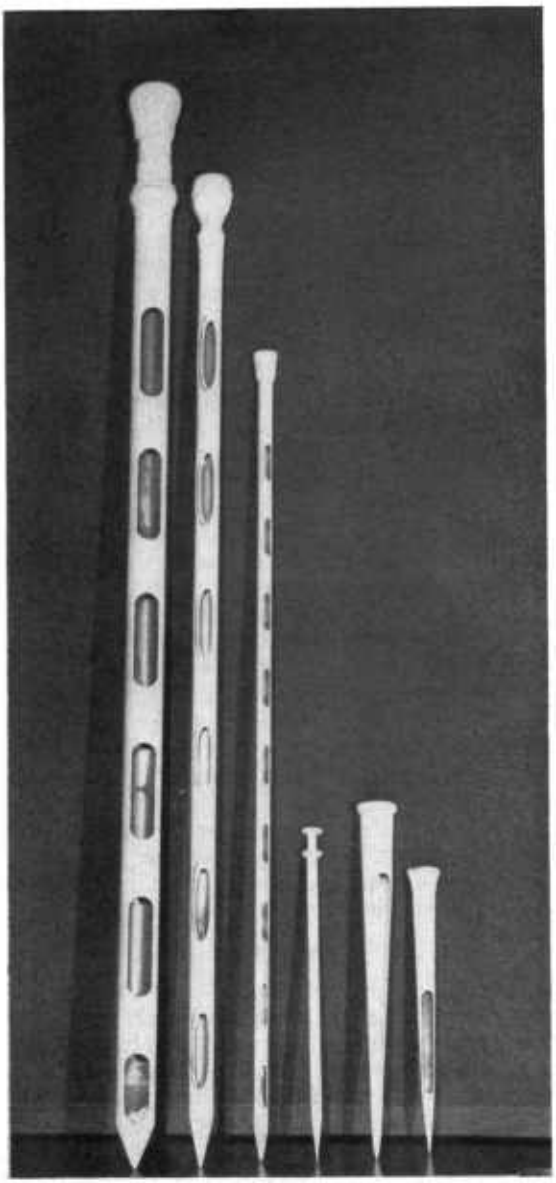

FIGURE 1.—Sleeve-type seed and grain triers. From left to right: Bin sampler for grain; bag trier for grain; bag trier for clovers and other small seed; 11-inch bag trier; two thief-type triers that are not recommended.

channels and spaces of equal width. They are arranged in a circle at their summit and are directed inward and downward, the channels leading to one spout and the spaces to an opposite spout. A valve or gate at the base of the hopper retains the seed. When the valve is opened the seed falls by gravity over the inverted cone where it is evenly distributed to the channels and spaces, then passes through the spouts into the seed pans.

In the large divider, designed for large seeds and grains, there are 19 channels and 19 spaces, each 1 inch wide. In the small divider, designed for small free-flowing seeds, there are 22 channels and 22 spaces, each $\frac{5}{16}$ inch wide. The over-all dimensions of the dividers are as follows: Large divider, 32 inches high and 14.5 inches in diameter; small divider, 16 inches high and 6 inches in diameter.

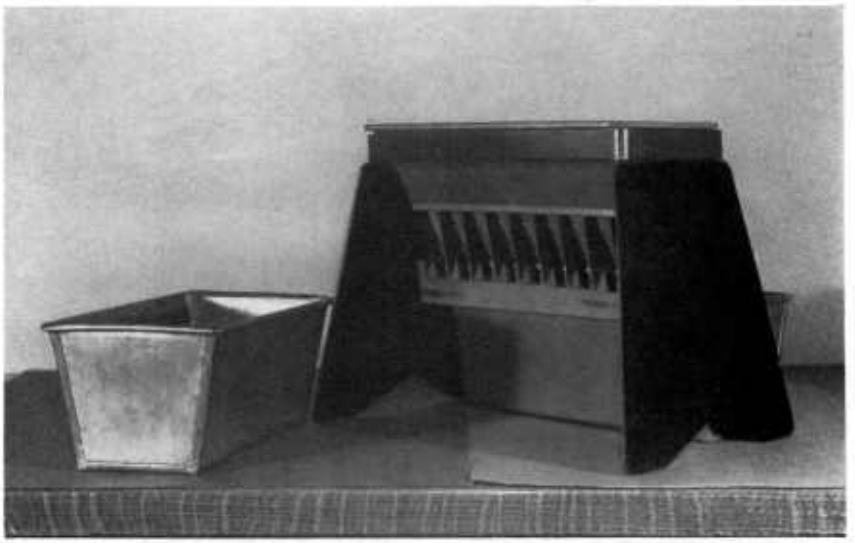

FIGURE 2.—Soil divider. A good divider for large seeds, such as corn and beans, and for chaffy grass seeds.

The following construction features should be observed when purchasing a Boerner divider: (1) The sliding valve should move with ease but not allow seeds to pass along the edges when closed; (2) sharp angles should be reduced to a minimum and there should be no small openings or rough edges on surfaces over which seeds flow. Seeds may lodge in these angles and crevices and be carried into other samples. The Boerner dividers are illustrated in figure 3.

Kny-Scheerer divider.—In the Kny-Scheerer divider the seed is spun around in a rotating hopper and divided into two approximately equal parts as it flows downward. The funnel-shaped hopper with valve is rotated by a hand-operated crank. While in motion the seeds are spun around with the hopper, and the valve is gradually opened either by screw adjustment or by manual manipulation. As the seed falls downward it is divided into two parts by stationary baffles and passes through spouts into the receiving pans (fig. 4).

Gamet precision divider.—The Gamet divider (fig. 5) makes use of centrifugal force to mix and scatter the seeds over the dividing surface. In this divider the seed flows downward through a hopper on a shallow rubber cup. Upon rotation of the rubber cup by an electric motor the seeds are thrown out by centrifugal force and fall downward. The circle or area where the seeds fall is equally divided into two parts by a stationary baffle so that one-half the seeds fall in one spout and one-half in the other spout. In using this divider care must be exercised in dividing very small samples as it is possible that a majority of the seeds may come out in one spout.

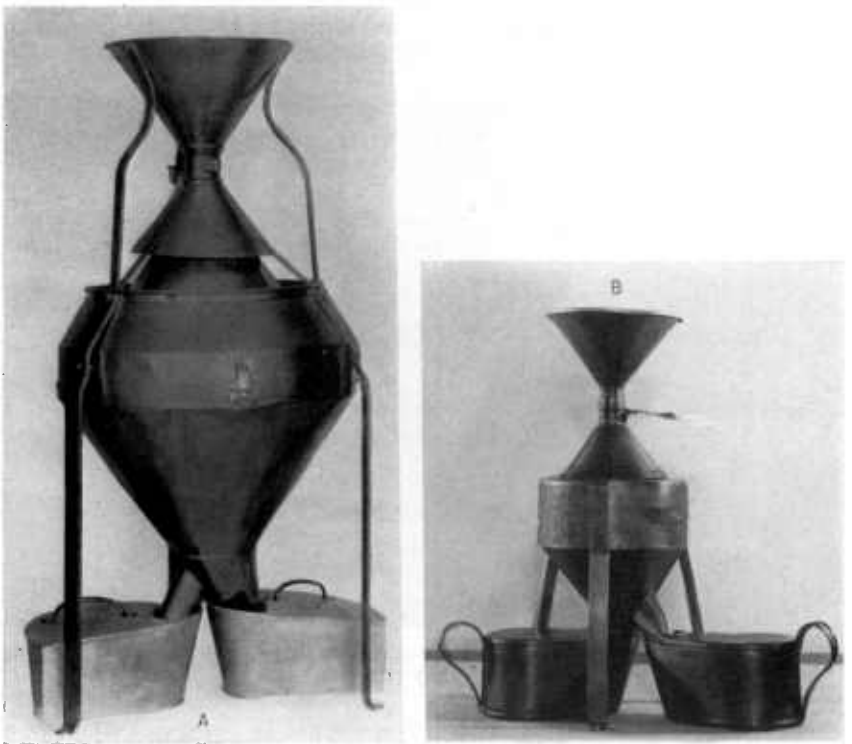

FIGURE 3.—Boerner dividers: *A*, Designed for dividing cereals and other large seed; *B*, designed for clovers and other small, free-flowing seed.

Hay-Bates divider.—This is a rather large divider intended primarily to eliminate undesirable dust when dividing seeds such as beet and chaffy grasses, and those treated with poisonous fungicides (fig. 6). The principle involved in dividing the sample is similar to that employed in the Boerner divider. However, instead of a circular arrangement of the channels, the construction and arrangement are similar to those of the soil divider previously described. The baffles which divide the neck of the hopper into equidistant channels are built into the hopper. This entire unit can be removed and replaced with hoppers having channels designed for three sizes of seeds. The seeds fall downward for a considerable distance through two cavities, each leading to

a separate seed pan. At the rear of the divider is a small vacuum attachment operated by an electric motor, the speed of which is regulated by a rheostat. In operation, the vacuum motor is turned on and the rheostat adjusted so there will be a slight suction in the

FIGURE 4.—Kny-Scheerer divider.

cavities through which the seed falls. Any dust extracted from the seed is collected in a bag attached to the vacuum outlet.

Ottawa divider.—The Ottawa divider (fig. 7) is a precision divider intended for use with free-flowing seeds the size of flax and smaller. The seed is introduced into a hopper and then falls down a shaftlike

column during which time it undergoes repeated divisions and recombinations to insure proper mixing. Near the bottom of the column is a movable baffle resting on knife edges of regular balance construction. The tilt of the baffle determines the proportion of seed that will

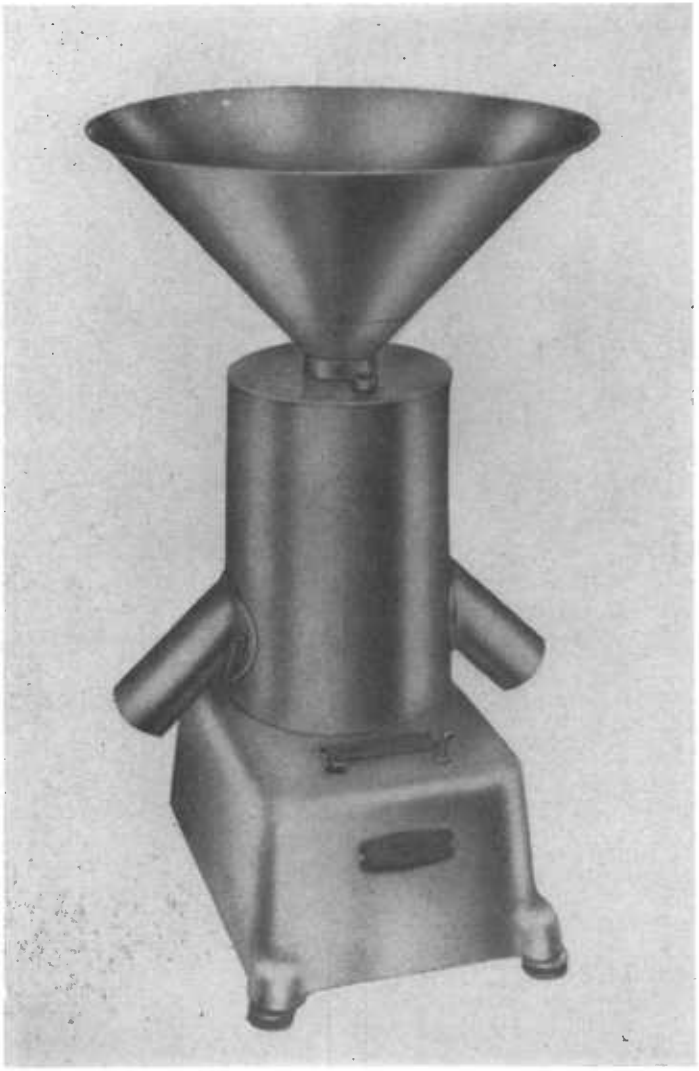

FIGURE 5.—Gamet divider; also known as Gamet precision divider.

flow into each of the two seed pans. To divide the sample into two parts of equal weight the seed is allowed to run gently through the leveled divider without any further adjustment. Unequal divisions can be made as desired by adding weights to one of the pans.

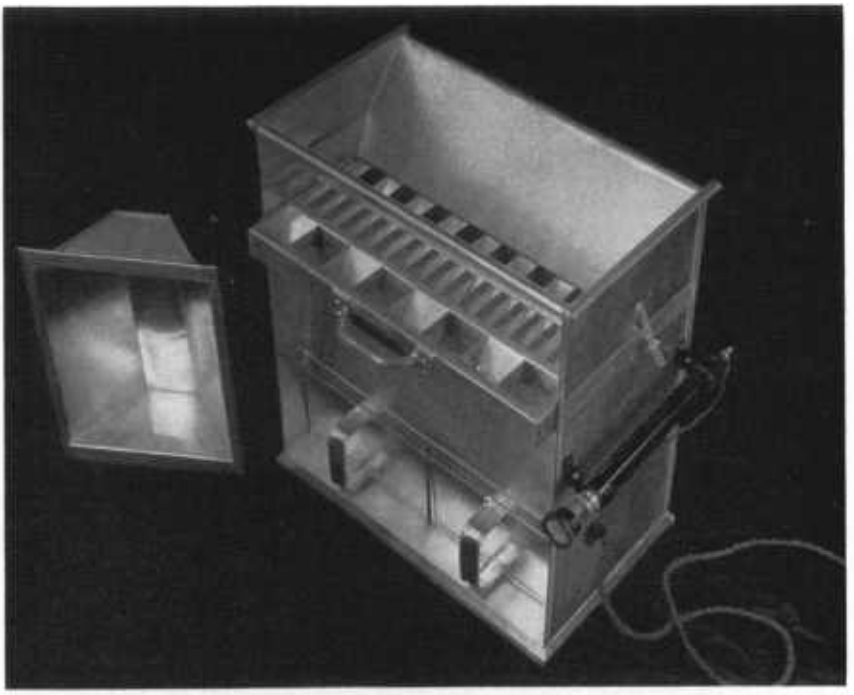

FIGURE 6.—Hay-Bates divider. Seed pouring pan on left.

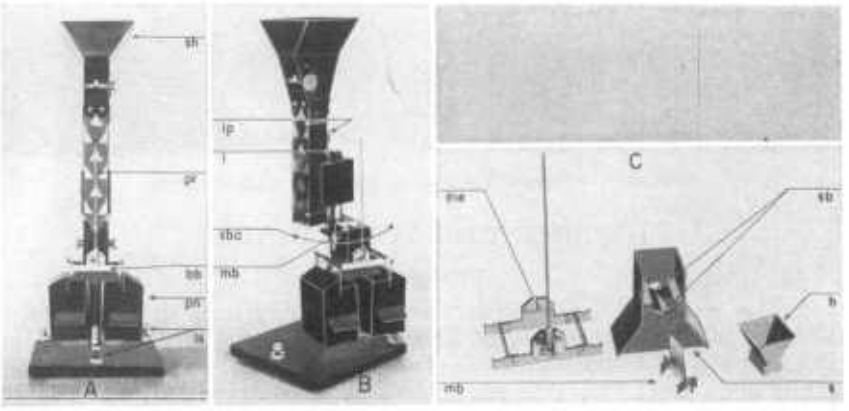

FIGURE 7.—Ottawa divider: *A*, front view; *B*, dividing column swung around; *C*, details of balance construction and hopper. Explanatory legend: *sh*, seed hopper; *pr*, pointer; *bb*, balance beam; *pn*, pan; *ls*, leveling screws; *lp*, lock pin; *l*, level; *sba*, spout and balance mechanism swing away; *mb*, movable baffle; *me*, mounting for knife-edge and indicator; *sb*, seating for movable knife-edge of movable baffle; *h*, hopper; *s*, spout.

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AIR BLAST FOR CLEANING SEED DIVIDERS

It is imperative that seed from one sample not become commingled with other samples. However, this is always a possibility in dividing the samples unless the greatest precaution is taken to dislodge any seed that may remain in the divider. Air blast can be used to clean this equipment. Laboratories which are housed in regular laboratory buildings usually have air lines hooked up with a central pumping system. In the absence of a central system a small portable electric blower can be obtained. A convenient and useful portable blower is illustrated in figure 8.

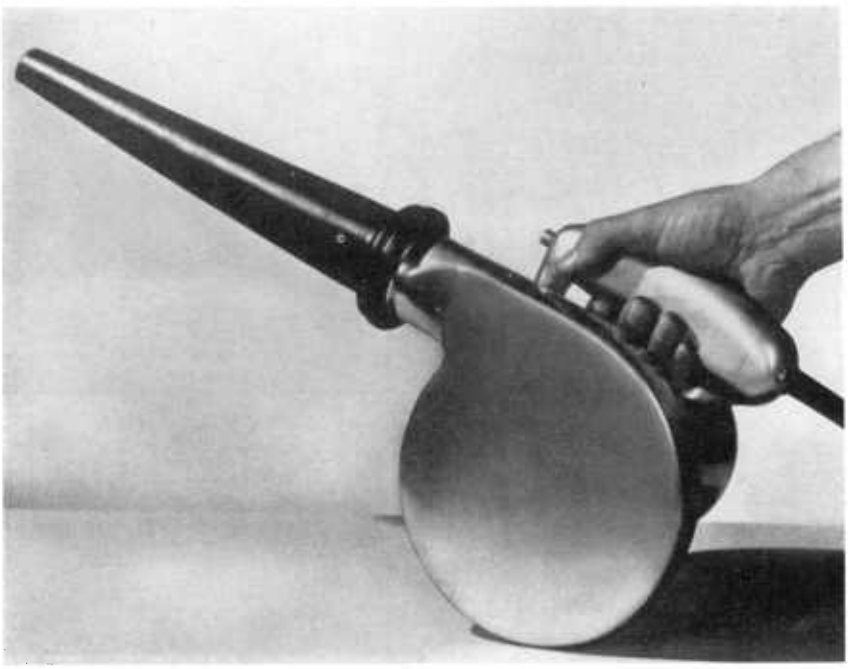

FIGURE 8.—Blower for use in cleaning seed dividers.

EQUIPMENT FOR PURITY TESTING

WORKBOARD

Tables or desks at which analysts make purity tests should average 30 or 31 inches high. In order to minimize fatigue of the eyes, neck, and shoulders the work must be elevated 3 to 6 inches above the level of the table top. This is accomplished by a workboard which is illustrated in figure 9. The height of the workboard should be constructed in accordance with the individual's needs, and the slope of the arm rests is important in reducing fatigue of the arms and shoulders. There are several modifications of the workboard, especially with respect to the covering. The top of the workboard illustrated in figure 9 is constructed of soft wood so that thumbtacks may be used to fasten a heavy grade of paper on which the seed is placed. Some

analysts prefer a glass slab as a working surface. If plate glass is used, it should be covered with nonglare and nonreflecting paper. A small drawer may be built into the workboard to hold forceps, lenses, and similar instruments or as a receptacle for the pure seed component. The arm rests may be attached to the body of the workboard at about a 30-degree angle from the horizontal. This provides support to the arms for a greater distance than in the model illustrated.

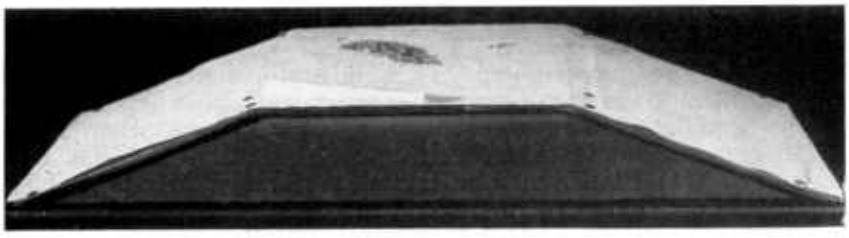

FIGURE 9.—Workboard, the working surface of which is made of soft wood and covered with paper as described in text.

FORCEPS AND SPATULA

Fine-pointed forceps are necessary for testing small seeds and are usually preferred over blunt forceps when testing larger seeds. Forceps are not standardized but for purity work they should be slightly flexible, offer slight resistance to pressure, and should be about as sharp as a common pin. Some analysts prefer to make the separations with a spatula or horn.

MAGNIFIERS

A 5 ×-, 6 ×-, or 7 ×-hand lens with wide field is necessary and will meet most of the seed analyst's requirements. The doublet-type magnifier is not satisfactory because the focal distance is so short the observer's hand and head usually cast a shadow on the seed being analyzed and the correction is not sufficient to give a plane field. The triple aplanat (triplet) magnifier is preferred and usually has good correction.

Reading glasses may be useful in making noxious-weed seed examinations on seeds the size of vetch and cereals. There are reading glasses (1) with handle for holding in the hand, (2) mounted on an adjustable stand, and (3) mounted on a flexible arm attached to a heavy base. The principal objection to reading glasses is the curved field which they give, resulting in eyestrain.

MICROSCOPE

A wide-field stereoscopic microscope with at least 3 pairs of objectives giving magnifications of approximately 10 to 15, 20 to 40, and 50 to 75 is essential. Microscopes with a revolving nosepiece are preferable to those having removable objectives. A compound microscope is not essential for purity work.

SCALES AND BALANCES

A scale having a capacity of at least 1,000 grams and accurate to 0.5 gram is essential. A rapid-acting scale is highly desirable. Table

models having a calibrated face behind a movable indicator are available. The weights can be read almost immediately in grams to an accuracy of 0.5 gram.

A torsion balance having a capacity up to approximately 120 grams and accurate to 0.01 gram is standard equipment. The working parts should be enclosed in a glass case and the pans protected with a hinged glass cover or hood for increased accuracy in weighing.

A chainomatic analytical balance with notched beam, or a keyboard-type balance, with sensitivity of 0.05 milligram is required. Numerous balances are satisfactory. A magnetic damping device will reduce the time required for weighing. Large laboratories will probably find it economical to use one of the new type semiautomatic balances, such as the "gram-atic" balance, even though they are very expensive.

To keep scales and balances in proper operating condition, they should be: (1) Placed on solid tables (preferably stone-top tables) which are not subject to vibration; (2) checked at the beginning of each series of use to see that they are in balance; and (3) checked regularly (about once a year) by a factory representative or some other person completely familiar with their construction and use.

SEED CONTAINERS

Several kinds of seed containers should be readily available to the analyst. These include shell vials with cork stoppers, Petri dishes, 50 cm. in diameter and 10 cm. high, sets of aluminum dishes which nest together when stacked, gelatin capsules, and envelopes of assorted sizes.

SAMPLE PANS

Sample pans are of different sizes but all should be tapered at one end to serve as a spout when pouring the seed. They should have no sharp angles, rough surfaces, or cracks in which small seeds may get lodged.

SIEVES

Each laboratory should have at least one set of dodder sieves, consisting of 10 to 12 sieves with diameter of the holes ranging from 0.5 mm. to 3.5 mm., and additional sieves with round holes as well as rectangular and oval slots. The sizes of openings should be graduated at close intervals and designed for the kinds of seeds tested. The bottom should be of single piece construction and the angle made by junction of the bottom and sides should be rounded out to prevent the lodging of seeds. Dodder sieves are illustrated in figure 11 *C* and *D*.

DIAPHANOSCOPE

So far as is known there is no commercial firm in the United States that manufactures a diaphanoscope. The principle of the diaphanoscope makes use of a beam of light directed obliquely upward through a small hole in the top of a workboard or similar base. Outside light should be excluded or reduced considerably for best results. A satisfactory diaphanoscope can be constructed as follows: Use an ordinary workboard 4 to 6 inches high and through its top bore a 1¼-inch hole, centrally located from end to end and 2 inches from the front side. Mount a concave mirror below and to one side of the opening so it will receive light from the direction of the back of the board and reflect it obliquely through the small hole in the top of the workboard,

away from the worker's eyes. Cut a slot in the rear of the workboard to allow light to enter. A microscope lamp placed on the table behind the workboard with its beam directed against the mirror will provide the necessary illumination. If desirable a reading glass can be used as a condenser by placing it between the lamp and mirror.

In lieu of the assembly just described, the lamp can be detached from its base and mounted below the workboard so the direct beam will pass obliquely through the hole in the top of the workboard. If this mounting is used, the mirror is not required but openings for ventilation must be provided to prevent the accumulation of hot air below the working surface.

The diaphanoscope may be placed in a dark corner or closet, or a hood may be constructed which can be placed on the table and around the diaphanoscope. The hood should be approximately 36 inches long, 18 inches deep, and 28 inches high. It may be made of light frame construction covered with heavy dark cloth, plywood, Masonite, or similar material. A coat of black paint inside the hood will aid in absorbing outside light.

SEED BLOWERS

The principal feature of seed blowers is a uniform flow of air of desired pressure upward through a column with a valve arrangement to regulate the magnitude of the pressure. At present there are three designs of seed blowers commonly in use in the United States, as follows: (1) The Iowa air-blast seed separator; (2) the South Dakota seed blower; and (3) the Ottawa seed blower. These blowers are briefly described in alphabetical order.

Iowa air-blast seed separator.—The Iowa blower (fig. 10) relies upon a uniform speed motor with attached fan and a single compression area to maintain a uniform pressure. There are two interchangeable seed cups and metal blowing tubes, the smaller accommodating grass samples up to 5 grams and the larger up to 10 grams in weight. Near the top of the tube is an adjustable trap to act as a receptacle for the light material. A screen-covered cap prevents loss of material from the tube. A gate-type valve located below the seed cup is an advantage in that the seed is not disturbed when the blower is operating with the valve turned to the closed position. A geared vernier attachment to the valve assists in making fine adjustments but this combination does not always give the desired degree of exactness of pressure.

Although the plans of the Iowa blower do not provide for alternate use of a glass-blowing tube the necessary accessories can be obtained with little difficulty. The following items are required: Collar to substitute for the seed cup, piece of bolting silk, rubber stopper for 1⅝-inch hole, ordinary glass-blowing tube, and a glass cylinder, open at both ends and with a hole in its wall for the blowing tube (fig. 11 *A* and *B*.) The collar is made of brass and is similar in construction to that of the regular seed cup with the following exceptions: (1) The screen is omitted and (2) the inside diameter of the upper part of the fitting must be 1⅝ inches instead of 1$\frac{5}{16}$ inches in diameter. A hole 1 inch in diameter is cut in the rubber stopper so it will slide over the end of the blowing tube. The bolting cloth is placed over the lower end of the blowing tube and is held in place by the rubber stopper

which is slipped over the end of the tube. The seed is placed in the open end of the tube and is allowed to fall upon the screen of bolting cloth. The tube is held in place by inserting the rubber stopper in the collar. Otherwise, the assembly is the same as described for the Ottawa blower.

The Ottawa seed blower.—In the Ottawa blower (figure 12) there is a metal box containing an air impeller or fan, a low-pressure space, and a high-pressure space. The impeller is operated by a uniform speed motor. The seed cup and blowing tube are mounted over the high-pressure area. The metal seed cup, with screen bottom, supports

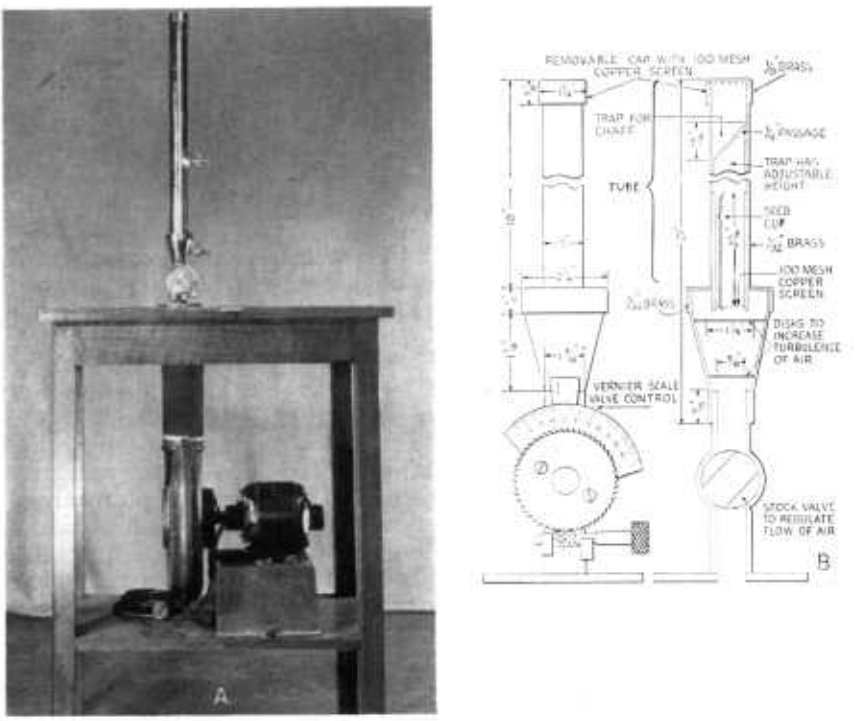

FIGURE 10.—Iowa air-blast seed separator: *A*, View of entire unit; *B*, construction details of valve with vernier scale, seed cup, blowing tubes, and caps.

the glass-blowing tube which leads to a glass cylinder designed to retain the light material. Air pressure in the system is controlled by a sliding gate operated by a closely threaded worm-gear adjustment. There is a manometer which is used for establishing the settings at which seeds are to be blown. For less exacting work the calibrations for the gate opening may be used. The Ottawa blower is designed specifically for small-seeded grasses and will not efficiently accommodate samples larger than 5 grams. The combination of uniform speed motor, 2 pressure areas, fine adjustment of gate opening, and manometer makes a very accurate machine.

South Dakota blower.—In the South Dakota and Iowa blowers uniform-speed motors and blowers made by the same manufacturer

are used. The important features of the South Dakota blower are as follows: (1) It has a small separating column for grasses that will handle samples up to 5 grams of chaffy seeds and 10 grams of non-chaffy seeds and a larger column that will handle a 50- to 100-gram sample of vegetable, cereal, sorghum, and vetch seeds; (2) the separating columns are made of a transparent plastic which enables the analyst to see the movement of seed during the blowing operation;

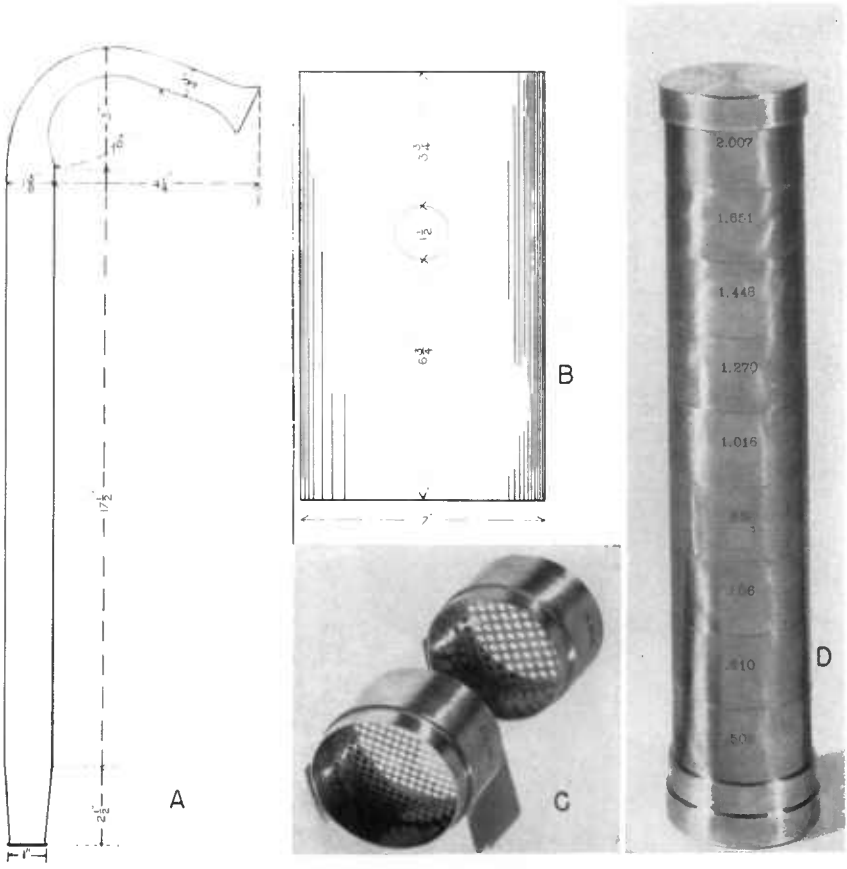

FIGURE 11.—*A*, Construction details of glass-blowing tube; *B*, glass cylinder with 1½-inch hole through which the short end of the blowing tube is inserted; *C*, and *D*, dodder sieves.

and (3) the valve is approximately one-half a disc, located at the top of the blowing tube, adjustable by circular motion. Of the three seed blowers described, this is the only one that will handle samples of more than 5 or 10 grams in weight (fig. 13). Three models are available.

It will be observed that each of the three seed blowers described herein employs a uniform speed motor and fan. Since line voltages are subject to considerable fluctuation, it is recommended that a constant voltage transformer be used with each.

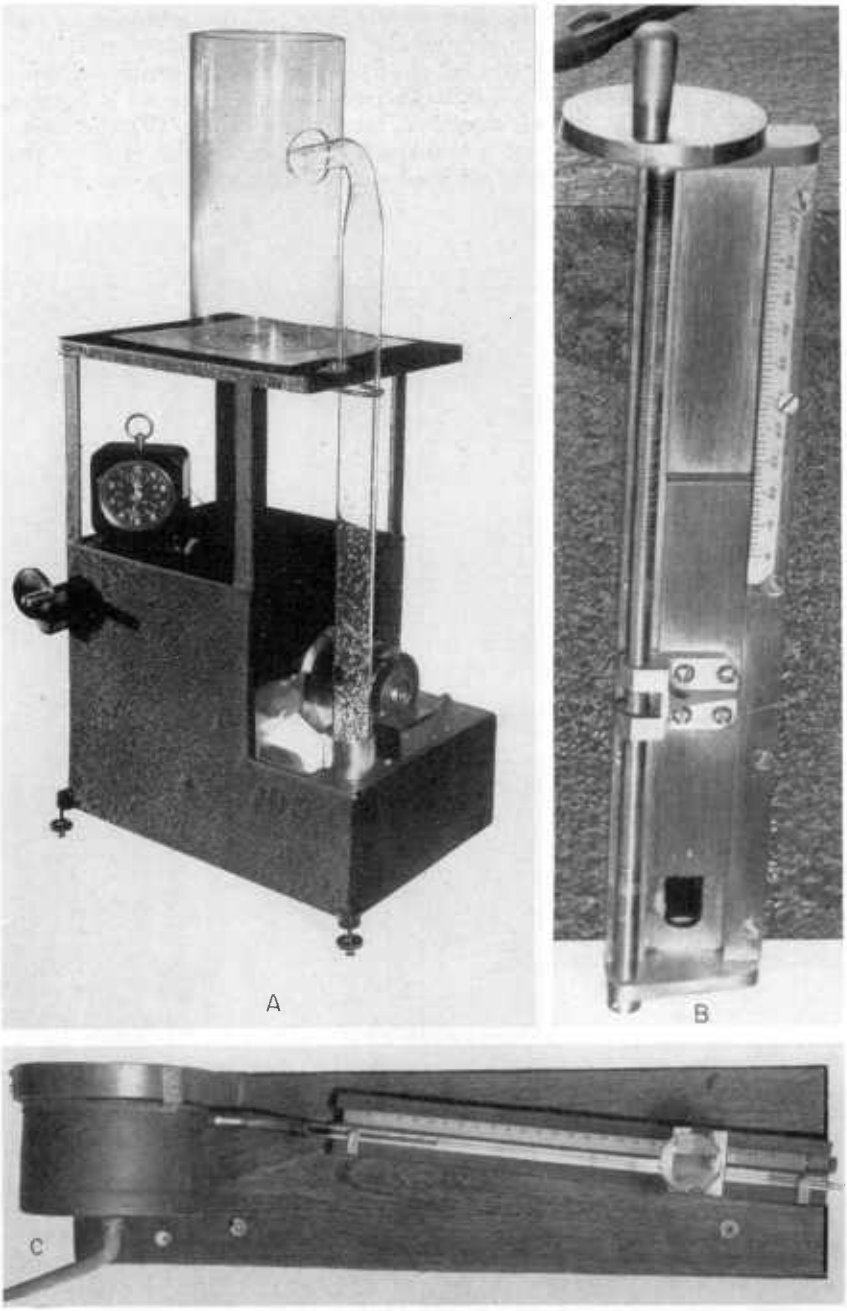

FIGURE 12.—Ottawa seed blower: *A*, General view; *B*, gate and gate adjustment; *C*, manometer with magnifier and liquid reservoir.

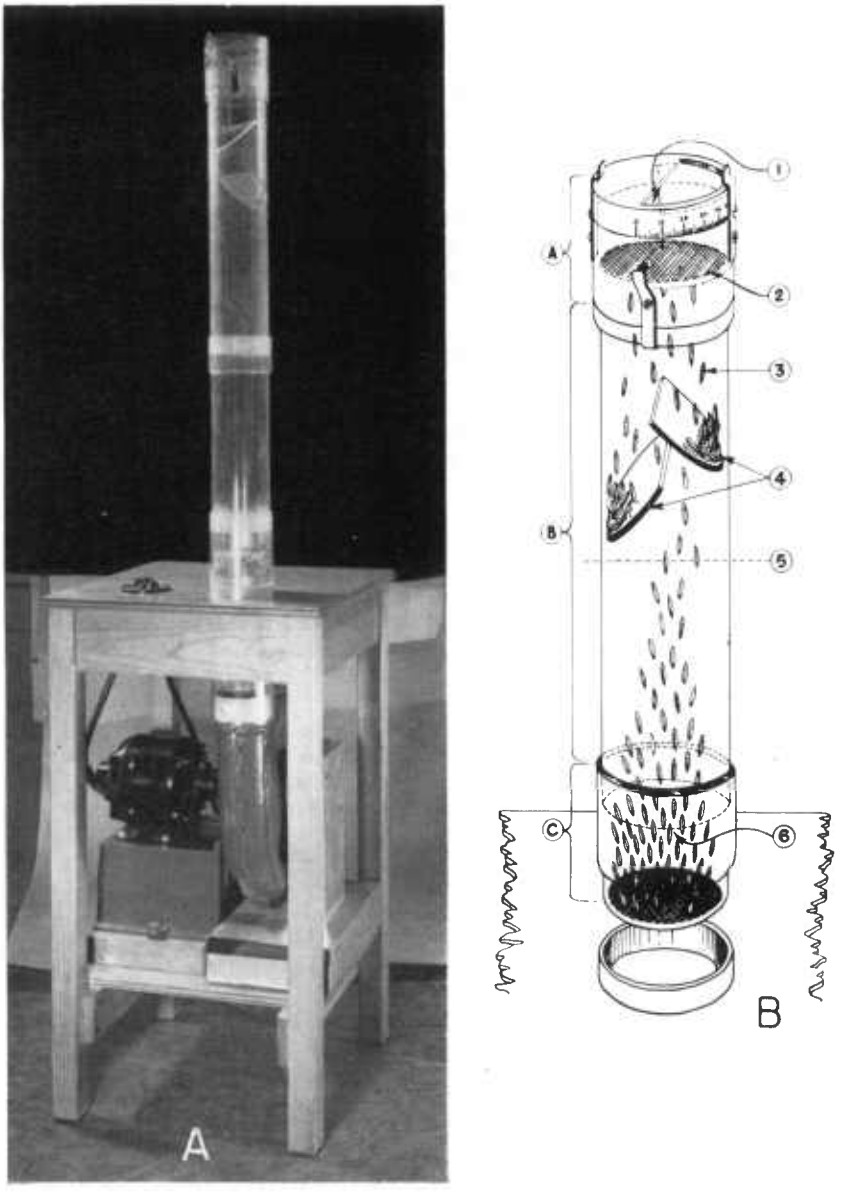

FIGURE 13.—South Dakota seed blower: *A*, View of entire unit with large blowing column; *B*, sectional view of large blowing column; *a*, top screen and air control or valve; *b*, column; *c*, seed cup and bottom screen; (1) valve; (2) top screen; (4) seed traps; (3, 5, 6) seeds of different specific gravity being blown.

SEED HERBARIUM

A good seed herbarium is essential to any modern seed-testing laboratory. Herbariums are not bought but are the result of years of effort on the part of interested, patient, and painstaking workers. The chief methods of obtaining seeds for herbariums are through collections from plants in the field or seed samples received in the laboratory, exchange, and gifts. Some seed-testing laboratories, as well as departments of botany and agronomy in State agricultural colleges, are in a position to assist in building up herbariums. The importance of correct identification and labeling of all samples which go into the herbarium cannot be overemphasized. Many samples of the same species or variety should be included to give the range of variation that may be expected. Several kinds of seed containers have been suggested for herbarium use but none seem as convenient as glass shell vials. Two types of trays for holding the vials are in use in the Federal laboratories. One is a strong cardboard box with lid, covered with durable, impregnated black cloth. These trays are made in ¾-, 1-, and 1¼-inch depths, the other dimensions being 17½ by 11¼ inches. The more shallow trays are divided by cardboard partitions into 100 spaces, and the larger into 30 or 48 spaces, the number depending on the kinds of seed for which they are intended. These trays can be labeled, stacked, and stored in a cabinet. A cabinet with closely spaced shelves to accommodate not more than 2 or 3 trays is preferred.

The other type of container consists of steel, blank sections designed for maps. Each section consists of either 6 or 18 drawers, each 16 by 9½ by 1½ inches. In both sections the drawers are arranged 6 deep and in the larger section they are 3 drawers wide, the over-all dimensions being 33 inches in length, 13 inches in height, and 17 inches in depth. Cardboard separators to fit into the drawers can be made to meet the needs of the individual laboratories. These can be made by hand for a small herbarium but paper-box manufacturers will make them when the quantity justifies.

LAMPS

Every effort should be made to provide maximum window space with northern exposure for the analysts who test seeds for purity. Southern and western exposure must be avoided. Many laboratories are not so fortunate as to have sufficient daylight space and must resort to electric lights. Also, daylight is totally inadequate at times, even with a maximum amount of window space and the most desirable exposure. Of the different kinds of lamps and tubes commonly used, daylight-type fluorescent lamps appear to be the closest approach to natural daylight. If natural daylight is weak, overhead fluorescent lamps should be provided. For close work in purity testing, individual desk lamps equipped with daylight type tubes are also required. Only multiple tube lamps in which the tubes are synchronized to minimize the stroboscopic effect or "flicker" should be used. The so-called floating fixtures, consisting of movable arms with swivel and hinged joints, that are held to desired positions by a spring under tension have been found satisfactory.

EQUIPMENT FOR GERMINATION TESTING

FORCEPS

Forceps for removing seedlings should neither be blunt nor as sharp-pointed as described for purity testing. Blunt forceps are awkward to use when removing small seedlings, and fine-pointed forceps are dangerous owing to the fact they must be handled with rapidity and they pierce the paper substratum easily.

MAGNIFIERS AND MICROSCOPE

Hand lens as described under equipment for purity testing are required by the germination analyst. A good reading glass mounted on a stand is desirable for counting very small seedlings. A stereoscopic microscope and compound microscope should be available, if samples are to be examined for fungi.

SAMPLE PANS

Sample pans similar to those described under equipment for purity testing, except that the pouring spout should be very narrow, are necessary for the germination laboratory.

GLASSWARE

The germination laboratory should keep on hand a supply of assorted sizes of beakers, flasks, bottles for chemical solutions, graduate cylinders, burettes, distilled-water bottles, and Petri culture dishes. Since Petri dishes are used for seeds that require light exposure during germination, the number needed will depend upon the requirements of each laboratory. Petri dishes, 100 mm. in diameter, are generally used for seeds the size of *Lactuca* and *Poa* but 120-mm. dishes are preferable for *Dactylis* and *Bromus*. However, it has been impossible to obtain this larger sized dish in recent years. Bell jars or similar covers are necessary for covering seed on the workboard when the analyst finds it necessary to leave an unfinished sample. Plastic cake covers and plastic bell domes are preferred as they are not so heavy to handle as glass bell jars and are resistant to breakage.

SOIL AND SAND BOXES

Different kinds of containers have been used to hold soil and sand in germination testing. The most commonly used containers are paraffined cardboard boxes, sizes 4½ by 4½ by 1½ inches and 8½ by 8½ by 1¾ inches. The boxes are usually purchased unassembled but creased and perforated. To assemble, the sides are folded upward, the corners folded over, along the creases, and fastened by inserting a staple with an ordinary stapling device. The advantages of using these boxes lie in the fact that they can be discarded after each use. Thus, problems incident to storage and cleaning are eliminated.

The sides of the large boxes tend to sag when filled, thus allowing the soil to dry along the edges. This can be eliminated by having metal bands constructed with inside dimensions to fit over the cardboard boxes. The bands should be 1½ to 2 inches wide and made of aluminum or other noncorrosive metal. They may be stored and used repeatedly.

Recently plastic boxes have been introduced as soil and sand containers. A popular size now on the market is 4½ by 4½ by 1⅛

inches. When ordering plastic boxes one should make sure the size and shape conform to the shape and dimensions of the appropriate counting head.

SPRINKLING DEVICES

Florists' rubber bulbs which hold approximately 250 to 300 cc., with perforated nozzle, are excellent for remoistening most types of substrata in laboratory tests. However, it is preferable to use a medicine dropper with rubber bulb when remoistening substrata in Petri dishes or other small closed containers. Otherwise, the tests can easily be flooded.

SOIL AND SAND STERILIZERS

It is essential that occasional sand or soil tests be made in the laboratory, or greenhouse if available, chiefly as a guide in evaluating tests made on artificial substrata. Sand or soil used for this purpose should always be relatively sterile to devitalize any weed or other seeds and fungi which may be present. Some laboratories located at experiment stations or near commercial greenhouses have found it possible to make arrangements whereby they can obtain soil or sand already sterilized. Some laboratories sterilize their sand in an ordinary gas-heated laboratory oven. The sand is placed in shallow trays or pans and heated for approximately 2 hours.

Some of the large companies that manufacture electrical appliances have electrical heating units for sale and provide plans and specifications for electric soil sterilizers. For example, one firm has plans for a ½ cubic yard sterilizer that requires 4 electrical units wired in parallel on a 110-volt circuit. The plans may be modified for a smaller box by using 1, 2, or 3 heating units.

SEED COUNTERS

Counting devices are now regarded as standard equipment in seed-testing laboratories. There are two types of seed counters: (1) Counting boards; and (2) vacuum counters.

Counting boards.—Counting boards are frequently used for large seeds such as corn, beans, and peas. A typical counting board has a stationary bottom, approximately the size of the substratum to be used, perforated with 50 or 100 holes the general shape and size of the seeds to be counted (fig. 14). Below the perforated base is a thin solid board which serves as a false bottom and can be moved forward and backward. In operation, the counting board is placed over the substratum, the seed scattered over the board, and the excess seed removed by tilting the board slightly. After checking to see that there is only one seed per hole the movable bottom is withdrawn and the seeds fall in place upon the substratum.

Vacuum counter.—There are three essential parts to a vacuum counting device: (1) Vacuum system including lines; (2) counting plates or heads; and (3) valve. A laboratory which expects to count corn and large-seeded beans by vacuum will need a system that will support from 20 to 27 inches of mercury at the point where the counting head is attached. The capacity for suction must be great enough to hold the seeds with leakage caused by their irregular surfaces. The hose, valve, line, and all connections should have openings of sufficient size so as not to restrict the flow of air. For the counting of

large seeds no constriction should be less than 3/8 inch. A capacity of 5 to 8 cubic feet per minute appears to be sufficient for clovers whereas larger seeds such as corn and beans may require a capacity of 15 to 18 cubic feet per minute.

The vacuum counters used in most laboratories are direct acting, that is, the vacuum at the counting head is created only when the vacuum pump is in operation. This requires that the operator switch

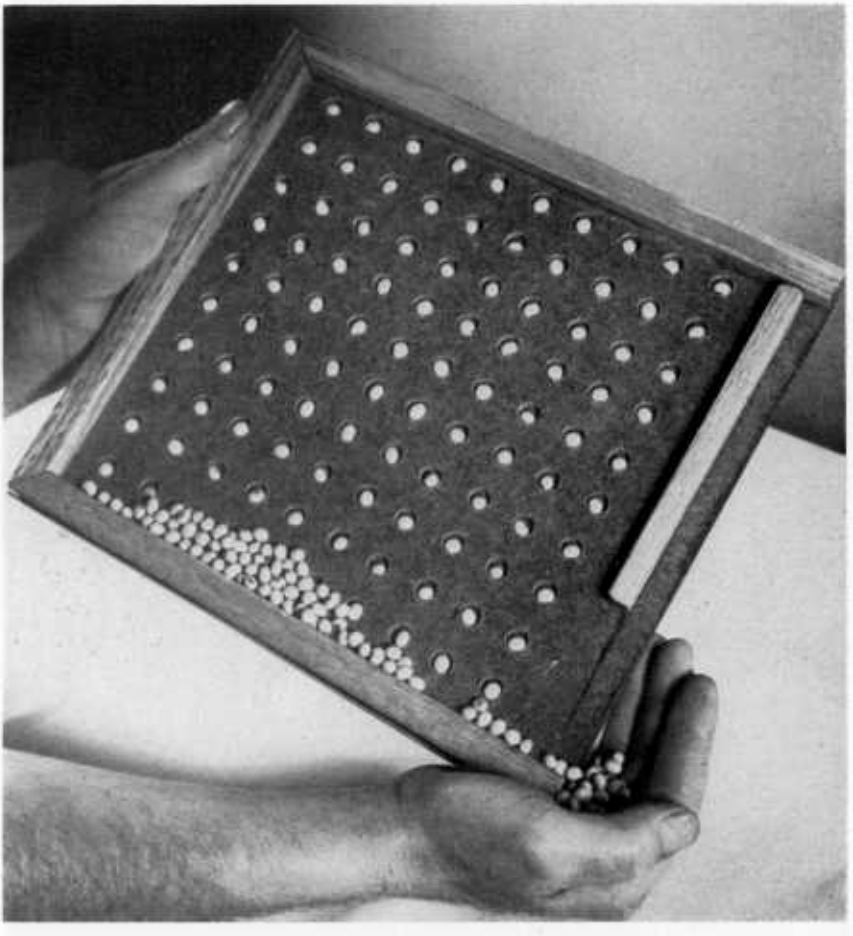

FIGURE 14.—Counting board for large seeds.

the motor on and off with each use. On the other hand, a few laboratories have a tank between the counting head and pump. In the latter case the pump operates automatically as the partial vacuum in the tank is reduced. The following precautions should be kept in mind when selecting a vacuum unit: (1) Avoid noise in the laboratory by selecting a pump that is relatively noiseless or else locate the pump in an unused adjacent room; (2) avoid pumps which expel oil through the exhaust. A vacuum counter is shown in figure 15.

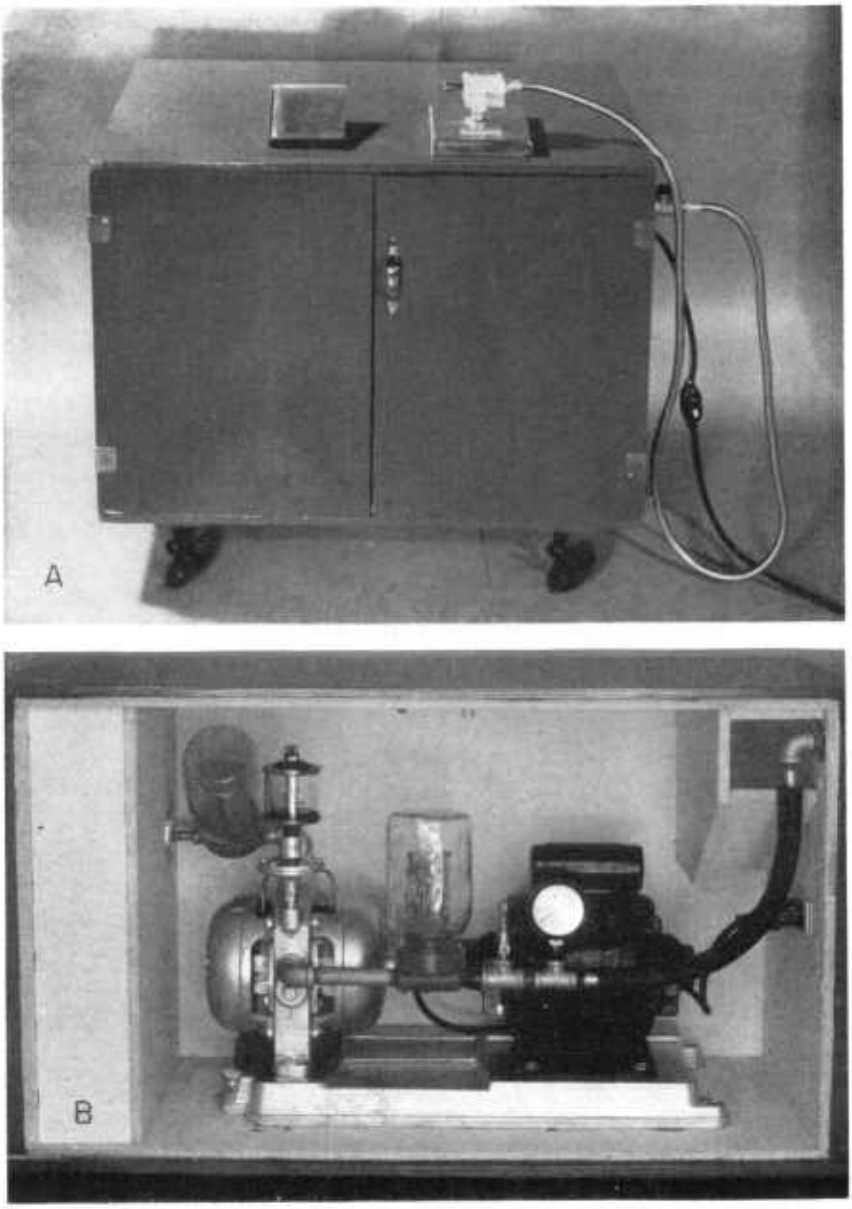

FIGURE 15.—Vacuum seed-counting unit: *A*, Unit enclosed in sound-insulated cabinet; *B*, interior view showing electric motor, pump, filter, and gage.

Seed-counting heads are made in square, rectangular, or disc shapes to fit the substratum. The head has front and back faces between which there is a cavity for air passage. It is a completely airtight system except for the hole in the back plate for attachment to the valve and the holes for seeds in the front face. The opening for attachment to the vacuum system should be a standard female fitting

for a ⅜-inch nipple. The size of head and the number and arrangement of holes for the seeds will be determined by the size of seed to be counted and the dimensions of the seed bed. Typical examples of counter heads used in the Federal laboratories are indicated in table 1. Counting heads may be made of brass, aluminum, or other noncorrosive metals and plastic. Plastic is preferred for the large counter heads (that is, larger than approximately 50 square inches) because of its lighter weight.

The valve should: (1) Have a standard ⅜-inch female fitting for the end or side connecting to the counter plate, and either a tapered fitting for rubber hose on the other end (fig. 16) or a ⅜-inch female fitting for connection to flexible tubing (fig. 15); (2) be easily adjusted to different settings between "on" and "off" positions; (3) remain in fixed position at any point of adjustment; and (4) be free of leakage at all times. Adjustment to different positions is necessary as the tenacity with which seeds cling to the openings determines, to a large extent, the ease and success of counting small and irregularly shaped seeds. Some vacuum-counting heads are illustrated in figure 16.

TABLE 1.—*Examples of vacuum-counting heads*

Kind of seed	Size of head	Holes in head	Diameter of holes
	Inches	*Number*	*Inch*
Corn, beans, peas	6 x 9	25	0. 050
Do	9½ x 12	50	. 050
Cereals	5 x 6	50	. 040
Beets, vetch, field peas	5 x 6	100	. 035
Clovers, lespedeza	4¼ x 4¼	100	. 016
Ryegrass, brome, orchard grass, fescue	[1] 4¼ diam.	100	. 016
Poa, Agrostis, Phleum	[2] 3¼ diam.	100	. 010

[1] Circular head for 120-mm. Petri dishes.
[2] Circular head for 100-mm. Petri dishes.

THERMOMETERS

The laboratory should have each germination chamber equipped with at least one thermometer and an additional supply should be kept on hand for replacements and special checking. Ordinary chemical thermometers calibrated to the Centigrade scale and with clearly legible numbers are preferred. A few laboratories have self-recording thermometers or thermographs. These are excellent as they provide a record of temperatures for the entire period covered. However, because of the high cost of these instruments most laboratories find it beyond their budgets to install a thermograph on or within each chamber. They are to be recommended for use in germination rooms or unusually large germination chambers. Ordinarily, it is sufficient to check the temperature of small chambers which are in good operating condition, once or twice daily.

GERMINATORS

Water-cooled germinator.—The kind of germinator is not particularly important so long as the conditions of temperature and mois-

ture are met. The type of germinator most commonly used in the United States consists of a small chamber with provision for cooling and heating to insure adequate temperature control and which has a shallow layer of water at the bottom to maintain high humidity. A chamber of approximately 9 cubic feet capacity with inside dimen-

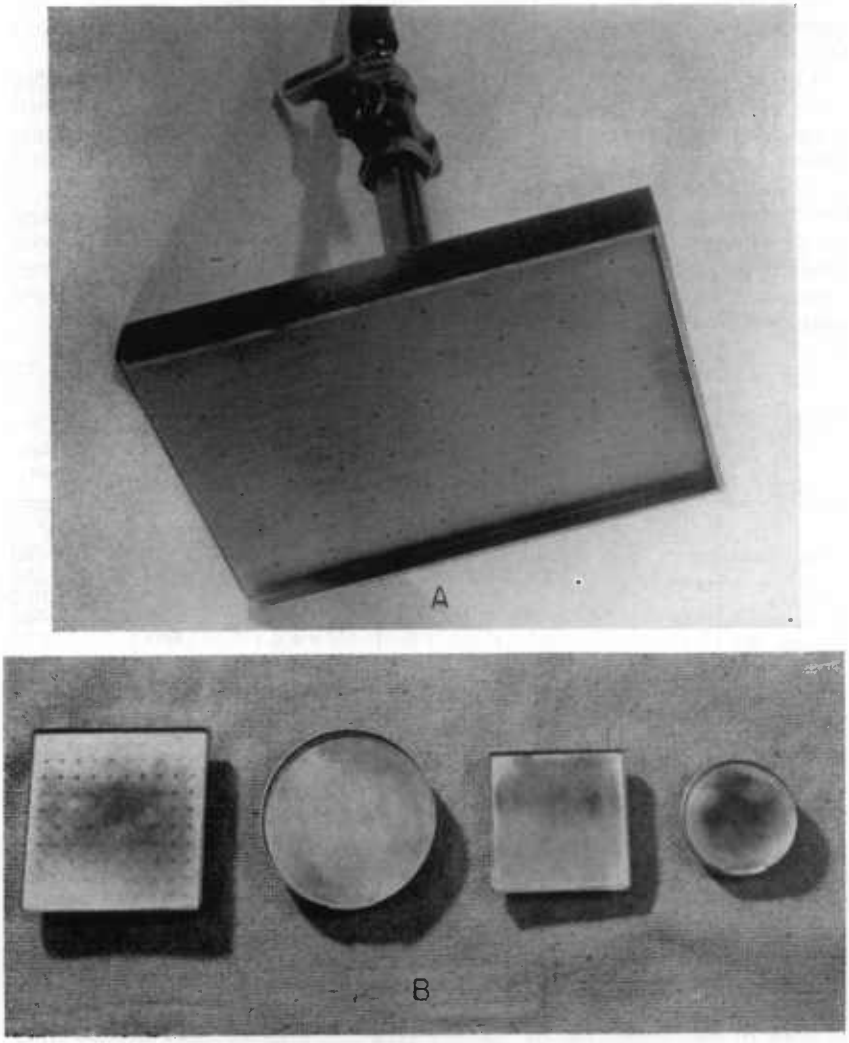

FIGURE 16.—Vacuum counter heads: *A*, Rectangular head for 50 seeds the size of wheat; *B*, different shapes and sizes of counter heads.

sions of 26 inches wide, 24 inches deep, and 27 inches high will accommodate 13 trays 18½ by 19½ inches spaced at 2-inch intervals and will provide ample additional space between trays and around the edges for the movement of air (fig. 17).

In most parts of the country it is necessary to have means of refrigeration during a part or all of the year. It is very difficult to main-

tain high humidity in the air when the temperature is reduced below approximately 20° C. In fact, it is not unusual to find serious drying of the substrata at 10°. Perhaps the most reliable germination chamber in use is the type which is cooled by refrigerated water passing through coils that line the inside of the chamber or through a water

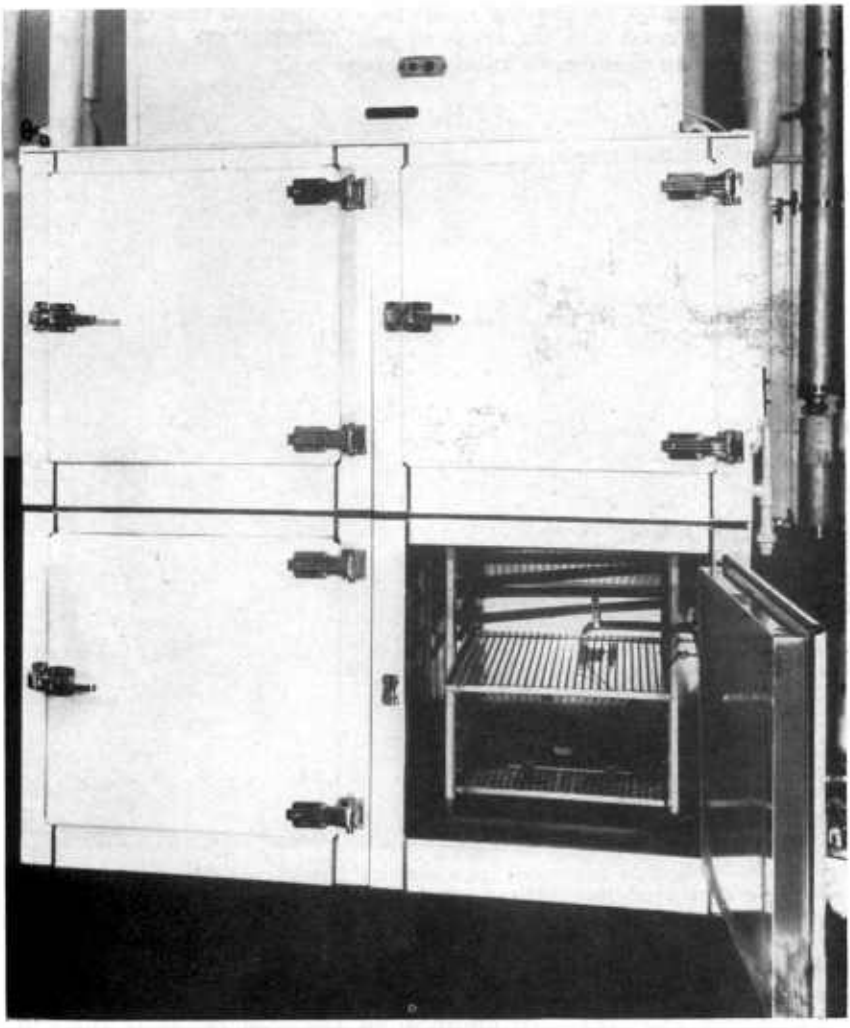

FIGURE 17.—Four-unit water-cooled germinator. The refrigerator unit is located on top of germinating units. The cooling coils can be seen in the open chamber.

jacket between the walls of the chamber. There are various types of electric heaters that can be used inside the chamber, either submerged in water or suspended in the air. The chambers may be constructed of 24-gage noncorrosive metal, or if cooling coils are used they may be lined with stone.

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In the water-cooled germinator, valves are adjusted to allow a flow of water that will cool the chamber slightly below the desired temperature. The heater, which is hooked up with a temperature regulator, holds the temperature at the preestablished setting. The water-cooled germinator does not lend itself to a rapid reduction in temperature when used as an alternating temperature chamber. For seeds requiring an alternating temperature, two constant temperature chambers are used and the trays of test material are usually transferred from one chamber to another as required.

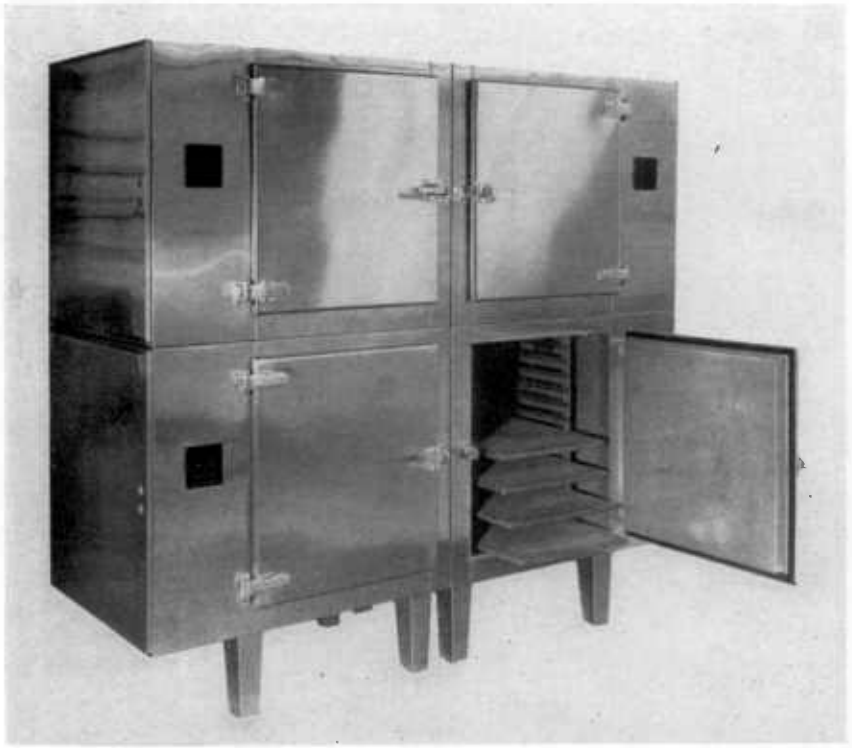

FIGURE 18.—Four-unit air-cooled germinator. The air-conditioning boxes are immediately behind the electrical switches which appear as black squares near the door hinges.

Air-conditioned germinator.—A germination cabinet has recently been designed which is heated and cooled on the principle of air conditioning (fig. 18). In addition to the seed chamber there is a small air-conditioning box, the two being joined by openings at the top and bottom of the germination chamber. Air is either heated at the top of the box as it is forced downward past heating coils or is cooled as it passes over a curtain of cool water near the bottom of the box. The air is circulated throughout the air-conditioning box and germination chamber by a small fan which operates when either the heating or cooling system is in operation. The entire system, including alternation of temperature at preestablished times, is automatic.

The air is humidified by a constant spray of mist in the air-conditioning box. Temperature can be increased from 20° to 30° C. within 20 minutes and reversed within 30 minutes. The principal advantages of the air-conditioned germinator are: (1) Space is conserved as the test material remains in the same germinator both day and night; (2) no manual work is required in transferring the test material; (3) the temperature is alternated at times when the laboratory staff may not be working. The following disadvantages have been observed: (1) The electrical system is rather complex and either one of several devices (such as relays, heaters, fans, solenoids) may become inoperative and require the services of an electrician; and (2) the spray jets become clogged rather easily if the water contains sediment, calcium, or iron, and require frequent attention, or else the test material suffers from loss of moisture.

Room-type germinator.—This type of germinator, which is sometimes referred to as a walk-in germinator, is in use in several of the larger laboratories. Room germinators are usually from 6½ to 7 feet high and occupy sufficient space to allow a row of trays along each wall with passage way between them. Like the germination chambers previously described, the inner walls, floor, and ceiling should be made of moistureproof, noncorrosive materials.

The problems incident to maintaining uniform temperatures and high humidity of the atmosphere increase as the capacity of the germinator is increased. Provision must be made to avoid stratification of temperature, differential of air currents, and areas of low humidity. Since the relative humidity in germination rooms is less than 100 percent the amount of drying of the substrata is materially affected by the amount of moist substrata or number of tests in the room. In other words, there may be no appreciable loss of moisture if the room is used to capacity but if only a few tests are being carried there may be serious drying of the substrata.

The essential requirements of a germination room are as follows: (1) Room, adjacent to regular germination laboratory, 6½ to 7 feet high, 6½ to 8 feet wide, and of desired length, constructed of water-resistant walls and ceiling and of waterproof floor; (2) automatically controlled heating system that will meet the requirements for the desired constant or alternating temperatures; (3) refrigeration system, preferably cool air, which will maintain the lowest temperature needed; (4) reliable spray system to maintain high atmospheric humidity; (5) fans to slowly circulate the warm and cool air; and (6) cold-cathode fluoresuent lights for a section of the room where light-sensitive seeds may be tested or special soil or sand tests may be made.

Daylight germination chamber.—One or more daylight germinators are required for grass and some vegetable seeds. The illumination should provide from 75 to 150 foot-candles of light on the different areas where seeds are to be placed. This may be provided by either natural daylight, fluorescent lights, or both. Because of the temperature effects a daylight germinator should not be placed in windows where the direct sunlight will fall upon it. When artificial light is used to supplement daylight, special provision must be made to keep the temperature down. In the Northern States the temperature can be kept to 30° C. when 4- or 5-foot fluorescent tubes are used if the tubes are placed from 10 to 15 inches from the wall of the chamber.

If the laboratory arrangement requires closer spacing of the tubes, provision must be made for cooling, particularly in the warmer sections of the country. To avoid stratification of temperature it is advisable to introduce cold water at the inside, top, and front of the germinator, allow it to run over a sloping glass retainer to the rear wall and trickle down the latter into a reservoir at the bottom. The water may be either drained away as waste or returned to the refrigerator for continuous use.

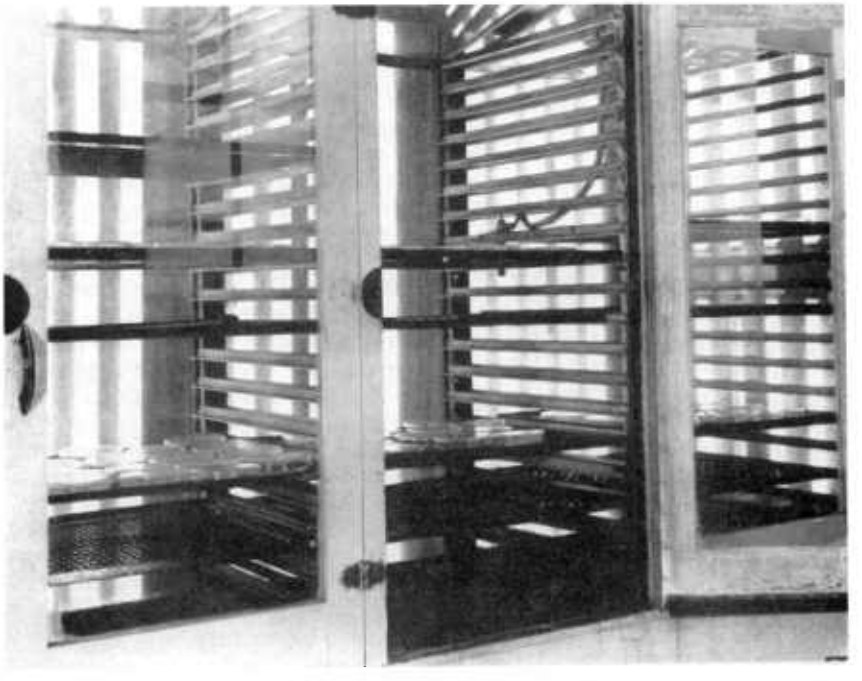

FIGURE 19.—Custom-built daylight germinator. Natural light is supplemented by the fluorescent tubes at the back and ends of the chamber. This unit consists of three sections, but without partitions.

In the germinator illustrated in figure 19, 4-foot fluorescent tubes are placed 3 inches from the glass wall of the chamber. Refrigerated water is released as described above and flows into a water reservoir in the bottom of the chamber with overflow pipe leading to the drain. An immersion-type heating coil is located in the water reservoir. The heater is controlled by a temperature regulator and the flow of cool water is regulated by a solenoid valve which in turn is controlled by another temperature regulator. The chamber illustrated in figure 20 is a commercial model which operates very much on the same principle as the chamber just described. In the commercial model, the water is returned to the cooling system for continuous use.

GERMINATION TRAYS

Standard trays.—Germination trays are usually made of heavy metal gauge with interspaces ¼- to ½-inch square. The frame must

be of solid construction and the wire gauze which supports the substrata must be firmly fastened to the frame.

If the edge of the frame is bent upward for ¼ to ½ inch to form a 90° angle with the flat surface of the tray, it will serve as a guard to keep the seeds from sliding off when the tests are being handled. In lieu of the above construction, sheet metal may be perforated to form

FIGURE 20.—Commercial model daylight germinator. The refrigeration unit is at the bottom of the chamber.

suitable trays (fig. 21). The holes should be approximately ½ inch in diameter and within ¼ inch of each other. The edges can be turned upward and welded to serve as guards, as just described. Copper, aluminum, magnesium alloys, or monel may be safely used in constructing trays. Galvanized steel or any other metal which may contain soluble zinc salts should not be used. It has been shown that the zinc from galvanized trays will produce toxic effects upon certain kinds of seedlings.

Trays for upright towel tests.—The following type of holder for upright towel tests has been found satisfactory. By using 1-inch strips of 20 gage copper, aluminum, or other suitable metal, a frame in the form of an ordinary box is made and attached to a bottom of the same construction as the standard tray, except for size. When complete the holder consists of 4 corner posts, top, center, and bottom strips or rails along the ends and sides as shown in figure 22. Two sizes are made as follows: (1) 9 by 17½ by 8 inches; and (2) 9½ by 18 by 8

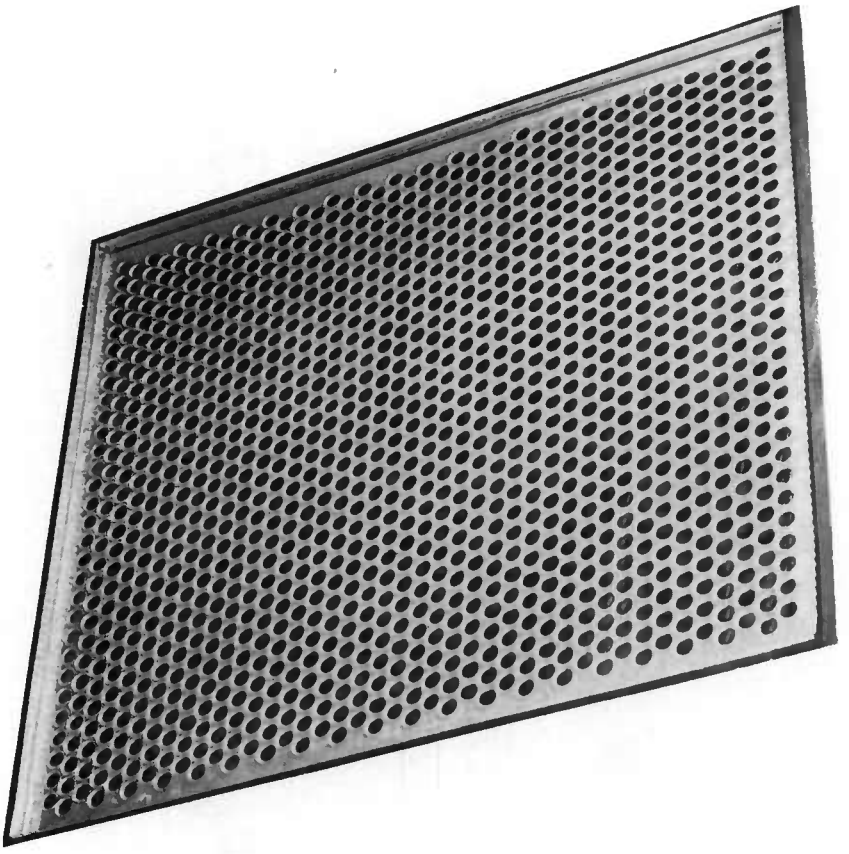

FIGURE 21.—Standard germination tray constructed of perforated No. 16 gage stainless steel.

inches. The two sizes offer the following advantages: (1) Two of these holders will fit on an 18½- by 19½-inch germination tray; (2) the analyst has to handle only one-half the load of a full tray; and (3) when not in use the smaller holder nests inside the larger, thus economizing on storage space.

ULTRAVIOLET LAMP

An ultraviolet lamp is required in laboratories testing the roots of ryegrass (*Lolium*) for fluorescence. The requirements of the lamp or unit are as follows: (1) Radiation of ultraviolet waves with a maxi-

mum peak at approximately 3650 AU (Angstrom units); (2) radiation of sufficient intensity to activate the weak fluorescent lines; (3) filtering out of most visible light; and (4) exclusion of daylight from the working area.

The kind of ultraviolet lamp or unit which a laboratory should install or have on hand will depend, to a great extent, on the number of samples to be tested during the course of a year. A good lamp permanently mounted in a dark room, closet, or chamber is desirable in laboratories that test relatively large numbers of samples. A lamp that employs an EH 4 mercury lamp and Corning 5840 Red Ultra or 5874 Red Purple Ultra filter has been found to be excellent. Certain small portable units are satisfactory if only an occasional sample is to be tested. These usually consist of a metal or plastic frame, a metal

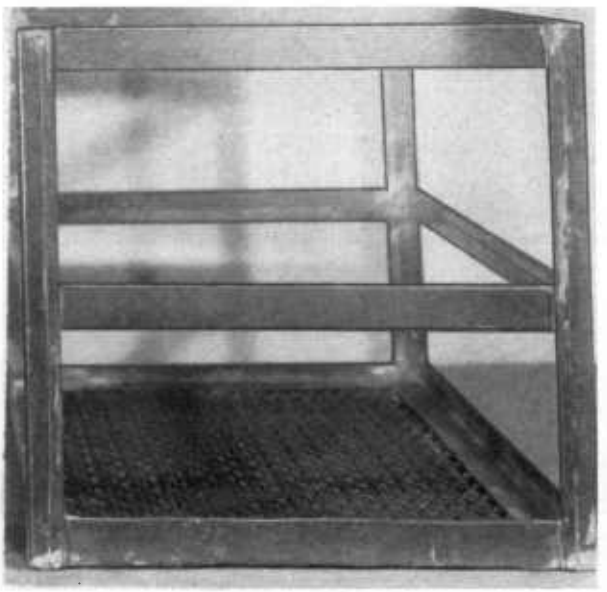

FIGURE 22.—Rack or container for upright roll towel tests.

reflector, and one or two black, fluorescent, mercury-filled tubes. Of several models tested the one found to be most satisfactory had two 5-inch tubes, plastic frame with handle, and the starting ballast located at the end of the electrical cord which plugs into the wall receptacle. The so-called "black lights" which resemble incandescent bulbs in shape should not be used as they do not activate some of the weak fluorescent lines.

FLUORESCENT-LIGHT GRIDS

The fluorescent-light grid illustrated in figure 23 is placed horizontally in the germination chamber to provide uniform lighting over the entire area where the tests are located. The outside dimensions are the same as the dimensions of the germination trays so the grids may rest upon the tray slides. The grids are mounted on every third tray slide, thus permitting the placement of two trays of test material under each grid. At midday the positions of the two trays are re-

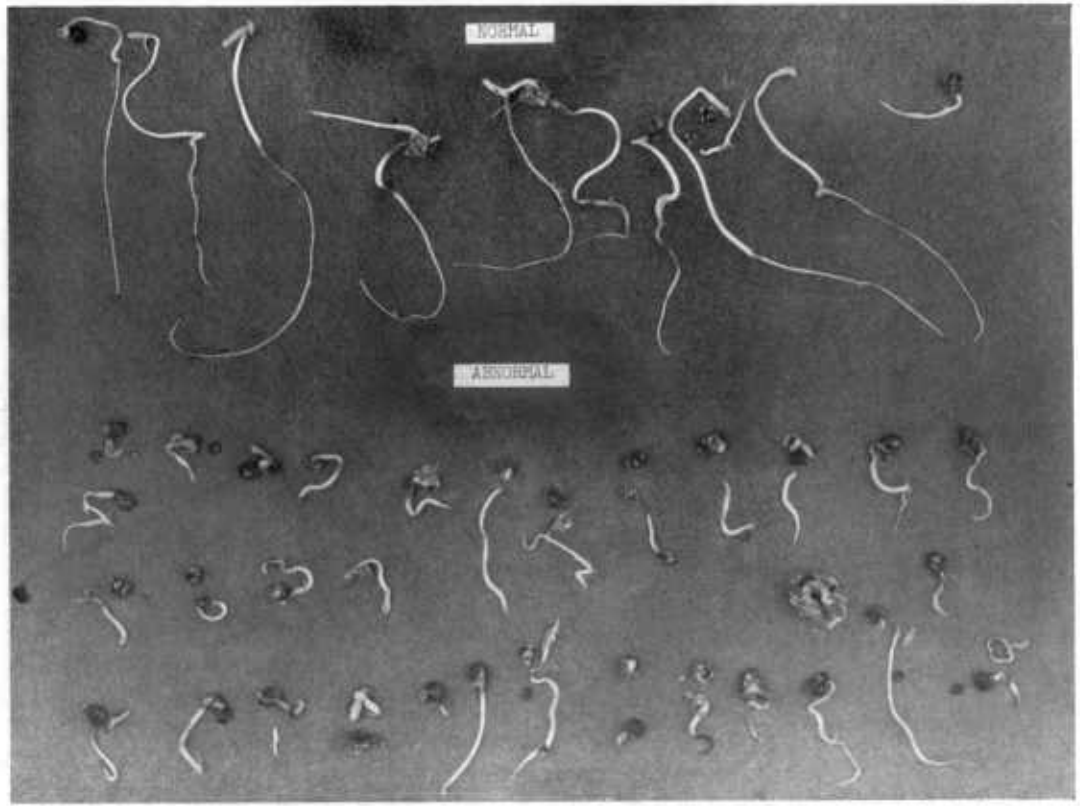

FIGURE 24.—Beets (*Beta vulgaris*). Normal and abnormal seedlings from 14-day tests between blotters

amperes for best operation. Four grids may be operated by a 9,000-secondary-voltage transformer but usually it is better to operate two grids on one 5,000-volt transformer and the other two grids on a similar transformer. This permits the switching off of two grids at any time they are not needed. All connections must be secure and all high-voltage wires that are located inside the chamber should be covered with glass insulators. The transformers should be located outside the germination chamber. As a precaution it is advisable to place in the door casing a switch which will break the primary voltage leading to the transformer when the door is opened.

Stratification of temperature can be overcome by bending copper tubing of ½-inch outside diameter into grids of similar shape and dimensions as those of the fluorescent light grid. A metal grid is mounted immediately above each light grid and connected to a source of refrigerated water. The free end of each metal grid is continued to one side near the bottom of the chamber and terminates in a needle valve which is used for adjusting the flow of water. The valves are adjusted to permit more water to pass through the upper cooling grid than the one next below. Proper temperature control of the entire chamber can be accomplished by either of two methods: (1) Adjust the flow of cold water so it will reduce the temperature slightly below that desired. Raise the temperature up to the degree desired through the use of electric heaters wired in series with a thermostat. (2) Place a solenoid valve in the incoming water line and wire this in series with a thermostat set at the desired temperature. The valve will cut off the supply of cold water when the desired temperature is reached and will open the valve when the chamber becomes too warm. A pool of cool water in the bottom of the chamber is undesirable as it interferes with proper adjustment of temperature.

BEET SEED WASHER

Occasional samples of the different varieties of *Beta vulgaris* seed require washing with running water from 2 to 4 hours to remove the toxic principles causing darkening of the radicles. This washing may be done by placing the seeds loosely in cheesecloth bags and the bags in beakers into which water is running. If very many samples are to be tested a device to hold the seeds, while washing, is recommended. Baskets 1½ by 1½ inches in cross section and 2 inches high made of 20 by 6 mesh copper gauze make good seed holders. The baskets may be placed in a stream of running water.

If uniform washing is desired this can be accomplished by constructing a pan having walls 2½ inches high with drain spout ¾ inch from the top and a false bottom soldered to the walls 1 inch from the bottom. The false bottom has a $\frac{3}{32}$-inch hole beneath each basket. When the hose is attached and the faucet is opened water enters the compartment between the bottom and false bottom and squirts up through each hole agitating the seeds while washing them. The size of the pan is determined by the number of baskets to be used.

GREENHOUSE

It is sometimes desirable to conduct germination tests on questionable samples over a sufficient period of time to observe development beyond the seedling stage. Greenhouse space with provision for con-

trol of temperature within the range suitable for the kind of seed to be tested, and other facilities, should be available for this purpose. The greenhouse should be located in close proximity to the seed-testing laboratory.

FILING CABINETS

Among the problems of retaining file samples for future reference is that of protecting them from rodents. Some laboratories use all-metal boxes which may be stacked or placed on shelves built for that purpose whereas others store official samples in glass fruit jars. The Federal laboratories have found sections of close-fitting drawers to be convenient for this purpose and to protect the samples from rodents. Each section is composed of 16 drawers, 4 across and 4 down. The front and back of the drawers, and the frame are of oak while the sides and bottom of the drawers are of galvanized metal. Each drawer is 12 inches wide, 24 inches deep, and 6 inches high.

OBTAINING THE SEED SAMPLE

SAMPLING THE SEED LOT

OBJECTIVE

The basic objective in sampling a lot of seed is to draw a portion which is representative of the entire lot. Such a sample is the basis for analyses to determine the purity, germination, noxious-weed seed content, origin, variety, composition, and other quality factors. The results of these tests, of course, cannot be more accurate than the sample submitted.

USE OF SAMPLING INSTRUMENTS

There are numerous instruments designed for drawing a sample from seed in bags or in bulk in bins. These are described in detail in the section on equipment. The short thief trier or sticker type of instrument is widely used, presumably because of the convenience in using and carrying it. However, it is generally agreed that an accurate sample cannot be drawn with this type of instrument. Regardless of the number of places a single bag of seed might be pierced only the outer few inches of seed will be sampled, and no portions would be obtained from the center of the bag.

The double-tubed sleeve-type triers are the most satisfactory of the sampling devices in general use for sampling seed in bags. They should be long enough to take seed from different locations in the seed bag. Equal quantities may be taken from each seed bag probed with the sleeve-type trier, whereas the amount of seed drawn from each bag with a thief trier is purely a matter of personal choice.

HOW TO DRAW THE SAMPLE

The theory of sampling assumes that a seed lot is made up of homogenous material and that a composite sample drawn in accordance with established procedures will represent a particular lot of seed. This sample should be made up of equal portions taken from evenly distributed parts of the quantity sampled. In quantities of five bags or less, each bag should be sampled and in quantities of more than five bags every fifth bag, but not less than five, should be sampled.

If the sleeve-type probe is employed, seed bags should be in a horizontal position to insure that as the tube of the trier is opened, seed will drop in along the entire length of the bag. Perhaps the best sample coverage comes from following a diagonal path through the seed bag to an opposite corner. The probe should be inserted with the slots facing downward so that as it is inverted, or placed upright for collecting the sample any seeds "dragged along" by the cross ribs will be dislodged and will not be added to the portion drawn. Sampling a bag of seed standing upright results in obtaining unequal portions from various parts of the bag.

Each probeful of seed from each bag sampled should be examined before adding it to the composite sample in order to determine that

the seed being sampled is uniform in quality. Uniformity of color and general weed-seed content should be noted and any probefuls deviating from previously drawn portions should not be added to the composite sample. The bags of seed in question should be appropriately identified, set aside, and cannot be considered a part of the lot being sampled. If this procedure is followed, there will be little danger of mixing seed from improperly segregated seed lots.

Certain chaffy grass seeds and nonfree-flowing seeds such as *Bromus* spp., *Andropogon* spp., or *Paspalum* spp. which may not be easily sampled with a probe can be sampled by hand. Hand sampling necessitates opening the seed bag, thrusting the hand to different parts of the bag, and removing small portions of seed from the bottom, center, and top.

SIZE OF SAMPLES

Too often laboratories receive samples of insufficient size for testing. The inspector or sampler should make every effort to obtain samples of at least the minimum quantities set out in the rules. An inspector or sampler may hesitate to draw a large quantity of seed having a high retail value but it is necessary to submit samples of at least the size stated in order to provide adequate seed for standard tests, and retests if necessary.

CAUTIONS TO BE OBSERVED IN SAMPLING

Whether the seed sample is drawn by a seedsman or farmer for his own guidance or by an official seed inspector, there are general cautions to be observed in order to obtain an accurate sample. The sampler must first determine that all seed bags being sampled are identified as belonging to a single lot, either by a label or stencil mark on the bag. He must sample the prescribed number of bags for the size of lot at hand. If, in sampling a large lot, more seed is obtained than is feasible to forward to a laboratory, care must be exercised in reducing the quantity for shipment. As a mechanical divider is usually not available, the sample reduction might best be done by placing the entire quantity on a sheet of paper or canvas, thoroughly mixing the seed by hand and halving the sample until the desired quantity is obtained. The value of this procedure becomes more obvious in instances where official inspectors are required to leave duplicate samples with the dealer. A haphazard splitting of the sample could not be expected to produce two similar portions.

Damage to seed bags is of prime consideration to seed inspectors as well as to merchants. The thief trier does little damage to cotton bags, but its accuracy in drawing a representative sample is questionable. The longer probes can safely be thrust into burlap bags which are easily "scratched over." A few stitches at one of the top corners of machine-sewed cotton bags can be broken and then this break can be closed with a hand-stapling device, after the contents of the bag have been sampled.

SAMPLING RECORD

It is essential that the inspector keep accurate records concerning the history and manner of sampling each lot of seed forwarded for official tests. Each sample should be clearly marked so as to be easily identified. Any sample known to have been treated with a poisonous fungicide should be so identified by the inspector or sampler so the

analyst may be warned of that fact. The sample envelope should be sealed to prevent any contamination and if forwarded by mail the samples should be packaged to arrive in an undamaged condition.

REDUCING THE SAMPLE IN THE LABORATORY

OBJECTIVE

Seed samples received by a laboratory generally need to be reduced to a working sample of standard weight. These weights are tabulated in the rules, for the various kinds of seeds, and have been determined to provide an adequate number of seeds for purity analyses and for noxious-weed seed determinations. Since the working sample is such a very small portion of a large bulk of seed, the value of obtaining a valid original sample cannot be overstressed. Whenever possible, the sample should be divided by a mechanical divider or sampler. In cases where a mechanical divider is not available for reducing the sample other methods described herein may be followed.

USE OF MECHANICAL DIVIDERS

The use of mechanical dividers eliminates the personal element in reducing the bulk to a working sample. All mechanical dividers in common use, except the Ottawa divider, are designed to split the sample into two approximately equal parts. The working sample is obtained by repeatedly dividing the sample until a quantity of approximately that stated in the rules is obtained. It is frequently necessary to run the "unused" part of the sample through a series of divisions to get a few seeds to bring the sample up to the necessary weight.

The Ottawa divider is designed to divide samples into: (1) Two parts of equal weight; and (2) two parts of unequal weight. To divide into two parts of equal weight the seed is allowed to run gently into the divider without any further adjustment. If the sample is of such a size that even divisions will not give the desired weight of working sample, an unequal division is made to give two parts, one of which can be reduced by even division to the desired weight. The sample is weighed and the closest weight that can be reduced to the desired weight, by equal divisions, is determined by calculation. By adding the necessary balance weights to one pan the excess seed falls into this pan and the desired weight of seed into the other pan. The working sample is then obtained by repeated equal divisions.

Any attempt on the part of the analyst to correct the sample size by personally adding or removing seeds to obtain an even weight defeats the objective of using a mechanical divider.

HALVING METHOD

The sample should be placed in a pile on a clean surface and after thoroughly mixing by hand it may be successively halved by use of a sharp-edged instrument until the required approximate weight is obtained. Although this method is included in the rules for seed testing it is the least desirable of the methods discussed herein.

RANDOM CUPS METHOD

A series of small cups or thimbles of known capacity are arranged on a tray or pan, in definite pattern, and the sample poured systemati-

cally over this area. The working sample is obtained from randomly selected thimbles or cups. The method may be modified by using a tray, divided into an equal number of square compartments, every alternate one of which has no bottom.

CARE OF SAMPLES

SAMPLES AWAITING TEST

The large number of seed samples ordinarily received by a laboratory during a testing season necessitates care in: (1) Retaining the identity of each sample received; (2) avoiding damage by rodents or insects; and (3) avoiding exposure to extreme variations in temperature and moisture. Seed samples received by a laboratory should be unpacked as soon as possible and should be given a record number so that they may be readily located and referred to when necessary. Samples which cannot be tested soon after receipt should be stored in a systematic manner to prevent their loss and to provide for more efficient laboratory operation. If two or more samples have become mixed due to accidental breaking of the seed containers, new samples should be obtained.

Samples awaiting test or samples which have been tested and filed for future reference should be given adequate protection against possible damage by rodents. This is particularly true if seed is stored in attics or basements.

It is essential that samples infested with weevils, moths, or chalcid flies be kept intact, preferably in sealed containers. The seed envelope, if closed, will usually protect the sample during the routine period it awaits test. Samples that upon arrival are so badly infested as to be of little value or which show signs of recent insect activity should be destroyed and additional samples should be obtained. A small amount of paradichlorobenzene added to the seed envelope or other closed container will kill the common insects which infest seeds.

Care should be exercised to insure that seed samples are not exposed to extremes in temperature, or moisture, while awaiting tests. Only samples that are received in the laboratory in airtight containers should be tested for moisture content. The hard seed content of some legume seeds has been known to increase when stored in a dry atmosphere. It appears a strong possibility that there may be a change in hard seed content for certain legume seeds that are left in a laboratory with a dry atmosphere for a few weeks.

Caution should be exercised not to expose seeds to fumes from some of the more volatile herbicides as a few cases have been reported in which abnormal seedlings were produced by accidental exposure to fumes of some of these compounds.

SAMPLES FILED FOR FUTURE REFERENCE

Any sample that is filed may need to be tested for germination at some future date. Therefore, it is of utmost importance to store the samples under favorable environmental conditions. Either high temperature or high humidity may cause rapid loss of the viability of seeds and a combination of both conditions is particularly bad; whereas, storage in a cool dry environment is conducive to longevity of seed and tends to reduce or eliminate insect activity which might

otherwise make infested samples valueless. It is advisable to place approximately ¼ teaspoonful of paradichlorobenzene flakes in samples suspected of being infested with insects. Samples should be filed in rodentproof containers or cabinets. All seed-testing laboratories should have ample space and facilities to provide the most favorable storage conditions.

There is nothing in the rules for seed testing that will serve as a guide in respect to the length of time file samples shall be retained. However, the Rules and Regulations under the Federal Seed Act provide that records (including seed samples) pertaining to interstate shipments of seed shall be kept for 3 years, except that the seed sample may be discarded within a year after disposal of the seed lot which it represents. It is not feasible to retain all samples for 2 to 3 years; however, no sample should be discarded within 12 to 15 months after testing. Samples known to represent seed lots about which there is official or civil action should be retained until the cases are terminated. Commercial analysts can frequently perform a service for their patrons by arranging to retain their file samples. All file samples should be of sufficient size to permit a noxious-weed seed examination in accordance with the rules for seed testing.

PROCEDURES FOR DETERMINING PURITY COMPOSITION

The object in making the purity analysis is to determine the identity of the important kinds of seed present and the percentage by weight of each component; namely, pure seed, other crop seed, weed seed, and inert matter. Since the germination test is based on the pure seed component it can readily be seen that the purity analysis and germination test complement each other. Thus, the actual plant-producing power of the seed lot can be determined only when the purity analysis and the germination test are considered together.

ACCOMMODATIONS

LABORATORY SPACE AND LIGHT

Testing seeds for purity is a meticulous, painstaking operation, requiring constant use of the eyes. To avoid serious eyestrain the purity-testing laboratory should be located as ideally as possible. Large, single-paned windows extending to within approximately 30 inches from the floor and overlooking a wide expanse of green are ideal. The first consideration in choosing a location for the purity-testing laboratory should be window space with northern exposure. It is believed that daylight causes less eyestrain and fatigue than any other light. Also, shadows from the head, hands, and instruments are reduced to a minimum if north light is used. Examination of seeds by natural daylight often avoids confusion over color, texture, and brilliance. With proper provisions for daylight, artificial light is required only on the darkest days or during early mornings and late afternoons of the short winter days. If artificial light is used the analysts should have individual, adjustable, multiple-tube, fluorescent lamps of the daylight type.

DESKS AND TABLES

Work tables or desks should be large enough to accommodate the worker's arms, his workboard, working tools, and instruments as well as to provide space for writing. It is highly desirable to have movable desks or tables, especially if light from a northern exposure is not available. In this way the analyst can shift his table to obtain the greatest benefit from the available natural light and at the same time avoid direct sunlight and shadows.

THE USE OF EQUIPMENT

WORKBOARDS

In testing large seeds a workboard equipped with a drawer or a pan which will hold all the pure seed is desirable. The height, width, and covering for the board should suit the individual analyst. The following working surfaces are commonly used: (1) Frosted glass

slab; (2) plate glass covered with a lightweight, nonglare blue or white paper, applied wet and fastened firmly to the under side of the glass with gummed paper; and (3) a wooden surface covered with a nonglare white or light blue bond paper which is resistant to wear and tear from constant motion of the forceps and does not buckle.

If the workboard is made of soft wood, the paper may be fastened in place with thumbtacks. The usual method of applying the paper is to cover the arm rests first. Two sheets of paper are used for the top cover, each a little narrower and a little longer than the top of the board. One sheet is fastened flush with the front of the board by inserting thumbtacks in the two front corners. The other sheet is placed over the first sheet so that it extends from the back of the board to within approximately 2 inches of the front edge. The second sheet is attached by thumbtacks at each end of the four corners. A scoop or pouring device can be made from an ordinary card by folding approximately 1 inch, along one side, until it makes a 90° angle with the remainder of the card. The wide part of the card is slipped between the two cover sheets and the upright edge serves as a retainer to keep the seeds from being pulled off the board. The card is easily removed and serves as a convenient pouring device. The scoop cannot be conveniently used with the glass slab and plate glass workboard covers mentioned above.

SEED CONTAINERS

Containers for seeds must be large enough to accommodate the sample, yet not so large as to be awkward to handle. Any container which is light and does not take on a static charge is satisfactory. Glass has some advantages over other materials, the principal advantage being that, when slipped under a microscope to examine seeds, light is not reflected into the eyes of the observer; bright metal containers should not be used because they are such good reflectors. Small Petri dishes, 50 mm. in diameter and 10 mm. deep are adequate for samples up to 10 grams. When testing large samples one larger container is needed for the pure seed component but the small dishes can be used for the other three components. There is an obvious space-saving advantage in containers which nest. An assortment of seed pans with pouring spouts is almost indispensable. Glass vials with corks, gelatin capsules, and two or three sizes of coin envelopes are essential for filing the components after the final weighing. Bell jars or plastic cake covers should always be on hand to cover the working sample if the analyst leaves his work, even for a moment.

SEED DIVIDERS

The sample submitted for test must be reduced to the size recommended for the kind of seed under consideration. Mechanical dividers are generally used to accomplish this. Different kinds of dividers are described under "Seed Sampling and Testing Equipment" and methods of reducing the sample are discussed under "Obtaining the Seed Sample." In most dividers there is a possibility that seed will lodge. Unless the divider is thoroughly cleaned these lodged seeds will be left to contaminate other samples. As insurance against such possible contamination the habit of thoroughly cleaning the divider before and after each use should be definitely established. The divider may be

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cleaned by a strong air current from air under pressure, a portable dust blower, or other means.

Most dividers are constructed so as to cut the sample into two parts with each division. The seeds in one pan should be set aside after each division and the other half run through the divider again until the sample is approximately the size required for test. It is convenient at this point to have a torsion balance or a scale, accurate to a tenth of a gram, to determine the approximate weight of the reduced sample. If it is found that the weight of the sample is less than that required for purity analysis it can be increased by dividing the set-aside-portion of seed from the other pan a sufficient number of times to provide the difference. If the sample is too large it can be reduced by repeated mechanical division. The sample must not be altered by adding or removing seeds by hand.

SCALES AND BALANCES

Scales and balances should be located on heavy, level, stationary tables or shelves where they will be free from jolting and vibration. Scales and torsion balances should be checked for balance and accuracy at regular intervals, and analytical balances should be checked before each use. Extreme care in operating analytical balances is essential to their continued accurate service. The pans should always be gently lowered to the weighing position and released with an easy gentle motion. Quick, abrupt movements do not make the balance work faster but get it out of adjustment quickly. The analyst must have a complete understanding of the metric system of weights and know the decimal fraction which each position on the beam and vernier represents. Errors in reports have been traced to misplacement of the decimal point and omission of a zero in the fraction.

The worm gear which operates the vernier and tape or chain sometimes requires cleaning and oiling. This can be done by cleaning the gear with carbon tetrachloride, removing accumulated dust with a soft lintless cloth and oiling with a drop or two of good-quality machine oil.

The rules for seed testing [2] provide that the working sample shall be weighed to four *significant* places and each component of the separation shall be weighed to the same number of *decimal* places. This causes a slight conflict because working samples, weighing 1, 10, and 100 grams, or slightly more, usually yield components whose weights are 1 digit less than the weight of the original samples. Thus, in samples of 1.015 grams, 10.15 grams, and 101.5 grams, the heaviest component (pure seed) might be 0.987, 9.87, and 98.7 grams, respectively. Hence, if the rules are followed strictly in these cases, the original sample is weighed to four significant places but the components to no more than three places.

The number of significant figures is determined by the weight of the greatest component, zeros of the same order in the lesser weights being considered significant. Digits are significant whether they are before or after the decimal point.

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[2] The expressions "the rules" and the "rules for seed testing" refer to the Rules for Seed Testing (see Appendix) as followed in the administration of the Federal Seed Act and the Rules of the Association of Official Seed Analysts.

Table 2 shows the number of decimal places to which samples of different groups must be weighed in order to insure four significant figures for the components.

TABLE 2.—*Guide to the number of decimal places for weighing working samples and components to insure four significant figures*

Working sample		Components [1] of separation	
Weight specified in rules	Example	Number of decimal places	Example
Grams	*Grams*		*Grams*
0. 5	0. 5108	4	P 0. 9876
1. 0	1. 012		C . 0014
			I . 0102
			W . 0031
			1. 0023
2. 0	2. 025	3	P 9. 876
5. 0	5. 108		C . 014
10. 0	10. 02		I . 102
			W . 031
			10. 023
25. 0	25. 59	2	P 98. 76
50. 0	51. 63		C . 14
100. 0	102. 8		I 1. 02
			W . 31
			100. 23
500. 0	504. 2	1	P 487. 6
			C 1. 4
			I 10. 2
			W 3. 1
			502. 3

[1] The components of the separation are indicated as follows: P=pure seed; C=other crop seed; I=inert matter; W=weed seed.

HAND LENS

A triplet (triple aplanat) hand lens which magnifies five, six, or seven diameters is an efficient and convenient size for ordinary use. One which magnifies ten, twelve, or fourteen diameters is often used for separations of smaller amounts of seeds such as 400-seed separations of redtop and creeping bentgrass. To prevent eyestrain, hold the lens in the left hand, supported by placing the base of the thumb or hand against the forehead in such a manner that the lens will be directly in front of one eye. The analyst should learn to keep both eyes open while using the lens and to use either eye. Lack of exercise may result in weakened muscles of the idle eye. With the lens in the left hand and forceps in the right hand lower the head

and arms until the forearms rest on the armrests of the workboard and the seed is in focus when viewed through the hand lens. The seed will be in focus when the lens is approximately 1½ to 2 inches away. Proceed with the separation as indicated under the heading "The Purity Separation."

SEED BLOWER

The analyses of many samples, especially grasses, can be facilitated by removing the lightweight material with the aid of a seed blower. The sample to be analyzed should be examined and if it contains lightweight material the appropriate blower or blower combination should be used. Generally, several blowings are made at successively wider gate or valve openings. The fraction from each blowing is examined at the workboard by the aid of a hand lens or magnifying glass and the different components present are separated and placed in dishes or vials. The blowing and examination are continued until all the lightweight material is removed from the heavy fraction.

A record book, in which are recorded the gate or valve openings used for the different kinds of seeds, should be kept near the blower. The point at which pure seed begins to blow over and the point at which all lightweight material has been removed should be indicated. This serves as a guide for blowing subsequent samples of the same kind of seed.

THE PURITY SEPARATION

PRELIMINARY SEPARATION

The sample is reduced in size (preferably with a mechanical divider) and the weight of the working sample determined in accordance with the foregoing procedures. The separation is then made as follows: Place the seed on the clean surface of a workboard and examine to determine whether the sample: (1) Conforms to the name under which it was submitted; (2) contains small inert matter which should be removed by sieving; and (3) contains lightweight material which may be removed by blowing.

If inert matter is present which can be removed by sieving or a preliminary blowing, use the appropriate sieve or blow the sample in accordance with the procedure previously described. After these operations pour the sample in a pile on the workboard, slightly to the rear and left of center. With the aid of forceps, scalpel, or spatula having straight smooth edges draw a few seeds at a time from the pile, spreading them apart by pulling them toward the front of the board. As small groups of seed are being examined pull the pure seed into the scoop or container at the front of the workboard and push all other material to the upper right of the board for further examination. Continue this operation until the entire sample is separated.

Many samples of grass seed will require several blowings beyond the first one which removes only the empty florets. The next blowing should remove some empty and some filled florets. The sample should be blown until the heavy portion or residue contains no inert florets of the seed under consideration. The portion removed at each successive blowing should be separated into pure seed, crop seed, weed seed, and inert matter.

CHECKING FOR ACCURACY

After this examination return the pure seed to the workboard for further examination as indicated below: If the kind of seed requires a working sample of 50 grams or more, it is usually not necessary to use magnification in checking, although it is frequently desirable to examine the foreign seeds and inert matter under magnification. In samples of less than 50 grams all components, including pure seed, should be checked under magnification. After all the pure seed is checked, examine and separate the foreign material into other crop seeds, weed seeds, and inert matter.

WEIGHING, RECORDING, AND CALCULATING PERCENTAGES

Each of the four components must be weighed. There should be not more than 1 percent variation between the weight of the original sample and the total weight of the four components. If the gain or loss is greater than this amount another test should be made.

All pertinent data should be recorded in ink on a permanent record card. The data to be kept include weight and percentage of each component, the character of inert material, kinds and numbers of other crop and weed seeds, name or initial of analyst, and date of test. All reports should be made from this record. The percentages of the components are determined by dividing the weight of each by the sum of the weights of the four components, and not by the original weight of the sample. The record should be filed in a readily accessible place.

SEPARATING SEEDS OF SIMILAR KINDS AND VARIETIES

The rules for testing provide for the use of as few as 400 seeds in those cases where the working sample consists of two similar species or a species and its variety, which would require an excessive amount of time, eyestrain, and effort for separation of the entire working sample. Since tolerance tables for 400, 800, and 1,000 seeds are included in the rules of the Association of Official Seed Analysts it is recommended that one of these amounts be used. Frequently, when the separation is so difficult that a reduced sample is used it will be found that a stereoscopic microscope will often be helpful or even essential. In testing mixtures of creeping and colonial bentgrass seed most of the separation can be made with a hand lens by an experienced analyst but the microscope is essential for identifying those few nontypical seeds which seem to be present in every sample. It is also essential to use the microscope in making positive identifications of some weed seeds.

INTERPRETATION OF CROP SEED

APPLICABLE RULE

The following rule applies to both the pure seed and other crop seed when determining whether shriveled, cracked, broken, insect-injured, and diseased "seeds" should be considered inert matter or seed: Any pure seed or crop seed that comprises one-half, or less than one-half, its original size (not weight) is considered inert matter; otherwise, it is to be regarded as a seed.

BROKEN AND CRACKED SEEDS

Legume seeds usually break along the line of cleavage between the cotyledons. To be considered as pure seed a seed fragment must have its half of the seed coat as well as the radicle attached. Rye and barley seeds frequently break transversely. When in question line up the broken fragments on a workboard and place several normal, unbroken seeds of various sizes alongside them. From this comparison estimate the original size of each fragment and decide whether it represents one-half or more of the original seed.

The fragment does not have to contain an embryo in order to be regarded as pure seed. A similar procedure can be followed in determining the relative proportion of the original size which seed fragments in different groups represent. All cracked seeds are regarded as pure seed if the seed or fragment consists of more than one-half the original structure.

IMMATURE AND SHRIVELED SEEDS

Occasionally samples contain relatively high percentages of immature seeds which the analyst may think should be sifted and included with the inert material. Immature seeds are particularly prevalent in uncleaned seed lots. All these seeds are to be regarded as pure seed if they can be definitely identified as being the kind under consideration.

IMMATURE SEEDS IN GRASSES

This group differs from the preceding one in that the caryopses or seeds are enclosed within the lemma and palea. To apply the half seed rule in determining purity in grasses the question arises as to just how well developed the ovary must be to fulfill the definition of a seed. The difficulty in making this determination in grasses has led to varying results when tests have been made by different analysts. Before attempting to separate inert matter from pure seed in grasses the analyst should thoroughly acquaint himself with all the structures of the normal pure-seed unit. The caryopsis should be removed and studied as a basis of comparison between it and the immature, diseased, or empty florets. Although most of the grass seeds received for testing are florets consisting of a caryopsis enclosed by the lemma and palea the seed unit in some kinds is composed of the entire spikelet.

The separation of pure seed and inert matter is rather simple in those grasses with thin papery glumes as it is possible to see through the lemma and palea and determine the presence or absence of a caryopsis. Grasses with thick, horny lemmas and paleas are more difficult to classify as one cannot see through them and must resort either to reflected light or to some form of pressure. Standard blowing procedures and schedules have been adopted for Canada bluegrass and Kentucky bluegrass seed. These procedures are set forth on pages 67 to 70.

EMPTY FRUITS IN THE COMPOSITE FAMILY

Although it appears logical that the one-half seed rule should prevail in testing seeds of chicory, endive, lettuce, and sunflower this procedure is not practical of application. The so-called seed is a fruit (achene) of which the outer structures are comparable to the pod in the legumes. The true seed may or may not form inside the fruit and

it is not feasible to make this determination for all seeds. For example, in chicory some fruits are thin-walled but have heavy seeds within whereas others have very thick walls with immature seeds or no seeds. The filled and empty fruits do not separate in blowing and it would be impractical to open each fruit to determine its content. Opening the fruits would render the sample inadequate for germination purposes. All of these whole fruits are considered to be pure seed or crop seed as the case may be. Only broken fruits found to contain no true seeds or one-half seed or less are to be regarded as inert matter.

SEEDS OF LEGUMES AND CRUCIFERS WITH THE SEED COAT REMOVED

Crop seeds in the legume and crucifer (mustard) families with the seed coat entirely removed are classed as inert. To properly classify seeds without the seed coats it is necessary that they be identified as belonging to one of these two families. As a means of identification some normal, well-filled seeds of known samples should have the seed coats removed for comparison with the seeds in question.

INSECT-DAMAGED SEED

Insect-damaged seeds of pure seed and crop seed are also classified by the so-called one-half seed rule. If one-half or more than one-half of the seed has been consumed by the insect it is considered inert matter. With experience, most analysts will be able to determine insect-infested seeds by visual examination alone. For further information on this subject the reader is referred to particular groups listed under the heading "Application of Purity Procedures to Specific Groups of Seeds."

SCLEROTIA AND NEMATODE GALLS

In some instances nematodes have replaced most or all of the contents of the seed, forming nematode galls. In other instances mycelia of fungi have developed to the extent that they replace the contents of the seed, forming sclerotia. Although these nematode galls and sclerotia alter the inner contents of the seed there is a marked resemblance to true seeds, from outer appearances. These structures should be considered inert matter. Nematode infestations are frequently found in fescue and bentgrass seed and occasionally in wheat. Ryegrass seed infected with the blindseed fungus (*Phialea temulenta*) is not a sclerotium and thus should be classified as pure seed. Frequently, ergot replaces only a portion of the seed, especially in redtop. In such instances each seed must be considered on its own merits in applying the one-half seed rule. A diaphanoscope is often helpful in detecting the presence of ergot and other sclerotia. If nematodes are suspected a positive test can be made by crushing the seedlike structure, placing it in water for a few hours and then examining it under a microscope. The nematodes (eelworms) become active and can be easily identified by their wormlike motion.

INTERPRETATION OF WEED SEED

APPLICABLE RULE

The rules for seed testing set forth the nature of seedlike structures of weeds which are not to be regarded as weed seeds, and they indicate nine specific kinds and types of structures to be included with inert

matter. The following example is an attempt to clarify procedure with respect to these characteristics and seed types, which may be found in the rules (see pp. 337–338). If the analyst encounters a structure not specifically covered in the rules he should regard it as a weed seed unless he can definitely demonstrate by visual examination that it either has no embryo, has a rudimentary embryo, or has an embryo that has been destroyed by a disease organism.

METHODS OF EXAMINATION

Dissection of the seed and examination by reflected light are acceptable methods of examination. By dissection the seed is divided into separate parts for examination. From this definition it is seen that crushing cannot be substituted for dissection. Crushing destroys the seed material and makes it useless for careful examination. In grasses, with thin glumes, and in composites, with thin fruit coats, examination over a diaphanoscope may assist in differentiating between weed seeds and inert matter.

RUDIMENTARY EMBRYO

A rudimentary embryo is one which is imperfectly developed and functionally useless. It is usually difficult or impossible to determine that a seed has only a rudimentary embryo, or the stage of development at which it ceases being a rudiment and actually becomes an embryo. The analyst must be able to correctly identify the seed and have an understanding of its morphology, especially the size and location of the embryo. If this is not known dissect good seeds to get this information. In seeds of *Cyperus* the embryo is very small and lies at the base of the seed (achene) just above the point of attachment. Unless the analyst knows the location of the embryo he could very easily fail to find it and possibly classify the seed as inert. The situation is different in the composites in which all the seed (except seed coat) is embryo. Therefore, if upon dissection there is any structure within, it must be interpreted as a seed. Before classifying any seed believed to contain a rudimentary embryo as inert the analyst must satisfy himself that it is positively incapable of producing a plant.

GRASS SEEDS WITH EMBRYOS BROKEN OR ABSENT

Quackgrass (*Agropyron repens*) seed is frequently broken, especially when occurring in sweetclover seed. If more than one-half the embryo in a grass seed is missing the seed is regarded as inert. Normal seeds of the kind in question should be critically examined to determine the length, width, and thickness of the embryo in relation to the whole seed.

DODDER SEEDS

Seeds of dodder which are fragile, ashen gray to brown in color, and somewhat enlarged are included with inert matter. Before checking for the presence or absence of an embryo the analyst must know the internal structure of the seed and recall that the embryo, surrounded by the endosperm, lies coiled in the center of the seed. The analyst will become more certain of his interpretations if he first judges the seed from outward appearances and then carefully dissects it, noting whether the embryo area is empty or filled. Many samples have some dodder seeds which are definitely inert, others which are

definitely weed seeds, and others which are of questionable classification.

To avoid the dissection of a large number of seeds the questionable group is lined up in the order of quality as determined by outward appearances. In this group the one least likely to contain an embryo is dissected; if it has no embryo, the next likely ones are dissected until one or two seeds with embryos have been found. All seeds appearing better than the latter are regarded as good seeds.

NAKED RAGWEED SEED

There is no difficulty in determining the presence or absence of the pericarp and involucre in ragweed seed. It is important that these naked seeds (embryos) be correctly identified as coming from ragweed and not from some other composite plant.

SHRIVELED SEEDS OF BUCKHORN

The rule requiring that shriveled blackened seeds of buckhorn shall be classified as inert matter has caused much trouble. Questions frequently asked are: "How shriveled and how blackened?" All degrees of shriveling and blackening exist in some samples. Any seeds which can definitely be identified as buckhorn (*Plantago lanceolata*), when compared with known samples, should be classed as weeds. If the seed is shriveled and discolored to the extent that it can be identified to genus only, it should be considered as inert matter. The identification should be based on the merits of each seed and not on the fact that the sample contains well-developed seeds of buckhorn and no other species of *Plantago*.

GRASS FLORETS WITH IMMATURE CARYOPSES

Seeds of grasses which have developed only slightly beyond the flower stage are to be classed as inert or weeds depending on the development of the ovary. This is not too difficult in larger seeds such as Johnson grass but it can be extremely difficult in small seeds such as the weedy species of *Agrostis*, *Eragrostis*, *Panicum*, *Poa*, and *Polypogon*. The only dependable criterion in either case is removal of the caryopsis from the palea and lemma and comparison with normal seeds of the same species. For small seeds it is necessary to use the stereoscopic microscope in making some of the determinations. Caution must be exercised not to confuse dried-up stamens with immature caryopses.

EMPTY FRUITS OR ACHENES

Empty seeds or fruits of weedy plants such as occur in the buckwheat and composite families can often be detected either with reflected light or by dissection. As in the dodders it may be necessary to dissect or examine only a few seeds in the questionable group.

WEED SEEDS WITH THE SEED COATS REMOVED

The only weed seeds with seed coats removed to be regarded as inert matter are those of the legume family and the genus *Brassica* of the mustard family. This differs from the classification of crop seeds in that crop seeds without seed coats in the entire mustard family are classified as inert matter, whereas the only weed seeds without seed coats in this family to be classified as inert matter are species of

Brassica. Thus, a weed seed without seed coat which can be identified as belonging to the legume family or the genus *Brassica* is to be regarded as inert matter.

WILD ONION AND WILD GARLIC BULBLETS

The basal or stem-end portion of bulblets of wild onion and wild garlic must be present if the bulblet is to be considered a weed. Regardless of size the bulblets must be considered as weed seeds if they possess characteristics by which they can be identified, provided that the stem-end portion is present.

SPECIAL TESTS AND PROCEDURES

VARIETAL IDENTIFICATION

Varietal separation by seed character can sometimes be made with accuracy but usually this is not possible. Frequently all the plants of certain varieties in field trials cannot be positively identified. It is the responsibility of each analyst to familiarize himself with the possibilities of variety identification of the kinds with which he works and to let that knowledge govern the extent to which such separations are attempted. Space does not permit a discussion of the varietal character in different groups. Usually, the identification of varieties must be accomplished through greenhouse and field plantings.

PLANTING INCIDENTAL SEEDS FOR IDENTIFICATION

Incidental seeds which cannot be identified in the laboratory with certainty should, wherever possible, be tested by planting in a greenhouse or field and the plants produced from these seeds should be identified by a specialist for the group. To make sure that no other seeds are present in the soil used for the test only sterilized soil should be used. Seeds planted in the greenhouse often do not respond as they do in their usual habitat and at times produce plants which are so different from the normal that specialists find it difficult to identify them. It is necessary that a person attempting to grow plants understand their requirements and try to provide these conditions for each kind of plant. Adverse weather and climatic conditions and danger of contamination with other kinds make field plantings for identification of incidental seeds hazardous.

TESTING OF COATED AND PELLETED SEED

In recent years seeds encased with an inert covering have appeared in trade channels under such designations as "coated" and "pelleted" seed. Two processes have been used in covering the seed. In one process individual seeds are covered, and in the other process the number of seeds covered may range from one to several. Occasionally, an inert fragment is covered. In that case the pellet would be devoid of a seed.

No special provisions have been incorporated into the present rules for the testing of such seed for purity and germination. If the "coating" or "pelleting" of seed becomes a regular practice, standard methods of testing will have to be devised whereby analysts may determine whether such seed is sold in compliance with existing laws. Laboratories conducting service tests will also be testing seed lots subsequent

to pelleting, particularly carry-over stocks, for seedsmen and merchants. The exact laboratory procedures adopted will depend to a great extent on whether the "pellets," including the seed and coating material, or the true seed within the coating material is to be considered the unit for testing. The present rules for testing seed would have to be interpreted to mean that the true seed is the unit for test. The principal problem in the purity analysis appears to be that of removing the "covering" in order to determine the component parts of the sample and whether weed seeds, including noxious-weed seeds, are present.

For purity analyses made in accordance with the present rules the sample sizes would have to be those set forth in the rules, after the inert coating is removed. The coating can be removed by soaking it loose and straining off the inert material after which the seed is thoroughly dried. The weights of the pure seed, crop seed, and weed-seed components are determined as in a regular test. The difference between the total of these weights and the original sample weight represents the weight of the inert component.

OTHER SPECIAL TESTS

Certain other special tests such as varietal analysis of Sudan grass, mottled-seed test of sweetclover, and fluorescence test of ryegrass will be found under the specific groups and kinds to which the tests apply under the heading "Application of Purity Procedures to Specific Groups of Seeds."

APPLICATION OF PURITY PROCEDURES TO SPECIFIC GROUPS OF SEEDS

The first step in making a purity analysis is to examine the sample of seed submitted for test to determine whether it is correctly named.

The purity analysis and noxious-weed seed examination of all the small grass and legume seeds must be made with the aid of a hand lens. A reading glass may be substituted for the hand lens in examining some samples of large seeds such as Sudan grass and Crotalaria. A stereoscopic microscope is necessary for examination of seeds of questionable identity or classification.

The principal aids in seed identification include seed keys, descriptions, illustrations, and comparison with seeds of known identity. In cases of doubt the identified seed should be compared with samples of the same species, or related species, showing a range of variation. When there is doubt with respect to the identification of naked caryopses of grasses, and naked seeds from achenes and other fruits, seeds of known identity of the kind suspected should be removed from the husks for comparison. The known range of plants as determined from botanical manuals is frequently an important aid in seed identification.

The grain or seed in the grass family (Gramineae) is frequently enclosed by the lemma and palea, referred to variously as glumes, chaff, and husks. Commercial seeds of the grasses (most cereals and some other grasses excepted) are usually enclosed within these structures and the entire unit is referred to as a seed. In some cases the seed unit is a one-seeded spikelet; whereas, in some species the seed unit is a spikelet with several seeds. The analyst must be familiar with the structures constituting the seed unit in each group in order to make accurate identifications and distinctions between pure seed and inert matter. A typical grass spikelet is illustrated in figure 63, page 195. Most elementary grass manuals contain descriptions and illustrations of the flowers, fruits, and spikelets in the grasses.

In seeds of the grass family the inert matter consists chiefly of the following: Florets, of both weed and crop species, which are empty or contain only anthers or undeveloped ovaries; pieces of pure seeds and other crop seeds which have been reduced to one-half or less their original size by mechanical injury, insect infestation, or destruction by rodents; pieces of sticks and stems, chaff, and dirt; occasional empty fruits or seeds of weeds; seeds of *Juncus* spp. if not more than one-tenth percent; smut (round, dark brown balls often contained in lemmas and paleas); ergot (dull purplish black, thicker and longer than caryopses); and nematode galls (shiny black to glossy amber and spindle-shaped). When dropped into water and allowed to stand for about half an hour nematodes will appear as a small cottony tuft. If a portion of a nematode gall is crushed and placed in water on a

microscope slide and examined under a microscope, the eelworms can be observed within a few moments.

Inert matter in legume and other seeds consists chiefly of: Pieces of pure seed and other crop seed which have been reduced to one-half or less of their original size by mechanical injury, insect infestation, or destruction by rodents; pieces of sticks and stems, chaff, and dirt; and occasionally empty fruits or seeds of weeds.

GRAMINEAE (GRASS FAMILY)

AGROPYRON AND ELYMUS—WHEATGRASSES AND WILD-RYE

Kind of seed	*Key to species, Page*	*Illustration, Plate*
Agropyron cristatum—Fairway crested wheatgrass	200	I, 13
A. desertorum (A. cristatum)—Standard crested wheatgrass	200	I, 14
A. trachycaulum (A. pauciflorum)—Slender wheatgrass	200	I, 11
A. smithii—Western wheatgrass	201	I, 10
Elymus canadensis—Canada wild-rye	215	IV, 81

Seed unit.—Free caryopsis or floret with a caryopsis.

Special treatment.—Samples should be partially separated with a seed blower. If extraneous material is present after blowing, some of the hand separation may be eliminated by sifting. Separate the multiple florets if one or more contains a pure seed. Include the empty florets with the inert matter.

Special problems.—A bulk sample of Fairway crested wheatgrass seed can be distinguished from seed of Standard crested wheatgrass but it is not possible to distinguish all of the individual seeds.

It is easy to overlook seeds of *Agropyron repens* and other species of *Agropyron* and *Elymus* spp. in samples of *A. trachycaulum*, *A. smithii*, and *Elymus canadensis*. Examine all seeds critically with a hand lens, removing any which appear not to have all the characters of the pure seeds. Under magnification place all questionable seeds next to known normal seeds for final determination.

AGROSTIS—REDTOP AND BENTGRASSES

Kind of seed	*Key to species, Page*	*Illustration, Plate*
Agrostis alba—Redtop	197	I, 1
A. canina—Velvet bent	198	I, 5
A. palustris—Creeping bent	198	------
A. tenuis—Colonial bent	198	I, 2
A. tenuis var.—Astoria bent	198	------
A. tenuis var.—Highland bent	197	------

Seed unit.—Caryopsis; floret or spikelet with caryopsis.

Special treatment.—Practically all samples of *Agrostis* require blowing. If samples contain fine dirt and small weed seeds it is advantageous to sift the heavy seed left after blowing. Sieves with round holes 0.508 and 0.612 mm. in diameter are most effective. These sieves will remove fine dirt as well as some tiny weed seeds.

While the purity test is being made the analyst should take special note of the *Agrostis* and determine whether there is more than one species present. If more than one species is present, a detailed separa-

tion of the different species must be made. At least 400 seeds must be taken indiscriminately from the pure seed fraction, after the regular purity analysis has been made, for this detailed separation.

Special problems.—Separating the species and varieties in the 400 or more seed test of *Agrostis* should not be undertaken except by trained and experienced analysts. Although most of the seeds can be separated into kinds, there are often a few seeds which cannot definitely be identified. Naked caryopses are included in the separation but no attempt is made to identify them.

The procedure and calculations are indicated in the following example (developed by the Standardized Test Committee) for a 400-seed separation of *Agrostis* with 95.07 percent pure *Agrostis*, no other crop seed, 4.32 percent inert matter, and 0.61 percent weed seed:

Where no field information is available—

	Weight, Grams	*Percentage in sample*
Total *Agrostis*, including naked caryopses	0. 9524	95. 07

400 seeds with lemma and palea plus naked caryopses are examined.

	No. seeds	*Percent*			
Naked caryopses	117	22. 63		21. 52	
(Report as unidentified)					
Creeping bent	173	33. 46	×95. 07	31. 81	=95. 07
Redtop	147	28. 43		27. 03	
Brown top	80	15. 48		14. 71	
Total	517	100. 00			

Samples of *Agrostis* submitted for test often have the glumes, as well as the lemmas and paleas, present. These seeds are generally termed as "unhulled." In the lighter blowings it is often necessary to remove the seed from these glumes before it is possible to determine whether or not there is a seed present. In the heavy portion it is sometimes possible to allow all those seeds with glumes to remain with the pure seed but enough should be removed from the glumes and examined critically to determine with certainty that these hulls contain seed and not ergot or other foreign substances.

Samples of *Agrostis* often contain naked caryopses of bluegrass which are not difficult to distinguish. The caryopses of *Agrostis* are amber brown in color, transparent, rounded at both ends with a rounded, well-defined embryo area on one side and a crease or definite fold along the other side. The seed lies flat on this fold. In cross section it somewhat resembles the capital letter "B."

Bluegrass caryopses are of similar sizes but orange brown in color, opaque, pointed at the ends with the embryo area obscure and poorly defined. The caryopsis of *Poa* has a keel on the embryo side and a flat face on the hilum or opposite side. In cross section bluegrass seed is triangular.

Tiny seeds of several weeds including some weedy species of *Agrostis* which might easily be overlooked in samples of *Agrostis* are: *Parentucellia*, *Juncus*, *Downingia*, *Lobelia*, *Epilobium*. In Redtop there are often light-colored, inflated, shiny seeds of *Achillea millefolium* which, when dissected, appear to contain insect larvae. These must be included with the inert matter.

ANDROPOGON, BOUTELOUA, SORGHASTRUM—BLUESTEMS, GRAMAS, AND INDIAN GRASS

Kind of seed	*Key to species, Page*	*Illustration, Plate*
Andropogon gerardi (A. furcatus)—Big bluestem	203	II, 25
A. hallii—Sand bluestem	203	II, 26
A. scoparius—Little bluestem	203	II, 27
Bouteloua curtipendula—Side-oats grama	209	II, 46
B. gracilis—Blue grama	209	II, 47
Sorghastrum nutans—Yellow Indian grass	-----	------

Seed unit.—Naked caryopsis; spikelet or floret with at least one caryopsis.

Special treatment.—Because of the presence of awns, hairs, and rachillae, the seeds stick together badly so that satisfactory sampling and blowing are difficult. If the sample mats to the extent that it cannot be accurately sampled with a mechanical divider, use the halving method. If the sample lodges in the blower tube, blow smaller portions at a time, combining the separations of the blowings; or use a 3- to 4-inch blowing tube. Multiple florets are not separated in these tests.

Special problems.—If it becomes necessary to determine whether the seed units contain caryopses examine the blowings critically as the glumes of these grasses are horny and not transparent. Dissection may be required but, in this event, care must be exercised not to injure any caryopses which may be present. The sample should be blown until all of the heaviest spikelets and florets contain pure seed. There are some confusing weedy species in the group which must be critically compared with verified specimens to determine their identity.

Lots of these species are sometimes processed in such a manner that most of the glumes are removed. In processing, the seed loses some of its characters commonly used for identification, making separation of species of crop and weed seeds difficult or impossible. Some seeds are broken during processing, making it necessary to judge them on the half-seed basis.

AVENA—OATS

Kind of seed	*Key to species, Page*	*Illustration, Plate*
Avena sativa—White oats	207	II, 36
A. byzantina—Red oats	207	II, 37

Seed unit.—Free caryopsis, floret or spikelet.

Special treatment.—If the sample contains empty florets or insect-infested florets it should be blown in a 3- to 4-inch blower tube; or the sample should be divided and a small portion blown at a time.

White oats should be sifted in a slotted sieve 0.064 x 3/8 inch which will remove chaff and single florets of *Agropyron repens*, if present. This sieve will not remove many of the multiple florets of *A. repens*. If after sieving one finds single florets of *A. repens* in the pan it is an indication of the possibility of multiple florets being present in the top sieve.

Special problems.—Because of lack of development or incomplete development, the lemma of the primary floret frequently encloses the secondary floret completely or in part. These should be separated

in those cases where the tip of the secondary floret protrudes or diverges from the primary floret. In those instances where the lemma of the primary floret encloses the secondary floret to the extent that the tips of the florets do not diverge, separation of the two florets is not practical, nor does it increase the accuracy appreciably.

Wild oat, *Avena fatua*, a weed, is often found in cultivated oats. Fatuoid forms of certain varieties of cultivated oats appear in samples of varieties from which they are derived. They usually have one or more of the characters of *A. fatua* such as the sucker mouth, hairy base, rachilla with a cup at the tip, rough lemma, and heavy twisted awn.

Among the fatuoid seeds there are some which are homozygous and produce only fatuoid plants but there are others which are heterozygous and produce both fatuoid plants and normal plants. The two forms are usually indistinguishable and must be put in the same classification. Fatuoid oats have been classified as pure seed, other crop seed, and weed seed by different laboratories. Since no method of eliminating fatuoid forms from pure varieties and strains of oats has been found they are placed with the pure seed for purposes of administering the Federal Seed Act. It is frequently desirable to determine the percentage of fatuoid oats separately and add this to the percentage of the component indicated by the particular State laws and regulations or by the seedsman.

There are sometimes seeds in cultivated oats which faintly resemble fatuoids which cannot be accurately distinguished from pure cultivated oats. Since these may produce pure cultivated oats, they are included with the pure seed.

It is possible to distinguish the seeds of certain varieties and groups of varieties of oats, particularly certain varieties of *Avena byzantina*. Testing oats for variety is generally done on a sample of 20 to 30 grams in weight which gives at least 400 seeds. This portion is taken indiscriminately from the pure seed fraction after a regular purity analysis has been made. The naked caryopses should not be used in making this separation unless a variety is present which is known to shatter from the lemma and palea to a greater extent than other varieties present.

The following example illustrates the procedure and method of calculating the results:

Example—

Total percentage of oats in regular purity analysis ..... 98.79 percent.
Weight of sample for variety determination ..... 25.35 grams.

	Wt. in gm.	*Percent*		*Percent of sample*
Victorgrain	23. 91	94. 43×98. 79	=	93. 29
Fulgrain	. 99	3. 91×98. 79	=	3. 86
Other oats	. 42	1. 66×98. 79	=	1. 64

AXONOPUS AND PASPALUM—CARPET GRASS, DALLIS GRASS, AND OTHERS

Kind of seed	*Key to species, Page*	*Illustration, Plate*
Axonopus affinis—Carpet grass	208	II, 42
Paspalum dilatatum—Dallis grass	222	VII, 140
P. notatum—Bahia grass	223	VII, 145
P. urvillei—Vasey grass	222	VII, 148

Seed unit.—Caryopsis, floret with caryopsis, or spikelet with caryopsis.

Special treatment.—All samples must be blown until all the florets which are closed (not gaping at the tips) resist the pressure of pointed forceps. Unless they are blown to this degree it will be necessary to press each seed in the sample to determine whether it is pure seed or inert matter.

Special problems.—*P. urvillei* is hairy and tends to lodge in both the divider and blower. If necessary, obtain the samples by the halving method and blow in a 3- to 4-inch blowing tube; or separate the sample into smaller portions and blow each separately.

The thick lemmas and paleas on the seeds of all *Paspalum* species make the purity determination very difficult. Some analysts find that in addition to blowing and pressing seeds with the forceps that examination of the individual seeds with the aid of a diaphanoscope assists in separating the pure seed from the inert matter. Seeds of all *Paspalum* species are subject to attack by ergot. The normal caryopses are hard, brittle, and translucent with well-defined embryo; those which are ergotized are hard but spongy and opaque with no clearly defined embryo or embryo area.

Until he becomes entirely familiar with the seeds and the problems associated with these tests, it is well for the inexperienced analyst to begin with the heavy portion left in the blower cup. From this portion remove as inert those florets gaping with ergot; next remove gaping florets which do not show any ergot. Put these on the workboard, palea side down; with a pair of sharp-pointed forceps slightly open, press on the seed toward the callus end and across the keel. If the floret contains a pure seed the caryopsis will resist slight pressure, but if it is inert the points of the forceps will penetrate the lemma. When a few florets have been determined in this manner it is advisable to separate the lemmas and paleas until their contents can be seen and the interpretations made without complete dissection. It will not be necessary to open all the florets removed from the heavy portion for the analyst will soon acquire the "feel" of both the pure seed and the inert.

After the heaviest portion has been examined the same procedure should be followed on each of the blowings, continuing with the next heaviest blowing successively until one blowing contains only inert florets. It is ordinarily safe to assume that all blowings lighter than this are inert matter.

BROMUS—BROME AND RESCUE GRASS

Kind of seed	*Key to species, Page*	*Illustration, Plate*
Bromus catharticus—Rescue grass	210	III, 56
B. inermis—Smooth brome	210	III, 55
B. marginatus—Mountain brome	210	III, 57

Seed unit.—Caryopsis, floret with caryopsis, or spikelet.

Special treatment.—Blow in 3- to 4-inch blower tube or blow smaller portions and combine the separations of the blowings. Separate the multiple florets if one or more contains a pure seed.

Special problems.—Bulk samples of *Bromus catharticus* and *B. marginatus* can be distinguished but there may be a few individual

seeds in the purity analysis which cannot be distinguished with certainty. If one species is found in the other, any indistinguishable seeds should be included with the pure seed and the following note affixed to the record: "Certain seeds of *B. catharticus* and *B. marginatus* are indistinguishable."

Weedy species of *Bromus* which might be confused with *B. catharticus* and *B. marginatus* include *B. breviaristatus*, *B. carinatus*, *B. polyanthus*. *Bromus inermis* often has much light chaff and also light seed present. Some of the caryopses, both naked and in the florets, are very thin. If the caryopsis is complete it must be included with the pure seed regardless of size. Some thin caryopses of *B. inermis* are as thin and limber as a sheet of bond paper but still must be classed as pure seed.

B. inermis often has seeds of several species of *Agropyron*. Each seed of *Agropyron* must be examined critically to separate the crops from the weeds. In the noxious-weed seed examination remove all *Agropyron* spp., then separate *Agropyron repens* from the other species by critical examination, including the use of hand lens and stereoscopic microscope, if necessary.

CYNODON, CYNOSURUS, AND PHALARIS

Kind of seed	*Key to species, Page*	*Illustration, Plate*
Cynodon dactylon—Bermuda grass	-----	III, 62
Cynosurus cristatus—Crested dogtail	213	III, 64
Phalaris arundinacea—Reed canary grass	223	VII, 152
P. canariensis—Canary grass	223	VII, 155
P. tuberosa var. *stenoptera*—Harding grass	224	VII, 154

Seed unit.—Caryopsis or floret with caryopsis.

Special treatment.—*Phalaris arundinacea* and *Cynosurus cristatus* are always blown; the other kinds are blown and sifted only if light florets, much fine dirt or many small weed seeds are present.

Special problems.—Determination of pure seed is difficult as the lemma and palea are so thick and opaque that it is not easy to see through them. The sample should be blown until all florets with undeveloped ovaries or only anthers are removed. Until the analyst becomes thoroughly familiar with the test he should develop the habit of critically examining those caryopses which he cannot classify with certainty, from the appearance and "feel" of the florets.

Bermuda grass seed is sometimes processed to remove the lemmas and paleas. This reduces the pure seed determination to identification of the species present and to determination of the relative sizes of damaged portions of seeds.

Those seeds of *Phalaris* with lemmas and paleas can be distinguished but the identification of the naked caryopses may or may not be possible depending on the species represented.

DACTYLIS—ORCHARD GRASS

Kind of seed

Dactylis glomerata—Orchard grass.

The seed is described on page 213 and illustrated in plate III, 66.

Seed unit.—Caryopsis or floret with caryopsis.

Special treatment.—Samples often have many multiple florets as well as other crop and weed seeds of varying sizes, shapes, and weights,

which make it difficult to get a representative sample. The sample should be thoroughly mixed before the dividing is begun. All multiple florets must be separated if one or more contains a seed. Separation of single and multiple florets is facilitated by sifting with slotted sieves. Sieves with round and triangular holes are aids in removing weed seeds.

Special problems.—It is advisable for the beginner to examine the heavy portion of seed first in order to become acquainted with the normal seed unit. He should note the light brown, soft-appearing caryopsis which can be seen with the aid of the hand lens if the light is allowed to shine through the structure. As the lighter blowings are examined one is often confronted with the structures which are approximately normal size but which are gray or orange and opaque. Remove these structures from the florets for critical examination to determine whether they are to be classified as pure seed or inert matter. In most instances they are not seeds and therefore are included with the inert.

Orchard grass seed often contains small slender seeds of weedy bromegrasses which can easily be overlooked unless the analyst suspects their presence. *Agropyron repens* is often found in imported samples but often only unfilled florets, or those with only anthers or undeveloped ovaries, are present. The small thick structures occasionally found may be either weed seeds or inert matter. Orchard grass grown in the United States is often infested with bulblets of *Allium vineale*, which are considered noxious weeds in many States. These bulblets are frequently shriveled, dried, or broken but must be removed and classified in accordance with the rules. They are to be regarded as inert matter when the basal or stem end has been removed, but if they can be identified as *Allium vineale* and the basal-end portion is present they are to be regarded as weed seeds.

FESTUCA—FESCUES

Kind of seed	*Key to species, Page*	*Illustration, Plate*
Festuca arundinacea—Tall fescue	218	IV, 94
F. capillata—Hair fescue	217	------
F. elatior—Meadow fescue	218	IV, 93
F. ovina—Sheep fescue	217	------
F. rubra—Red fescue	217	IV, 95
F. rubra var. *commutata*—Chewings fescue	217	------

Seed unit.—Caryopsis or floret with caryopsis.

Special treatment.—All samples should be blown; one or two blowings are usually sufficient to remove all the light material from the heavy.

Special problems.—Individual seeds of *Festuca elatior*, *F. arundinacea*, and *Lolium* spp. are frequently very similar in appearance and difficult to distinguish. However, they can be identified accurately with the use of seed keys, illustrations, and comparisons with verified samples. The most obvious characters used in their identification are given below.

Seeds of *Lolium* are symmetrical and have a thin wide callus with a slight depression between it and the lemma. The callus is so wide that the sides of the floret taper little but are almost parallel. There are no teeth on the veins of the lemma, which is brown in color. The

palea has no longitudinal depression and the teeth along its edges extend downward below its middle. The rachilla is flat with parallel sides and has no cup at its tip.

Seeds of *Festuca arundinacea* are symmetrical and have a thick narrow callus with a noticeable depression between it and the lemma. The sides of the floret taper down to the narrow callus. The color of the lemma is brown, similar to that of *Lolium*. There are teeth on the veins of the lemma, especially near the tip. The palea has a longitudinal depression and the teeth along the upper edges of the palea extend to only about its middle. The rachilla is round with parallel sides and has a cup at its tip.

Seeds of *Festuca elatior* are spindle-shaped and have a thick narrow callus with a noticeable depression between it and the lemma. The sides of the floret taper down to the narrow callus. The color of the lemma is lighter brown than *Lolium* and *Festuca arundinacea*. The texture of the lemma is smooth whereas it is grainy in the case of *F. arundinacea* and *Lolium*. There are no teeth on the veins of the lemma. The palea has a longitudinal depression and the teeth along the upper edges of the palea extend to only about the middle. The rachilla is round with parallel sides and has a cup at its tip.

Chewings fescue and other varieties of red fescue can be distinguished only in the bulk. The lemmas and paleas of Chewings fescue are brighter in sheen, more purple in color, narrower in proportion to length, and the lemmas appear to fit the caryopses neater than in the other varieties of *Festuca rubra*. In contrast the other varieties appear somewhat duller, whiter, broader, and the lemmas do not fit the caryopses as neatly as in Chewings fescue.

Many samples of *Festuca* are infested with nematode galls. These galls can be distinguished from the pure seed and are to be included with the inert matter. The lemmas and paleas in normal *Festuca* seeds fit tightly and adhere to the caryopsis making it difficult to remove the latter. Nematode infested lemmas fit loosely, become twisted longitudinally, and the structure within can be seen through the lemmas to be pointed rather than blunt as in the normal seed. The galls slip out of the lemmas easily and are then seen to be either shiny black or amber at the base graduating into black at their tips. These are nematode galls and are included with the inert matter. If the galls are soaked in water for about half an hour the nematodes or eelworms will appear as a cottony mass; or they can be observed under a microscope if crushed and placed in water on a microscope slide.

TRITICUM, HORDEUM, PENNISETUM, SECALE, ORYZA, ZEA—CERTAIN CEREALS

Kind of seed	*Key to species, Page*	*Illustration, Plate*
Triticum spp.—Wheat, Spelt, Emmer	-----	XII, 201
Hordeum vulgare—Barley	218	V, 104
Pennisetum glaucum—Pearl millet	223	VII, 149
Secale cereale—Rye	-----	XI, 184
Oryza sativa—Rice	-----	V, 117
Zea mays—Corn	-----	-----
Z. mays var. *everta*—Popcorn	-----	-----
Z. mays var. *saccharina*—Sweet corn	-----	-----

Seed unit.—Caryopsis (grain) or floret with caryopsis.

Special treatment.—Blowing is an aid in determination of insect injury. If badly broken, it is sometimes possible to remove some broken seeds by blowing; sifting removes fine dirt and seeds.

Special problems.—One of the commonest difficulties in making purity analyses in this group is in determining the size of broken fragments of pure and crop seed in relation to their original size. The analyst should first critically examine normal seeds of the kind being tested and note the size and shapes of normal seeds as well as the proportion of the seed occupied by the embryo. This will serve as a guide in determining whether more than a half seed is present in those parts of seeds containing the embryo.

The broken seeds, whether pure seed or other crop seed, should be removed from the sample, except those which upon first glance are seen to be obviously more than one-half the original size. All of the smaller fragments which are obviously less than one-half may be placed in inert matter. The remainder of broken fragments should be lined up side by side in order of relative size and each classified on the basis of its own original size. One can determine with little difficulty that some seed pieces are more than one-half and others less than one-half the original size, usually leaving only a very few fragments in doubt. If it is impossible to make a positive determination on these few remaining fragments allow one-half to be classed as pure seed and the others as inert; or if there is an uneven number put the larger number with the pure seed.

Seeds infested or damaged by insects present a problem somewhat similar to the broken-seed problem, although frequently more difficult. If the sample contains live insects they should be killed by a fumigant. Blowing in a 3- to 4-inch blowing column will remove some of the lighter seeds and inert material but in badly infested samples each seed in the heavy portion will need to be examined critically to determine whether more than one-half the original seed is present.

Immature and damaged grains of some of the kinds in this group are difficult to distinguish from others. For example, shriveled grains of wheat and rye occasionally appear very similar. The size, shape, and position of the embryo, the fold on the seed and the color and texture of the grain are characters which aid in distinguishing some of these cereals.

Wheat is sometimes infested with nematodes. The infested grains often retain a shape similar to the original but they appear somewhat charred or burned, and there is no embryo. These nematode galls are included with the inert matter. If there is a question as to identity one of the galls should be soaked in water for approximately half an hour to allow the nematodes to appear.

In this group ergot occurs chiefly in rye. There is no difficulty in distinguishing the long thick grayish black sclerotia from the normal grains of any of the kinds of seed in which they occur. Smut balls are found only occasionally but they are easily identified as they have little resemblance to seeds.

Red rice is so named because of the color of the outer covering of the rice grain. There is no problem in removing these red grains, which are defined as noxious weeds by some State laws, in samples of

milled rice which have the lemmas and paleas removed. In unmilled samples there is no way of identifying these red grains except to remove the hulls by a mill or by hand. This would be far too laborious a process for a noxious-weed seed examination.

If a purity analysis and noxious-weed seed examination are required of samples of unmilled rice containing red rice, it is advisable to make the 100-gram purity analysis without regard to the red rice; then make the noxious-weed seed examination on a 500-gram sample which should be milled, to remove the lemmas and paleas, and examined for the presence of noxious weed seeds.

LOLIUM—RYEGRASS

Kind of seed	*Key to species, Page*	*Illustration, Plate*
Lolium multiflorum—Italian ryegrass	220	V, 111
L. perenne—Perennial ryegrass	220	V, 110

Seed unit.—Caryopsis or floret with caryopsis.

Special treatment—Samples should be blown to remove light and empty florets. Generally, there are only a few florets which are difficult to interpret. The fluorescence test which is used to determine percentages of *Lolium multiflorum* in samples of *L. perenne* is fully described under the heading "Procedures for Determining Germination."

Special problems.—Seeds of perennial and Italian ryegrass can be distinguished if the awns of the Italian ryegrass have not been broken off. In commercial samples of ryegrass many awns are broken off making it impossible to make an accurate separation on the basis of seed characters alone. Bulk samples of the two kinds can usually be distinguished. *L. multiflorum* has awns, is arched on the lemma side so that it will not lie flat on that face, is coarser, heavier, and darker in color than *L. perenne*. *L. perenne* is devoid of awns.

The percentages of perennial ryegrass and Italian ryegrass seed in a sample can be determined by the fluorescence test more accurately than from seed characters. All samples submitted as perennial ryegrass should be tested for fluorescence in accordance with the methods described on pages 103 to 104. The following formula has been included in the rules for seed testing for calculating the percentages of pure perennial ryegrass after a fluorescence test has been made:

$$\text{Percent perennial ryegrass} = \frac{1.0526 \times \text{percent nonfluorescence} \times \text{percent ryegrass}}{\text{percent fluorescence} + \text{percent nonfluorescence}}$$

The following example will illustrate the substitution of test data in the formula for a sample found to contain 98.80 percent pure seed in the regular purity analysis:

Results of fluorescence test: Fluorescence=22.5 percent; nonfluorescence=71.5 percent. Upon substituting the results in the formula we have—

$$\frac{1.0526 \times 71.5 \times 98.80}{22.5+71.5} = \frac{7435.78}{94.0} = 79.10 \text{ percent of } \textit{Lolium perenne} \text{ in the sample.}$$

Ergot is not uncommon in ryegrass seed. Caution must be employed to insure that ryegrass seed is not mixed with some of the larger seeded species of fescue. *Agropyron* and *Elymus* seeds may also be

confused with those of ryegrass. It is advisable to remove all seeds about which there is any question and reexamine them later, comparing them with illustrations as well as verified samples.

Ryegrass seed is sometimes attacked by rodents as evidenced by the absence of the lemma and back part of the seed which have been stripped away, leaving the broken seeds in view. Some of these can be removed by blowing but each floret in the heavier fraction must be judged as to relative size on its own merits.

PANICUM, SETARIA, ECHINOCHLOA, ORYZOPSIS, AND ZOYSIA

Kind of seed	*Key to species, Page*	*Illustration, Plate*
Panicum antidotale—Blue panic grass	221	VI, 122
P. ramosum—Browntop millet (see footnote, page 397)	221	VI, 136
P. maximum—Guinea grass	221	VI, 132
P. miliaceum—Proso millet	222	VI, 133
P. virgatum—Switchgrass	222	VI, 138
Setaria italica—Foxtail millet	229	XI, 180–183
Echinochloa crusgalli var. *frumentacea*—Japanese millet	214	IV, 78
Oryzopsis hymenoides—Indian ricegrass	-----	V, 118
O. miliacea—Smilo	-----	V, 119
Zoysia japonica—Japanese lawngrass	231	XII, 202
Z. matrella—Manila grass	231	XII, 203

Seed unit.—Caryopsis; floret or spikelet with a caryopsis.

Special treatment.—All samples should be blown to remove the light chaff. The seed unit in all these genera have thick opaque coverings which make the determination of pure seed by vision alone impossible. In most samples it is advisable to make several blowings, being sure that the air pressure is strong enough to remove all inert florets and spikelets from the heavy portion. Examine the heaviest fraction first and work down through the lighter blowings. Samples containing fine dirt and weeds should be sifted.

Special problems.—One of the principal problems in this group is the separation of florets and spikelets with seeds from those which are empty. Separate a few of the seeds from the heaviest fraction on the basis of their resistance to the pressure of pointed forceps. When a few of these have been separated open the lemma and palea of a few to determine whether the floret or spikelet should be considered pure seed or inert matter. It will be necessary to open only a few to establish confidence in the operation.

Setaria italica, foxtail millet, contains two important varieties: German millet; and Common millet. These two varieties of millet hybridize readily in the field. Hybrid seeds cannot be definitely identified as to variety. Therefore, any variety separation on the seeds of millet must be of a negative nature. The presence of tubercled seeds in Common millet or smooth seeds in German millet suggests that the sample is not pure as to variety. Since an accurate separation to determine the percentages of varieties cannot be made such a separation cannot be used for labeling purposes. However, the test has some value in seed control work.

Samples of *Setaria italica* often contain seeds of *Setaria viridis* and *Setaria verticillata*. These seeds are smaller and rougher than foxtail millet and are usually mottled.

The florets of Japanese millet and barnyard grass (*E. crusgalli*) might easily be confused but the spikelets are readily distinguished by

the awns and the presence of teeth on the glumes of barnyard grass. The florets of barnyard grass are more slender, with the widest point about midway of the floret, whereas the widest point in Japanese millet is below the middle.

PHLEUM, ERAGROSTIS, AND SPOROBOLUS

Kind of seed	Key to species, Page	Illustration, Plate
Phleum pratense—Timothy	-----	V, 120
Eragrostis curvula—Weeping lovegrass	216	IV, 88
Sporobolus cryptandrus—Sand dropseed	231	XII, 197

Seed unit.—Caryopsis or floret with caryopsis.

Special treatment.—Blow samples which may contain empty or immature florets. Sift to remove fine dirt and seeds.

Special problems.—The identification of *Sporobolus cryptandrus* may be difficult, especially in samples containing seed of *S. contractus*. Seeds and florets of *S. cryptandrus* are very similar to those of *S. contractus* which occur in a much more limited area. Timothy seed may retain the lemmas and paleas (grains in the hull or chaff) or may be free of them. Seedsmen sometimes desire to know the percentage of hulled seed in lots of timothy. This separation should be made from the pure seed component of a regular purity analysis, using the entire sample. Ordinarily, there is no difficulty in separating the entire pure seed portion (approximately 2 grams); by doing so calculation of the results is simplified.

ALOPECURUS, ANTHOXANTHUM, ARRHENATHERUM, CHLORIS, HOLCUS, AND MELINIS

Kind of seed	Key to species, Page	Illustration, Plate
Alopecurus pratensis—Meadow foxtail	202	I, 22
Anthoxanthum odoratum—Sweet vernal grass	204	II, 33
Arrhenatherum elatius—Tall meadow oat grass	205	II, 35
Chloris gayana—Rhodes grass	212	III, 60
Holcus lanatus—Velvet grass	-----	V, 102
Melinis minutiflora—Molasses grass	-----	V, 114

Seed unit.—Caryopsis; floret or spikelet with caryopsis.

Special treatment.—If the sample lodges in the blower tube, blow smaller portions and combine the separations of the blowings; or use a larger, 3- to 4-inch, blowing tube.

Special problems.—Determination of pure seed is difficult as the lemmas and paleas are so thick and translucent that the presence or absence of a caryopsis cannot be ascertained without the use of pressure or reflected light. Make several separate blowings—until all florets with only anthers or undeveloped ovaries are removed from the heavy portion. Begin with the heaviest blowing first, removing, for critical examination, those caryopses whose value cannot be determined with certainty on the basis of appearance and "feel" of the florets.

When it is necessary to identify naked caryopses, compare them with caryopses removed from known samples.

Little, if any, seed of molasses grass and Rhodes grass is produced in this country. The imported seed is usually of low purity. The

light inert matter must all be blown off or the purity analysis will require critical examination of each floret involving more time than is justified.

The spikelets of *Chloris gayana* normally consist of one fertile and one sterile floret but occasionally both are fertile. Attached sterile florets are not removed in the purity test. Single florets are not usual. In examining the blowings be sure to critically examine both upper and lower florets for pure seed. Some help can be gained by using the diaphanoscope, but this test, more than any other, requires a great deal of interpretation by "feel." Use caution with respect to the amount of pressure exerted on the florets or the seed may be injured, resulting in low germination. The presence or absence of a caryopsis can be determined most accurately by stroking the spikelet from the callus to the tip with the edge of the spatula, forceps, or scalpel and not by exerting pressure with the points of these instruments.

Seeds of this group likely to be confused with other species include the following:

Alopecurus pratensis with seeds of *Alopecurus geniculatus;*
Anthoxanthum odoratum with seeds of *Anthoxanthum aristatum;*
Chloris gayana with seeds of *Chloris virgata* and *Chloris divaricata;*
Holcus lanatus with seeds of *Holcus mollis.*

BUCHLOË—BUFFALO GRASS

Kind of seed

Buchloë dactyloides—Buffalo grass.
Description on page 208; plate II, 45.

Seed unit.—Bur, floret, or caryopsis.

Special treatment.—If sample contains small incidental seeds and dirt, sifting eliminates some of the hand work.

Special problems.—None except possible broken caryopses in processed seed.

POA—BLUEGRASS

Kind of seed	*Key to species, Page*	*Illustration, Plate*
Poa annua—Annual bluegrass	226	VIII, 159
P. arachnifera—Texas bluegrass	226	VIII, 161
P. bulbosa—Bulbous bluegrass	227	VIII, 163
P. compressa—Canada bluegrass	225	VIII, 164
P. nemoralis—Wood bluegrass	226	IX, 166
P. nevadensis—Nevada bluegrass	226	IX, 167
P. pratensis—Kentucky bluegrass	225	IX, 169
P. trivialis—Rough bluegrass	225	IX, 170

Seed unit.—Caryopsis; floret or spikelet with caryopsis and in *Poa bulbosa* the bulblet.

Special treatment.—There are two basic procedures accepted for testing Kentucky bluegrass and Canada bluegrass seed for purity. The standard or generally accepted procedure consists of separating the sample into several fractions with a seed blower which may or may not be standardized, and working the sample normally.

Make several blowings until the heavy portion contains no inert florets of bluegrass. Examine the heaviest portion first to get acquainted with the feel and appearance of normal pure seed. Examine each blowing beginning with the heaviest. If there is question as to

whether some florets are pure seed or inert matter examine a few by "feel" or with a diaphanoscope; then open these and determine their classification on the basis of development of the caryopses. Examine each blowing for pure seed florets, beginning with the heavy fraction and continue until one blowing is found with no pure seed. It is safe to assume that any lighter blowings would contain no pure seed florets. Examine all blowings for other crop seeds and weed seeds, and the residue for inert matter, other crop seeds, and weed seeds. Multiple florets of bluegrass are not separated.

The other basic procedure consists in blowing the samples in seed blowers which have been standardized and calibrated for these kinds of seed. The two detailed methods which are discussed below are in use.

Iowa method.—By the Iowa method a sample, limited in size from 0.950 to 1.050 grams, is blown in an Iowa blower at four predetermined gate openings. The portions which collect in the trap from the two lowest blowings are examined only for crop and weed seeds. Any pure seed florets in these portions are considered inert matter. The portions from the two highest blowings are examined for pure seed florets, weed and crop seeds. The portion remaining in the cup is examined for crop and weed seeds and inert matter other than bluegrass florets. All bluegrass florets in this portion are regarded as pure seed.

The four components are weighed and the percentages calculated as in any other purity analysis.

If in examining the two blowings the analyst finds mainly inert florets he should again blow the heavy portion at one interval higher until the blowings contain some pure seed florets. If he should find mainly pure seed florets in these two blowings he should recombine the inert matter with the heavy fraction and blow again, starting at a point low enough to obtain some inert florets.

Either of the above conditions indicates that the blower is improperly calibrated. In such an event the blower should be calibrated by using the stained sample provided for this purpose. The blowings made above or below the scheduled openings should serve as an indication of the approximate starting point in making the calibration.

Ottawa method.—The Ottawa method is based on the Ottawa seed blower and eliminates any personal selection of florets in making the purity separation. A manometer on the Ottawa blower serves to indicate and regulate the velocity of the current of air used to separate the inert and the pure seed florets. The key manometer reading (K. M. R.) is that point on the manometer which indicates a current of air sufficient to separate the inert from the pure florets in a given kind of seed. The gate opening required to get a given K. M. R. may differ, depending on atmospheric pressure, electric current, or other outside factors but the manometer registers the current of air that is actually being driven to the seed; therefore, the pressure remains constant for a given cup or tube, within certain temperature limits. Since exposure of the manometer to direct sunlight will interfere with the calibration in determining the K. M. R., the blower should be kept out of direct sunlight and areas where the temperature may fluctuate considerably.

The manometer fluid should be at zero and the screen should be thoroughly cleaned before starting the motor. After the motor has

been warmed up for 10 minutes the indicator on the manometer should be placed over the K. M. R. Be sure there are no seeds or dirt under the edge of the cup. With tube and cup in place, switch on the motor and open the gate slowly until the lower edge of the meniscus of the red liquid in the manometer tube reaches the indicator. The meniscus is the concavely curved upper surface of the liquid in the tube. When this has been done switch off the motor, place the sample in the cup, and with the tube in position in the cup, switch on the motor and blow the sample for 5 minutes after the first floret goes over. All bluegrass florets remaining in the cup are regarded as pure seed and all which are blown into the trap are considered inert matter. The material in the cup must be examined for crop seeds, weed seeds, and inert matter other than bluegrass florets. The portion in the trap is examined for crop and weed seeds but not for pure seed. The four components are then weighed and the percentage of each component is determined by the usual method.

Both the Iowa and Ottawa methods have value and can be used for some purposes but there are some dangers associated with their use. Some samples of Kentucky bluegrass seed have been found to contain relatively high percentages of florets in which the caryopses have developed abnormally owing to insect injury. Because these structures are as heavy as filled florets they are not removed by using either of the standardized blowing techniques but will be left with the pure seed. These structures are inert matter because the flowers were blighted to the extent that seeds did not form. Unless the analyst is a very careful worker it would not be at all unlikely to read the dial incorrectly and blow an occasional sample too strongly or not strongly enough, thereby giving incorrect results. Also, unless the screens are clean the current of air passing through the cup and tube will not be uniform for a given valve or gate opening.

In commercial plants where a test on bluegrass is made to test the efficiency of cleaning processes these methods save much time. In laboratories making tests for labeling purposes or for control work these methods can be used with safety only in the hands of careful and experienced analysts. In testing for the latter purposes the samples should be examined carefully for inert florets in the pure seed and conversely for the presence of pure seed florets in the inert matter. A few empty or filled florets out of place is of little significance but these out-of-place florets must remain within a reasonable limit.

Regardless of the method used, the analyst must examine the pure seed carefully in order to determine whether seeds of other species of *Poa* may be present. Fortunately, the common weedy species are typical enough so they may easily be removed from the entire quantity tested. Some of the crop species are not always so typical; therefore, when more than one crop species of bluegrass is present a test to determine the proportions of the different species is made on a smaller sample of seed. If the sample is to be tested for germination it is advisable to use 800 or 1,000 seeds for the separation, because, if the sample is a mixture of species, a 400-seed test would yield an insufficient number of seeds for the germination test. The portion for this test is taken indiscriminately from the pure seed fraction (all species of *Poa*) of the regular purity analysis after it has been weighed and the percentages of the four components determined. The naked

caryopses are included in this portion but their identity cannot be determined.

The following example illustrates the methods for determining the percentages of kinds found in a sample with 88.09 percent of *Poa* spp.:

Of 1,000 seeds examined—

	Wt. in gm.	*Percent*		*Percent of sample*
Poa pratensis	0. 1209	56. 55×88. 09	=	49. 81
P. compressa	. 0925	43. 26×88. 09	=	38. 11
P. spp. (naked caryopses)	. 0004	. 19×88. 09	=	. 17

Kentucky bluegrass matures its seed earlier than does Canada bluegrass; consequently, it is usual to find Kentucky bluegrass seed in samples of Canada bluegrass but seeds of Canada bluegrass do not often occur in samples of Kentucky bluegrass unless they have been placed there intentionally.

Rough bluegrass, *Poa trivialis*, is generally not grown for seed in this country and it is seldom that it is found as an incidental seed in other crops except in lawn grass or pasture mixtures. It can be noted in bulk seed from the way the florets cling together by the tufts of hair at the callus. The bulk is a more golden brown than *Poa pratensis*.

Annual bluegrass seed, *Poa annua*, is occasionally found in any of the other bluegrasses, although seldom in large numbers. It can be classed as either a crop or a weed.

Seed of Fowl bluegrass, *Poa palustris*, is frequently found in domestically grown bluegrass seed. It is usually regarded as a weed seed unless labeled and sold as a crop. It is easily recognized in a sample because of its slim delicate appearance, light at the callus, orange at the tip of the lemma, and with a rachilla longer and more slender than the other common species of bluegrass.

In the development of bulbous bluegrass, *Poa bulbosa*, the florets are converted into bulblets. The bulblet is the so-called seed unit. Each bulblet is surrounded by bracts and it is necessary to determine the presence or absence of a bulblet in the same manner as that used in determining the presence or absence of a caryopsis.

SORGHUM

Kind of seed	*Key to species, Page*	*Illustration, Plate*
Sorghum vulgare—Sorghum	230	XI, 188–193
S. vulgare var. *technicum*—Broomcorn	230	XI, 194
S. sudanense (*S. vulgare* var. *sudanense*)—Sudan grass	230	XI, 186
S. halepense—Johnson grass	230	XI, 185

Seed unit.—Caryopsis or spikelet with caryopsis.

Special treatment.—It is advisable to blow most samples of sorghum seed unless it can be determined at a glance that the sample contains no light material which may be blown off. Blow Sudan grass and Johnson grass seed long enough to remove all light material from the sample. Sudan grass should be sifted to remove Johnson grass seed.

Special problems.—The positive identification of varieties of *Sorghum* from caryopses or spikelets alone can usually be made only by specialists in that group and this is limited to certain varieties. With training and practice the analyst can make some varietal separations with reasonable accuracy. Only partial separations can be made on

some samples in which case certain seeds can be identified, but there will be other seeds which cannot be positively identified.

The varietal separation should be made on at least 400 seeds taken indiscriminately from the pure seed fraction of the regular purity analysis.

The percentages of varieties in a test with a pure seed percentage of 98.80 percent are determined in the following manner:

Of 400 seeds examined—

	Wt. in gm.	*Percent*		*Percent of sample*
Honey	8. 552	93. 84×98. 80	=	92. 71
Sumac	. 301	3. 30×98. 80	=	3. 26
Undetermined	. 218	2. 39×98. 80	=	2. 36
Black Amber	. 043	. 47×98. 80	=	. 47

Samples of Sudan grass often contain seeds of Johnson grass. Sieves made with $\frac{3}{32}$-inch and $\frac{1}{16}$-inch mesh screen will allow single spikelets to go through but they will hold back any double spikelets. The spikelets caught in the pan should be examined for naked caryopses and smaller spikelets of Johnson grass. Those caught in the bottom sieve should be examined for normal size, single spikelets. Check the top sieve for multiple spikelets of Johnson grass.

The glumes of Johnson grass are generally dark mahogany or reddish brown in color but there are some straw-colored seeds. The two rachillae often remain on the spikelet, each one having a little cup at its tip. The union of the pedicel and the spikelet is articulated, allowing the spikelets to break off clean with no remnants of the pedicel as is common in Sudan grass. Johnson grass spikelets are much neater and trimmer in appearance than those of Sudan grass.

Identification can generally be made from the characters exhibited by the spikelets but if there is doubt the grain should be removed. This can be done, without injuring the glumes, by holding the spikelet between the thumb and forefinger of the left hand and slipping a pointed knife or scalpel between the glume and grain; then gently lifting and pulling the grain out. The glumes should not be destroyed as they are often needed, in combination with the characters of the grain or caryopsis, to make a positive identification.

In making a purity analysis of either Common or Sweet Sudan grass, those seeds which can definitely be identified as *Sorghum vulgare* are removed and included with other crop seeds. Seeds of most varieties of *Sorghum* run larger and are more nearly spherical in shape than those of Sudan grass. Glumes of most varieties of *Sorghum* seed are spreading at the tip and the grain seldom protrudes. When unidentified seeds are found in Common Sudan grass the following note should be included on the record: "Included with the pure seed are some seeds which appear to be Sorghum Sudan grass hybrids." In Sweet Sudan grass samples these would be classified in the varietal separation on the basis of color.

Since most available seed supplies of Sweet Sudan grass contain admixtures of Common Sudan grass and because it is impossible to make a complete, accurate separation of the two, based on seed characters alone, a special test designed to achieve uniformity, as well as reasonable accuracy has been developed.

The sienna color in the glumes of Sweet Sudan grass is said to have been bred into it intentionally in order to distinguish it from Com-

mon Sudan and Johnson grass. Since the sienna color is a recessive character all seeds having this glume color are pure Sweet Sudan grass seeds.

The black color in the glumes of some Common Sudan grass seeds is not found in the glumes of Sweet Sudan grass. All seeds having this glume color are Common Sudan or hybrids. Straw-colored glumes may appear in some lots of pure Sweet Sudan grass but this glume color is also found in Common Sudan grass. Straw-colored seeds, then, may be either Sweet or Common Sudan grass.

Seeds with red, chocolate, or mahogany glumes are interhybrids and are not included with the pure Sweet Sudan grass seed. Since seeds with straw-colored glumes may be found in both Sweet and Common Sudan grass, some adjustments must be made if uniformity is to be achieved. The procedure for making varietal separations of Sudan grass seed allows as much as 5 percent of the seeds with straw-colored glumes to be considered as Sweet Sudan grass. In the varietal separation only Sudan grass seeds with sienna-colored glumes and up to and including 5 percent of the seeds having straw-colored glumes are to be considered as Sweet Sudan grass seeds. All other seeds are to be classed as Common Sudan grass and hybrids.

After the regular purity analysis has been made at least 400 seeds (excluding naked caryopses or grains) shall be taken indiscriminately from the pure seed portion. These 400 or more seeds are separated on the basis of glume color alone into: (1) Sienna; (2) Straw; and (3) Black and Interhybrids.

The Sienna group shall include seeds varying from those completely sienna-colored to others with only a spot of sienna on some part of a glume, frequently at its base. (See exception under the "Interhybrid group" below.) Sienna includes glume colors of various sienna hues such as sienna with chocolate cast, and sienna with a rose cast, as well as seeds with golden-colored glumes. Seeds which are essentially purple but have a sienna spot are included in this group.

The Straw group covers all hues from pale straw (having a "washed-out" appearance) to tan, including hues with a suggestion of sienna or red but no definite spot of sienna. Seeds with purple on all or part of the glumes shall be classified in this group.

The Black and Interhybrid group includes all seeds having the following color characteristics: Glossy black; dull black; black with red cast; all seeds with some definite black on the glumes; typical red; dark red; chocolate; and mahogany—even though any in this group may contain streaks or spots of sienna. For standard color chart and color photographs of Sudan grass, see Testing Sweet Sudan Grass Seed for Purity and Germination—Instruction No. 959 (FSAct)—issued by Grain Branch, Production and Marketing Administration, U. S. Department of Agriculture, Washington 25, D. C.

The following example indicates the manner of determining the percentage of Sweet Sudan grass in a sample containing 98.50 percent of Common and Sweet Sudan grass seed:

	Wt. in gm.	*Percent*	*Percent in sample*	*Percent to be reported*
Sienna	3.255	88.50×98.50	= 87.17+5	= [1] 92.17
Black and Interhybrids	.173	4.70×98.50	= 4.63	= [2] 4.63
Straw	.250	6.80×98.50	= 6.70−5	= [2] 1.70

[1] Sweet Sudan grass.
[2] 6.33 (4.63+1.70) percent Common Sudan grass and Hybrids to be reported.

If there is less than 5 percent of straw-colored seeds in the separation the entire percentage is included with the Sienna leaving nothing to add to the Common Sudan and hybrid group.

The Common Sudan and hybrid group percentage should be reported separately if it constitutes more than 5 percent of the sample. If that group constitutes less than 5 percent of the sample it may either be included with the percentage of other crop seeds or reported separately.

LEGUMINOSAE (LEGUME OR PEA FAMILY)

ARACHIS, CICER, GLYCINE, LUPINUS, PHASEOLUS, PISUM, STIZOLOBIUM, AND VIGNA—LARGE-SEEDED LEGUMES

Kind of seed	Key to species, Page	Illustration, Plate
Arachis hypogaea—Peanut	-----	-----
Cicer arietinum—Chickpea	239	XIX, 366
Glycine max—Soybean	241	XIX, 377
Lupinus albus—White lupine	246	-----
L. angustifolius—Blue lupine	246	XX, 396
L. luteus—Yellow lupine	246	XX, 397
Phaseolus angularis—Adzuki bean	248	XX, 410
P. aureus—Mung bean	248	XX, 411
P. coccineus—Runner bean	-----	-----
P. lunatus var. *macrocarpus*—Lima bean	-----	-----
P. vulgaris—Field or garden bean	-----	-----
Pisum sativum—Garden pea	-----	-----
P. sativum var. *arvense*—Field pea	249	XXI, 412
Stizolobium deeringianum—Velvet bean	249	XXI, 415
Vigna sesquipedalis—Asparagus bean	-----	-----
V. sinensis—Cowpea	257	XXIII, 467, 468

Seed unit.—Seed, except in peanut in which it may be either a seed or a pod with at least one seed.

Special treatment.—Sift samples containing broken seeds to separate the broken cotyledons from the whole seeds. Small portions of samples which are badly infested with insects can be blown in a blower with a 3- to 4-inch tube or column.

Special problems.—Seeds of legumes with the seed coats entirely removed are classified as inert matter. Seeds with part of the seed coat still attached are classified as pure seed or other crop seed, as the case may be. In some rare instances there are such small portions of the coats left on the seeds that it is impossible to identify them as pure or foreign seed. Such structures are included with the inert matter.

Each broken seed must be individually judged to determine whether the remaining portion is to be classified as a seed or as inert matter. If the broken fragment contains one cotyledon with the seed coat attached, but does not contain the embryonic plant, it should be classed as inert matter. If it contains a portion of the seed coat, one cotyledon and the embryo, judgment will have to be exercised to determine whether it is more than half its original size and should be regarded as a seed, or is half or less the original size and should be included with the inert matter.

Insect-infested seeds are often very difficult to classify. Frequently, a single seed has been attacked by more than one insect. If the insects have broken through the seed coats the holes are obvious and the relative extent of injury can be determined by rotating the seeds. If the

insects have not broken through the coats the infested areas will look as though they were decayed and oily, often having dust particles clinging to the spots, or the entire seed may have a decayed oily appearance. The amount of infestation can be determined by rolling the seed between the thumb and forefinger or by piercing the coat with sharp-pointed forceps at each point of infestation, thus determining the relative amount of destruction at each point.

Complete and accurate varietal separations of cowpeas, soybeans, beans, and peas can be made only for a few varieties in each kind. If varietal identification is contemplated the analyst must learn the limits of identification for the varieties grown in the areas for which the tests are being made. The varietal separations should be made on at least 400 seeds taken indiscriminately from the pure seed portion of the regular purity analysis.

The method of calculating the results of a 400-seed separation is illustrated by the following example showing soybeans with a pure seed content of 99.64 percent:

Of 400 seeds examined—

	Wt. in gm.	*Percent*		*Percent in sample*
Mammouth Yellow	141. 37	86.58×99.64	=	86. 27
Ogden	21. 91	13.42×99.64	=	13. 37

CROTALARIA, AND LEGUMES OF LIMITED USE

Kind of seed	*Key to species, Page*	*Illustration, Page*
Crotalaria intermedia—Slender-leaf crotalaria	240	XIX, 369
C. juncea—Sunn crotalaria	240	------
C. lanceolata—Lance crotalaria	240	XIX, 370
C. spectabilis—Showy crotalaria	240	XIX, 372
C. mucronata (C. striata)—Striate crotalaria	240	------
Desmodium tortuosum—Beggarweed	241	XIX, 375
Lathyrus hirsutus—Rough pea	243	XIX, 382
Onobrychis viciaefolia—Sainfoin	248	XX, 407
Pueraria thunbergiana—Kudzu	249	XXI, 413
Sesbania exaltata—Sesbania	249	XXI, 414

Seed unit.—Seed, except in *Desmodium tortuosum* and *Onobrychis viciaefolia* in which it is either a seed or a pod containing a seed.

Special treatment.—Samples should be sifted to remove dirt and foreign seeds and blown to remove the light insect-infested seed.

Special problems.—Broken seeds must be judged individually in order to properly classify them in accordance with the one-half seed rule.

For information regarding the classification of insect-infested seeds in this group refer to the treatment on the genus *Trifolium*, pages 77 to 78.

LESPEDEZA

Kind of seed	*Key to species, Page*	*Illustration, Plate*
Lespedeza cuneata (L. sericea)—Sericea or chinese lespedeza	244	XX, 389
L. hedysaroides—Siberian lespedeza	244	------
L. stipulacea—Korean lespedeza	244	XX, 388
L. striata—Common, Kobe, and Tenn. 76 lespedeza	244	XIX, 386, 387

Seed unit.—Seed, or pod with seed.

Special treatment.—Sifting is an aid in removing dirt as well as some incidental seeds. Blowing of samples containing pod fragments

or other lightweight inert matter lessens the amount of hand picking or manual work.

Special problems.—*Lespedeza striata* and *L. stipulacea* can be separated with accuracy whether or not the pods are present. In bulk the pods of *L. striata* are grayish brown whereas those of *L. stipulacea* are reddish brown. The pods and calyx of *L. striata* are pointed and rather loose fitting and those of *L. stipulacea* are blunt at the tips and rather close fitting. The seeds of *L. striata* are generally mottled, purple and green, with the scar in a small notch at the end of the seed. *L. stipulacea* is usually plain purple although mottled seeds are occasionally found; the seed has no notch near the tip and the scar is nearer the end of the seed than in *L. striata.*

Seeds of Kobe and Common lespedeza can be separated but not with complete accuracy in all cases. In general, seeds of Kobe are larger and the pods grayer and larger than in the Common variety. The small seeds of Kobe probably cannot be accurately separated from the large seeds of Common.

LOTUS—TREFOIL

Kind of seed	*Key to species, Page*	*Illustration, Plate*
Lotus corniculatus—Birdsfoot trefoil	245	XX, 391
L. uliginosus—Big trefoil	245	XX, 394, 395

Seed unit.—Seed.

Special treatment.—Sift to remove dirt and small foreign seeds.

Special problems.—Some samples contain some seeds of alfalfa and red clover. Small seeds of *Galium* are often present. Seeds of birdsfoot trefoil have a variety of shapes. In general, they are plump, round, and dull brown with purplish mottling but it is not unusual to find some seeds that are almost cylindrical and others roughly heart-shaped, faintly resembling red clover in outline.

Seeds of big trefoil are smaller and greener than those of birdsfoot trefoil. A few (usually shriveled) seeds of the two species may be indistinguishable; if so, the following note should be placed on the record card and report: "Certain seeds of *Lotus corniculatus* and *L. uliginosus* are indistinguishable."

If the sample is infested with insects follow the same procedure as described for *Trifolium.*

MELILOTUS—SWEETCLOVER AND SOURCLOVER

Kind of seed	*Key to species, Page*	*Illustration, Plate*
Melilotus alba—White Blossom sweetclover	247	XX, 404
M. indica—Sourclover	248	XX, 406
M. officinalis—Yellow Blossom sweetclover	247	XX, 405

Seed unit.—True seed or pod with seed.

Special treatment.—Samples can be sifted to remove the fine dirt and small incidental seeds or blown to remove fragments of pods or light dirt.

Special problems.—Seeds of alfalfa and red clover are sometimes found in samples of sweetclover. Only a few of these will be difficult to distinguish. Alfalfa seeds usually have one face that is angled.

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Sweetclover seeds are rough in texture as contrasted to the smooth seed coats of red clover and alfalfa.

Mottled seed in a sample of white blossom sweetclover indicates that there is present seed of yellow blossom sweetclover. The amount of mottling in a sample of yellow blossom sweetclover varies from only a few percent to as much as half the sample. It has been determined from greenhouse and field plantings that in most samples there are about four times as much yellow blossom sweetclover present as mottled seeds. Thus, the present rule provides that each percent of mottled seed present will be construed as representing 4 percent of yellow blossom sweetclover. Hence, 1.3 percent of mottled seed indicates that there are four times that amount (5.2 percent) of yellow blossom sweetclover seeds in the sample, making the sample a mixture of white and yellow blossom sweetclover.

If the sample is submitted under the name "sweetclover" it is unnecessary to make a test for mottled seed. If submitted as yellow blossom sweetclover and containing no mottled seeds, examine the sample carefully for large, light yellow, plump, rough-coated seeds which are recognizable as seeds of white blossom sweetclover. However, a detailed separation of the two species cannot be made. The fact that there are no mottled seeds to indicate yellow blossom sweetclover should be noted and that there are seeds which appear to be white blossom sweetclover. Only a growing test can provide actual percentages.

When a sample is submitted as white blossom sweetclover a test to determine the percentage of mottled seeds should be made. A hand lens is essential for an accurate separation and a stereoscopic microscope for detection of some of the more obscure markings.

True mottling should not be confused with spotting by red and purple abrasions or lesions. The latter cannot be regarded as mottled; this condition has no effect on germination.

Mottling of the seeds appears as small irregular purple spots which, when seen under magnification, suggest a spot of color shining through frosted glass. The lesions are generally larger, more clearly outlined, and a brighter reddish purple in color. A stereoscopic microscope is often necessary to distinguish these differences.

Because the seeds are rough and are sometimes considerably rubbed before they are received for test there may be small dark areas which appear to be mottled but which upon closer examination are found to be only the protuberances on the coat rubbed smooth, making them appear darker green than the remainder of the seed. Since these spots are not a different color they must not be classed as mottled.

In a mottled seed test of *Melilotus alba*, the percentage of mottled seed is determined in the following manner:

$$\frac{\text{Weight of mottled seed}}{\text{Weight of entire sample}} = \text{percent mottled seed.}$$

Example:

	Wt. in gm.
Pure sweetclover	4. 9291
Other crop, inert, and weeds	. 1004
Mottled seed	1. 0421

Substituting we have—

$$\frac{1.0421 \text{ gm.}}{5.0295 \text{ gm.}} = 20.72 \text{ percent mottled seed.}$$

Since each percent of mottled seed is construed to represent 4 percent of yellow blossom sweetclover the 20.72 percent×4=82.88 percent yellow blossom sweetclover. Then, 98.00−82.88=15.12 percent of white blossom sweetclover.

ALYSICARPUS, MEDICAGO, AND TRIFOLIUM

Kind of seed	Key to species, Page	Illustration, Plate
Alysicarpus vaginalis—Alyce clover	238	XVIII, 356
Medicago arabica—Spotted bur clover	246	XX, 398
M. hispida—Bur clover	246	XX, 399
M. lupulina—Black medic	247	XX, 400
M. sativa—Alfalfa	247	XX, 402
Trifolium alexandrinum—Berseem clover	254	XXII, 446
T. dubium—Suckling clover (small hop clover)	252	XXI, 427
T. fragiferum—Strawberry clover	253	XXII, 437
T. glomeratum—Cluster clover	252	XXI, 419
T. hybridum—Alsike clover	253	XXII, 439
T. incarnatum—Crimson clover	254	XXII, 448
T. lappaceum—Lappa clover	253	XXI, 429
T. pratense—Red clover	253	XXI, 431
T. procumbens—Large hop clover	252	XXI, 428
T. repens—White and Ladino clover	253	XXI, 432

Seed unit.—Seed; pod with seed, or "bur."

Special treatment.—The separation will be made easier if the sample is sieved. Mixtures should also be sieved to help separate the species, if there is a differential in size. Insect-infested samples should be blown to remove the light inert matter.

Medicago hispida and *M. arabica* in the bur are difficult to divide and can probably be sampled fairly well by the halving method.

Samples that show evidence of insect infestation should be blown at high enough pressures to remove the infested seeds. This may remove some pure seed, but it will reduce the amount to be examined critically for insect infestation.

Special problems.—Alfalfa and red clover seeds are often infested with an insect known as chalcid fly. The chalcid fly deposits its egg in the ovary of the flower where the egg develops along with the ovary which provides food for the developing insect. When the seed is harvested, the insects will be in all stages of development from the egg to the mature fly. Infested seed is considered inert matter only when half or more than half of the original seed has been destroyed. The infested seed can be removed by blowing but in using enough air to remove all the infested seed some pure seed will also be removed. This makes it necessary to separate the infested seed from the pure seed in this portion.

The infested seeds are generally swollen and appear decayed, their color lacking the lifelike appearance of normal seeds. An analyst unfamiliar with these infested samples can easily detect those seeds from which the adult fly has emerged and left a hole in the seed coat. It may be more difficult to learn to recognize those seeds with the seed coat unbroken. Until the analyst becomes completely familiar with the nature of the infestation, all seeds that appear as though they might be infested should be removed and gently squeezed with the forceps. If the major portion has been eaten away the seed will collapse easily; these should be included with the inert matter. Those which resist this pressure should remain with the pure seed. The

analyst will soon learn to recognize the insect-infested seeds by visual examination alone or by applying pressure to only a few questionable seeds in a sample.

The separation of insect-infested and insect-damaged seeds from noninfested seeds can often be facilitated by use of a seed blower. The blower should be set to remove the infested seeds and only the smaller and lighter of the noninfested seeds. The "blowings" must then be examined in accordance with the usual procedure.

Broken seeds must be judged individually to determine whether the seed is more than half its original size, and is to be regarded as a seed; or half or less than half its original size, and to be included with the inert matter. The irregular shape of the seeds makes this determination more difficult. Those fragments which are difficult to classify should be placed alongside unbroken seeds of the same kind, size, and shape as a means of comparison.

Certain seeds of several of the species are difficult to identify. As each sample is tested the analyst should recall those kinds of seeds of similar appearance which might be present. For example, red clover may contain seeds of berseem clover, sweetclover, alfalfa, or weedy species of *Trifolium*, which are distinguishable but similar enough to be overlooked unless the analyst is aware of their potential presence.

Thin green, or shriveled brown seeds, frequently found in alfalfa, are included with the pure seed and take their place among the others in the germination test provided they are more than one-half their original size. Low-quality seed stocks often contain many of these immature seeds.

Some seeds of alfalfa, sweetclover, and red clover are difficult to distinguish. Alfalfa is borne in a coiled pod containing many seeds, whereas sweetclover and red clover are borne in single-seeded pods. Alfalfa seeds usually have one face with an angle which has probably been produced by the seeds crowding against one another in the pod. Sweetclover and red clover seeds are more symmetrical and rarely have a distinct angle. Where several analysts are working together it is desirable to check each other's identifications on these seeds, until a high degree of confidence is attained.

The identification of seeds of the bur clovers may be difficult. In addition to the keys and illustrations of bur clover given in this manual Isely (*29*) has described and illustrated seeds of these species.

Mixtures of alsike, white, suckling, cluster, large-hop, and other clovers often occur and the sample may contain weedy species of *Trifolium* such as *T. arvense* and *T. striatum*. These seeds are distinguishable, with the exception of a few immature or shriveled darkened ones. Throughout the test, the analyst should call to mind as many of these kinds as possible and maintain constant vigilance for them as he works through the sample.

If the sample contains a few seeds which are indistinguishable, a statement along the line of the following should be affixed to the record and report. "Certain seeds of *Trifolium* ------ and *T.* ------ are indistinguishable."

Some insect infestations, such as occur in seeds of white clover, are manifested by open holes. The determination of the relative amount of destruction can be made by careful visual examination, being sure that both faces of the seeds are examined for holes made by the insects.

VICIA—VETCHES AND BROAD BEAN

Kind of seed	Key to species, Page	Illustration, Plate
Vicia angustifolia—Narrowleaf vetch	257	XXIII, 463, 464
V. articulata—Monantha vetch	257	
V. atropurpurea—Purple vetch	257	XXII, 459
V. dasycarpa—Woollypod vetch	257	XXIII, 466
V. faba—Broad bean		
V. pannonica—Hungarian vetch	256	XXII, 455
V. sativa—Common vetch	257	XXIII, 462
V. villosa—Hairy vetch	257	XXIII, 465

Seed unit.—Seed.

Special treatment.—Place a blotter, piece of paper toweling, or filter paper on the board to keep the seed from rolling. To examine the hilum, chalaza, and other surface features the seeds can be placed in a shallow dish of white sand to hold them upright. Insect infested samples should be blown in a blower with a 3- to 4-inch tube to remove the light, insect-infested seeds.

Special problems.—Seeds of some species are difficult to separate; for example, *V. villosa* from *V. dasycarpa* and some seeds of *V. sativa* from those of *V. angustifolia*. If indistinguishable seeds are present affix a note on the record card and report somewhat as follows: "Certain seeds of *Vicia sativa* and *V. angustifolia* are indistinguishable." If seeds of *V. villosa* have been attacked by insects the scar takes on some of the same characters as those of the scar of *V. dasycarpa*. If insect "stings" are noted, make an exhaustive study of the seed before identifying it as *V. dasycarpa*.

Reference is made below to pressing seeds with forceps, particularly those "seeds" from which the contents, or a part of the contents, have been eaten from within leaving the seed coats intact around the resultant cavities. The amount of pressure necessary to break through the seed coats over these cavities is *slight*. It is somewhat comparable to the amount of pressure needed to force a pair of sharp-pointed forceps through a sheet of bond paper. Caution must be exercised when testing samples representing "unclean, farmer-run seed lots" to avoid removing the immature seeds as inert matter. Do not remove seeds which show evidence that insect eggs have been deposited in them but which show no evidence that there has been further development of the eggs.

Samples of hairy vetch frequently contain insect-infested seed with openings in the seed coat. The analyst can usually determine by visual examination whether the major or minor portion of the seed has been destroyed. This may require careful study of individual seeds including "feeling" with pointed forceps to determine the extent of the damage.

If the insect has made no opening in the seed coat the infested seeds can usually be detected by their decayed and oily appearance and by the dust particles which often cling to them. It is necessary to use pressure to determine the relative extent of the destruction of each seed. The infested seeds with the major portion destroyed will crumble easily when rolled between the thumb and forefinger. When broken at the points of infestation by pressing slightly with a pair of sharp-pointed forceps the relative amount of damage can be determined.

VALERIANACEAE (VALERIAN FAMILY)

VALERIANELLA

Kind of seed

Valerianella locusta var. *olitoria*—Cornsalad.
The seed (fruit) is illustrated in plate XXXI, 652.

Seed unit.—A single seed or fruit.

Special treatment.—Blow to remove broken fruits without seeds.

Special problems.—Before beginning the purity analysis take a few fruits from the bulk, break some apart and make sections of others to see the position of the seed in the fruit and also to learn to recognize the free or naked seed without the fruit. The fruit is three parted but only one compartment or locule contains a seed. The empty parts do not break apart easily but the one containing the seed breaks off rather easily allowing the seed to fall free, or to cling to the fruit structures.

Blowing does not separate all of the fragments containing seeds from those which are free of seed but it reduces the number of fruits which must be turned over to determine whether or not they contain seeds. In classifying broken seed, those pieces having more than one-half of their original size are classed as pure seed, whereas those pieces representing one-half or less of the original size are classed as inert matter.

UMBELLIFERAE (CARROT FAMILY)

APIUM, DAUCUS, PASTINACA, PETROSELINUM

Kind of seed	*Illustration, Plate*
Apium graveolens var. *dulce*—Celery	----------
A. graveolens var. *rappaceum*—Celeriac	----------
Daucus carota—Carrot	XXVI, 535
Pastinaca sativa—Parsnip	----------
Petroselinum crispum (*P. hortense*)—Parsley	XXVI, 537

Seed unit.—Seed or fruit, fruit being a mericarp or half-fruit (referred to below as a seed).

Special treatment.—Blow or sift the samples to remove dirt and foreign seeds.

Special problems.—Seeds which adhere to one another must be separated in the purity analysis. Whole unbroken seeds are considered pure seed and no attempt is made to determine whether an embryo (true seed) is present. Broken seeds are classified by the one-half seed rule. Seeds of celery and celeriac are indistinguishable.

SOLANACEAE (NIGHTSHADE FAMILY)

CAPSICUM, LYCOPERSICON, PHYSALIS, SOLANUM

Kind of seed

Capsicum spp.—Pepper.
Lycopersicon esculentum—Tomato.
Physalis pubescens—Husk tomato.
Solanum melongena var. *esculentum*—Eggplant.

Seed unit.—Seed.

Special treatment.—Sift samples to remove the fine dirt and blow to remove fragments of fruits and seeds.

Special problems.—Seeds often cling together and must be separated in the purity analysis. If broken seeds are present they must be judged by the one-half seed rule. Shriveled, immature seeds are classed as pure seed.

POLYGONACEAE (BUCKWHEAT FAMILY)

FAGOPYRUM, RHEUM, RUMEX

Kind of seed

Fagopyrum esculentum—Buckwheat.
Rheum rhaponticum—Rhubarb.
Rumex acetosa—Sorrel—Seed illustrated in plate XIII, 235.

Seed unit.—Fruit, rarely a naked seed.

Special treatment.—Seeds of rhubarb have wings which may present a problem when dividing them mechanically. If the sample cannot be divided mechanically, pour the seed onto a flat surface and successively cut it in half until the sample is approximately the correct size.

Special problems.—In processing the seed the outer husks (fruit coats) may be broken off of some seeds. As an aid in identifying these naked seeds they should be compared with known seeds of the same kind from which the husks have been removed.

Samples of Buckwheat sometimes contain seeds of tartarian buckwheat, *Fagopyrum tataricum.* These two species can be distinguished but because of their similarity may be overlooked unless the analyst suspects their presence.

MALVACEAE (MALLOW FAMILY)

GOSSYPIUM, HIBISCUS

Kind of seed

Gossypium spp.—Cotton.
Hibiscus esculentus—Okra.

Seed unit.—Seed.

Special treatment.—Cottonseed with lint on it can be passed through a large mechanical divider with difficulty. When this is not feasible pour the bulk sample onto a flat surface and divide it repeatedly until the approximate amount required for the test is obtained.

Special problems.—Cottonseed with some of the lint on it should be carefully examined for weed seeds which cling to the lint. There is little difficulty in testing delinted samples.

LINACEAE (FLAX FAMILY)

LINUM

Kind of seed

Linum usitatissimum—Flax.
See plate XXIII, 476, for illustration.

Seed unit.—Seed.

Special treatment.—Sift the samples to remove dirt and small fragments of broken seeds.

Special problems.—Samples often have broken seeds which must be judged individually on the basis of the original size. If in doubt, the questionable seeds should be lined up with unbroken seeds of a similar size and shape. Fragments more than one-half the original size are considered pure seed and pieces one-half or less than one-half the original size are considered inert matter.

LILIACEAE (LILY FAMILY)

ALLIUM, ASPARAGUS

Kind of seed

Allium cepa—Onion.
A. porrum—Leek.
Asparagus officinalis—Asparagus.

Seed unit.—Seeds.

Special treatment.—Sift the samples if fine dirt is present.

Special problems.—Many samples of each of the species contain seeds which have not attained the dark color typical of these kinds. These off-color seeds have the other characters of their kinds and should be included with the pure seed. Seeds of onion and leek are somewhat similar but can be distinguished from each other. The faces of the seed of leek have small pitlike depressions while those of onion do not.

GERANIACEAE (GERANIUM FAMILY)

ERODIUM

Kind of seed

Erodium cicutarium—Alfilaria.
Seed illustrated in plate XXIII, 469.

Seed unit.—Fruit or seed.

Special treatment.—The awn of the seed is spirally twisted making it difficult to sample. The only satisfactory method is to pour the sample on a flat surface and to halve it successively until the sample is approximately the correct size.

Special problems.—The seed units (fruits) are considered to be pure seed if they are unbroken. If they are broken, they must be judged individually and classified in accordance with the rule relating to one-half of a seed.

CUCURBITACEAE (CUCURBIT FAMILY)

CITRULLUS, CUCUMIS, CUCURBITA

Kind of seed

Citrullus vulgaris—Citron and Watermelon.
Cucumis sativus—Cucumber.
C. melo—Muskmelon or Cantaloup.
Cucurbita pepo—Pumpkin.
C. maxima and *C. moschata*—Squash.

Seed unit.—Seed.

Special treatment.—Sift the samples to remove chaff.

Special problems.—Unbroken seeds, even though they are thin, empty, or shriveled, are considered pure seed. If the seed is broken, the contents are determined on the basis of the ½-seed rule.

CRUCIFERAE (MUSTARD FAMILY)

BRASSICA, LEPIDIUM, RAPHANUS, RORIPPA

Kind of seed	Description of species, Page	Illustration, Plate
Brassica campestris—Bird rape	235	XVI, 315
B. campestris vars.—Turnip rape	235	
B. chinensis—Pakchoi	235	
B. hirta—White mustard	234	
B. juncea—Cult. India mustard	235	XVII, 316
B. napus var. *annua*—Annual rape	234	
B. napus var. *biennis*—Winter rape	234	XVII, 318
B. napus var. *napobrassica*—Rutabaga	234	
B. nigra—Black mustard	235	XVII, 319
B. pekinensis—Pe-tsai	235	
B. perviridis—Spinach mustard	235	
B. rapa—Turnip	235	
B. spp.—Vegetable mustard	-----	
B. oleracea var. *acephala*—Collards and Kale	-----	
B. oleracea var. *botrytis*—Broccoli and Cauliflower	-----	
B. oleracea var. *capitata*—Cabbage	-----	
B. oleracea var. *gemmifera*—Brussels sprouts	-----	
B. oleracea var. *gongylodes*—Kohlrabi	-----	
Lepidium sativum—Garden cress	-----	
Raphanus sativus—Radish	-----	XVII, 337
Rorippa nasturtium-aquaticum—Water cress	-----	

Seed unit.—Seed.

Special treatment.—Sift to remove dirt or species or varieties of different sizes.

Special problems.—Seeds of all crop plants of the Cruciferae with the seed coats entirely removed are considered inert matter. The principal problem in this family is identification of the seed. The seeds of many of the kinds and varieties of *Brassica* can be identified, especially by those who have made detailed studies of the group. However, the specialist, at times, has to resort to growing tests to make positive determinations of some seed lots. All samples of *Brassica* should be checked to see that they are correctly named. In doing this it is good practice to attempt to name the kind or variety before observing the name under which the sample was submitted. After the sample has been tentatively named it must be checked with the name under which it was submitted.

After a period of practice the analyst will find that he can correctly name many kinds in the bulk by observation with the naked eye and hand lens. Individual seeds of many kinds can be accurately and positively identified only by growing tests. Keys, descriptions, and illustrations are valuable aids in identifying seeds of *Brassica* but skill in their identification can be developed only through comparisons with actual samples and growing tests.

Seeds of wild mustard or charlock (*Brassica kaber*), a weed, are occasionally found in samples of other *Brassica* species. Seeds of the former can be distinguished by their round shape, smooth and oily appearance. A stereoscopic microscope is necessary in identifying seeds of *Brassica*.

COMPOSITAE (COMPOSITE FAMILY)

CICHORIUM, CYNARA, HELIANTHUS, LACTUCA, TARAXACUM, TRAGOPOGON

Kind of seed	*Illustration, Plate*
Cichorium endivia—Endive	
C. intybus—Chicory	XXXII, 690
Cynara cardunculus—Cardoon	
C. scolymus—Artichoke	
Helianthus annuus—Sunflower	XXXIII, 702
Lactuca sativa—Lettuce	
Taraxacum officinale—Dandelion	XXXIV, 730
Tragopogon porrifolius—Salsify	

Seed unit.—Fruit; rarely a true seed.

Special treatment.—Blow badly broken samples to remove fragments of the husks.

Special problems.—Seeds which adhere to one another must be separated in the purity analysis. Whole unbroken seeds are considered pure seed regardless of whether they contain embryos (true seeds). Broken seeds which can be seen to contain half or less than half an embryo are considered inert matter. Naked seeds or embryos which can be identified as the kind of seed being tested are classified as pure seed. Seeds of chicory and endive cannot be positively distinguished from each other. Seeds of chicory are generally darker colored than those of endive but the color varies in different seed lots.

CHENOPODIACEAE, CANNABINACEAE, AND AIZOACEAE (GOOSEFOOT, HEMP, AND CARPETWEED FAMILIES)

BETA, SPINACIA, CANNABIS, AND TETRAGONIA

Kind of seed

Beta vulgaris and varieties—Beet, Mangel, Swiss chard, Sugar beet.
Spinacia oleracea—Spinach.
Cannabis sativa—Hemp.
Tetragonia expansa—New Zealand spinach.
Hemp seed is illustrated in plate XIII, 225.

Seed unit.—Fruit, specifically an achene in spinach and hemp; fruit with enclosing calyx and one to many seeds in New Zealand spinach; seed ball consisting of fused flower parts and one to many seeds in *Beta*.

Special treatment.—Sift samples to remove the dust and particles from broken fruits.

Special problems.—The unbroken fruits of spinach and hemp are classed as pure seed regardless of whether they contain true seeds or embryos. Broken seeds (fruits) are classified in accordance with the ½-seed rule. Clusters of seeds should be separated and each examined and classified on its own merits.

In testing spinach be on the alert for *Fumaria* sp. which is similar in appearance. Carefully note both the point of attachment and the opposite end of the seed and compare these characters with the same points on known seeds of both kinds.

All unbroken seed balls of *Beta vulgaris* are regarded as pure seed. Broken seed balls in which all the seed cavities are exposed and which appear to be devoid of seed are classed as inert matter. They are

not infrequent in lots of "sheared" seed. The naked seeds are judged by the ½-seed rule. Seedsmen and growers sometimes request that certain specified sieves be used for sugar beet seed.

The seed (fruit) of New Zealand spinach is hard and bony and usually contains several seeds arranged in a ring around its top, These structures are classed as pure seed except when the top portion containing the true seeds is missing in which case they are classified as inert matter.

PROCEDURES FOR DETERMINING GERMINATION

DEFINITION AND OBJECT

In seed-laboratory practice, germination is defined as the emergence and development from the seed embryo of those essential structures which for the kind of seed in question are indicative of the ability to produce a normal plant under favorable conditions. Germination is expressed as the percentage of the pure seed of the kind under consideration which produces normal seedlings.

The environmental conditions for laboratory germination must not only be specific enough to initiate growth in the seeds, but also must be favorable for development of the resultant seedlings to a stage whereby interpretation into normal and abnormal types may be made. Definite methods for laboratory germination of the more common agricultural and vegetable seeds have been set up in the rules for seed testing. As knowledge of the germination behavior of seeds increases, certain changes will undoubtedly take place in these methods. Although it is important that analysts keep abreast of new developments in research, it is more important that they follow the methods set forth in the rules if any degree of uniformity in test results is to be expected.

THE KINDS AND USE OF SUBSTRATA

GENERAL CONSIDERATIONS

The kinds of substrata listed in the rules for testing seeds are: Germination blotters; paper toweling; soil; sand; filter paper; cotton; and creped cellulose paper wadding. Other substrata used in some laboratories but not at present listed in the rules include sawdust, peat moss, and mica. The substrata should (1) be nontoxic to the germinating seedlings, (2) be relatively free of molds, other microorganisms, and their spores, and (3) provide adequate aeration and moisture for the germinating seeds. From the standpoint of uniformity in testing, standard detailed specifications for the different kinds of substrata would be most desirable. At present the Committee on Standardized Tests [3] is working on this problem; except for blotters, only general specifications have been developed. Whenever an analyst wishes to check any substratum for toxicity to germinating seedlings, timothy may be used as its roots will not develop normally in the presence of toxic materials. In making such a test some seed from the same seed sample should also be planted on similar substrata known to be nontoxic, such as a high-quality filter paper.

The exact methods in the preparation of the substrata and the placement of seeds thereon will vary in the different laboratories, de-

[3] Membership of the Committee on Standardized Tests, Association of Official Seed Analysts, consists of representatives of the United States Department of Agriculture, Canadian Department of Agriculture, Association of Official Seed Analysts, and the Society of Commercial Seed Technologists.

pending on the kinds of equipment, size of trays, vacuum counter heads, and other variable factors. Certain techniques and procedures, however, are more or less standard and are discussed herein to aid analysts in interpreting the rules and footnotes applicable thereto.

BLOTTERS

The Committee on Standardized Tests has proposed the following specifications for germination blotters:

Seed germination blotters: Weight 275 pounds per 500 sheets, 25 x 40 inches; 100 percent chemical wood; ash content not to exceed 1 percent; bursting strength to be not less than 100 points; *p*H to be between 6.5 and 7.5; water absorption as measured in accordance with U. S. Federal Specifications UU–T–591 to be not less than 5; Sulfides and other toxic chemicals not to exceed 0.0002 percent; tensile strength (Kg. per 15 mm. width): Machine direction—at least 40, cross direction—at least 10. Blotters must be open and porous, insoluble in water and slate gray or slightly lighter in color. Specifically, the color should approximate that found in the bluish Purple-Blue chart of the Munsell color scheme, designated as: 2.5 PB 4/2 (i. e. bluish Purple-Blue, Value 4, Chroma 2). If the fibers run mostly in one direction they should be in the short direction. Commercial tolerances may be applied to these specifications.

In the rules the capital letter B indicates "between blotters" which is interpreted to mean a single blotter folded over so the seeds may be placed between the upper and lower folds. It is desirable that blotters be cut to such a size that an appropriate number may be placed on a germination tray with the least loss of space. The standard germinator tray in use in many laboratories is 18½ by 19½ inches which will accommodate 24 blotters, cut 9½ by 6 inches if folded and placed 2 deep. In no case should the folded blotters be placed more than 2 deep on a tray, and their position should be alternated at the time of each preliminary count.

The symbol TB in the rules indicates "on top of blotter." If drying of the blotters is excessive, two thicknesses of blotters will provide moisture over a longer period of time than a single layer. If the moisture in the germination chambers is adequate, a single blotter under the seeds may suffice.

"Raised blotters" are listed as an alternate method for some kinds of seeds for which top-of-blotter tests are indicated. The seeds are placed between folded blotters on which the edges of the bottom fold have been turned up about one-quarter inch so as to provide a support for the top or cover, thus avoiding contact of the cover with the seed. This method is of particular value for use in germination chambers where excessive drying of seeds or seedlings on top of blotters may occur.

When blotters are used in Petri dishes, they are cut to size and two thicknesses placed in each dish. Certain seeds when placed between blotters or on top of blotters may roll easily. When placing such seeds in test, it is desirable to turn up the outside edges of the blotters slightly to avoid this danger. The moisture content of the blotters should be observed daily and water added with a sprinkling bulb as necessary. Care should be taken not to saturate the tests at any time or to let them dry out. There will be less spread of mold on tests held at the higher temperatures if they are kept slightly on the dry side. After the initial intake of water less moisture will be required. The position of the top and bottom blotters should be reversed at the time of each preliminary count when they are stacked two deep.

PAPER TOWELING

The Committee on Standardized Tests has not developed specifications for toweling. The National Bureau of Standards has tested several samples of towels for the Grain Branch, Production and Marketing Administration. On the basis of these tests it would appear that toweling meeting the following proposed specifications would be acceptable as a germination substratum:

Paper toweling: Towels shall be 11 inches wide and cut or perforated in 14-inch lengths; bursting strength shall be 25 to 30 points, tensile strength shall not be less than 2 kg. per 15 mm. width strip. The absorptivity shall be such that when a strip of the paper ½-inch wide is suspended vertically with the lower end immersed in water to a depth of 1 inch, water shall rise in the strip to a height of not less than 1½ inches within 5 minutes; fiber composition to be 100 percent chemical wood; ash content shall be not more than 0.7 percent; the *p*H shall be not less than 6.0 and not more than 7.5; sulfide content not to exceed 0.0002 percent; towels shall be relatively free from any other chemicals injurious to germinating seeds; must be water insoluble, color to be brown.

In the rules the symbols applicable to toweling are as follows:

T=between folded paper toweling.
R=rolled towels.

It is usually desirable to have paper cut to such a size that it can be used for both the folded and rolled towel tests. The Federal laboratory has found that a size 11 by 14 inches so folded or placed that three thicknesses will be both under and over the seeds is very satisfactory. In no case should folded towels be stacked more than two deep on a tray. Rolled towel tests may be placed in either a horizontal or vertical position on the trays, the latter being preferred in most laboratories. Various types of metal racks in which the rolls may be placed in an upright position are in use.

Upright rolls should not be crowded on the trays because of the possible spread of molds and because excessive heating may occur toward the center of a large mass of closely spaced rolls. The towels should be rolled loosely enough to allow normal expansion of seeds and seedlings during the test period. The large-seeded kinds such as beans should be observed closely as they often double in size upon absorption of water. Tightly rolled towels may (1) cause abnormal swelling of the hypocotyls or roots on seedlings the size of beans and peas, (2) encourage the spread of fungi, and (3) make unrolling difficult because seedlings frequently break through the rolls and grow into adjacent tests.

Attention must not only be given to the initial rolling but also to the rerolling at the time of the preliminary counts. Even though it is not possible or feasible to make a preliminary count it is recommended that all rolled towel tests be unrolled and the seeds examined on the day designated in the rules for the preliminary count. If the tests are too wet, the upper layer of towels may be wrung out and again placed over the seeds, or a single dry sheet may be inserted over the upper towels before they are rerolled, to absorb some of the excess moisture. It has been found that sometimes very hard seeded legumes or seed of low viability will not use the expected amounts of water, necessitating the above procedure. The position of the bottom row of seedlings may need to be adjusted at this time to give the hypocotyls and roots an opportunity to develop normally. This

is particularly true if the bottoms of the towels have been turned up to guard against seeds falling out during the course of the test.

Flat, folded towels may be stacked two deep on the trays, but the position of the upper and lower towels should be shifted at the time of the preliminary counts. To guard against losing seeds, especially round ones, during the germination test, the edges of the towels should be folded up for about ¼ inch. They should not be as wet as upright rolled towels at the time the tests are set up, since water may be retained in the folds with subsequent "flooding" or lack of aeration. It is recommended that when folded towels are used they be immersed in water until saturated, allowed to drain a few minutes, and then some of the excess water pressed out before the seeds are placed in test.

Since an even supply of moisture should be maintained during the progress of the test, daily observations should be made and tests rewatered as necessary. Care should be taken not to saturate the tests at any time or to let them dry out. A rubber sprinkling bulb will be an aid in rewatering.

SAND AND SOIL

Specifications.—Detailed specifications for kinds of sand and soil have not been approved by the Committee on Standardized Tests. A clean, sharp quartz or builder's sand, not too fine, is preferred over soil by some analysts. A sandy loam soil with a moderately high water-holding capacity is a suitable soil type. If the available soil is too heavy (contains considerable clay), it can be mixed with sand to obtain a more friable, easily handled substratum. Based on tests made by the National Bureau of Standards in which sand used in different seed-testing laboratories was tested, the following proposed specifications appear to be appropriate:

Quartz sand.—Approximately pure quartz which shall yield upon analysis not less than 99.5 percent SiO_2, practically free from dust and fine particles; particle size to vary from approximately 0.05 to 0.8 mm.

Builder's sand.—Washed and relatively free of organic material, 98 to 100 percent quartz yielding not less than 99 percent SiO_2, particle size to fall between 0.05 and 0.8 mm. in diameter.

Sterilization.—Most garden soils, and sometimes sand, contain organisms that may cause damping-off of seedlings. Also, weed seeds are frequently present, the emergence of which in a laboratory test would be undesirable. To avoid the damping-off of seedlings and the growth of weed seeds, sterilization is recommended for all soil and sand used in laboratories. Owing to the breakdown of organic materials and possible formation of toxic compounds, soil should be exposed to the air from a day to a week subsequent to sterilization before using. The time required depends on the organic content of the soil, the efficiency of aeration and possibly other factors.

Moisture content.—The amount of water to be added to sand for germination tests is specified in the rules for seed testing. When sand alone is used it is very important to measure the water accurately because it is impossible to approximate the moisture content by "feel" alone. The following formula is to be used as a basic guide in the preparation of sand, either the quartz or builder's type:

$$\frac{\text{118.29 cc. (1 gill) sand}}{\text{Its weight in grams}} \times 20.2 - 8.0 = \text{The number of cc. of water to add to each 100 grams sand.}$$

The amount of water provided by this formula may have to be modified slightly, depending on the kind of seed being tested. For example, slightly more moisture should be added when the larger seeds are to be tested. Only general directions are given in the rules for adding moisture to soil. Water should be added until the consistency of the soil is such that a ball is formed by squeezing in the palm of the hand but will break freely when pressed between two fingers or dropped.

Preparation and care of the test.—Paraffined cardboard boxes which come in two sizes, 8½ by 8½ by 1¾ and 4½ by 4½ by 1½ inches, are generally used as containers for sand and soil tests. Four of the former and 16 of the latter fit on the standard germination tray used in many laboratories. The first step in the preparation of sand or soil is to sieve it in order to remove any large particles or foreign bodies. A sieve made of hardware cloth (8 mesh per inch) has been found very satisfactory for this purpose. After the sand or soil has been sieved the water should be added gradually according to the directions outlined above. The dampened mixture should then be again passed through a coarser mesh sieve (about 4 mesh per inch) than that used for the dry materials. This second sieving insures a more even moistening and aeration of the substratum.

At least one-half inch of sand or soil should be placed in the bottom of the containers to be used for the laboratory test, and should be carefully leveled off. The seeds may be placed by hand or with a mechanical counting plate, care being taken to gently force the seeds part way into the substrata so that they will remain in place while being covered. The depth of the covering will vary somewhat with the size of the seed being tested, ranging from approximately one-fourth of an inch for clovers to one-half to three-fourths of an inch for corn and beans. The placement of damp blotters over the sand or soil boxes until the seedlings emerge will help in the maintenance of the initial moisture supply of the substrata. Care must be exercised not to overwater the sand or soil for the duration of the test.

FILTER PAPER

Filter paper is to be used as the substratum for the fluorescence test of ryegrass. The specifications in use in the Federal laboratory for filter paper are as follows:

Filter paper.—The paper shall be white, cut in sheets 9 x 9½ inches. Bursting strength shall be not less than 12 points. The absorptivity shall be such that when a strip of paper ½-inch wide is suspended vertically with the lower end immersed in water to a depth of 1 inch, water shall rise in the strip to a height of not less than 2½ inches within 5 minutes; fiber composition—100 percent rag; ash content shall be not more than 0.2 percent. The *p*H shall be not less than 6.5 percent and not more than 7.5 percent. Paper shall be free, exclusive of tolerances, from any chemicals injurious to germinating seeds; must be water insoluble.

When filter paper is used as a substratum in Petri-dish tests, Whatman's No. 2 or its equivalent is specified in the rules.

COTTON

A layer of nontoxic, sterile, absorbent cotton may be used as the substratum in Petri-dish tests. Pieces approximately the size of the dishes can be cut from the rolls and then pulled into a round shape to fit. It

may be desirable to add a measured amount of water to each dish, since it is rather difficult to judge the moisture content without feeling each piece of cotton after the water is added. If the latter procedure is followed, any excess water may be squeezed out and the cotton replaced in the dish. One objection to the use of cotton is that the roots of the seedlings will grow into it making removal of the sprouts for observation difficult. It is possible that it may be used more widely if a single disk of blotter or filter paper is placed over the cotton, thus providing a more resistant surface to root penetration. The blotter would also form a dark background, contrasting in color to that of the seedling.

CREPED CELLULOSE PAPER WADDING

A material commonly known under the trade name "Kimpak" may be used as a substratum for broadbean, lima bean, velvetbean, and *Beta vulgaris*. The rules define creped cellulose paper wadding as 0.3-inch Kimpak or its equivalent. In using this substratum a piece approximately 9 inches square is covered with a single thickness of blotter through which holes are punched for the seeds. The seeds of lima bean, broadbean, and velvetbean are pressed for about one-half their thickness into the creped paper wadding.

Since creped cellulose wadding will fall apart when wet it is necessary to place a sheet of waxed paper under it and then add the water carefully, preferably squirting it on with the aid of a hand sprinkler. To each square of creped wadding, add 250 cc. of water for beans and 85 cc. of water for beets. Saturate a 9- by 9½-inch blotter, allow to drain, fold over all four edges for approximately one-fourth inch to elevate them slightly, punch a slit in the blotter at each position a seed is to be placed and then put the blotter on the Kimpak with folded edges down. The beans should be carefully inserted into the slits, care being taken to evenly space them and to push them in far enough to make contact with the moist Kimpak and yet to be held upright by the blotter. After the seeds are in place, one or two tissues of the dry cellulose wadding should be peeled off and placed over them to keep the seed coats moist. The covering should be lightly sprinkled with water before being placed in the germinator.

Because of its high water-holding capacity, extreme care must be taken in using this type of substratum to always measure the water and to use a covering blotter. The blotter as used with beans serves as a support for the germinating seeds, keeps them from touching each other, and allows more aeration than if the seeds were embedded in the Kimpak. For beets, it merely serves as a cover. It will not be necessary to rewater these tests unless excessive drying occurs during the course of germination.

PEAT MOSS

Granulated peat moss mixed with sand or soil is preferred by some analysts as a substratum for tests requiring a long period of treatment at a low temperature. It has a large water-holding capacity, is light and spongy, and its acid nature tends to discourage the growth of mold. A mixture of peat moss with soil and sand makes a good substratum for germinating New Zealand spinach seed. Peat moss is not included in the rules for seed testing and its use is not recommended except in mixtures containing soil or sand.

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SAWDUST

Sawdust has been recommended as a substitute for soil and sand. It has several good qualities but owing to the different oils and resins contained in wood, it is necessary to check each lot carefully as the sawdust may contain toxic materials injurious to germinating seedlings. This is one of the principal objections to the use of sawdust as a standard germination substratum. Sawdust has not been standardized nor included in the rules as there is no known source of an acceptable quality. As in the use of sand, it is absolutely necessary to measure the amount of water used. Sawdust should not be used in laboratory testing until such time as it may be included in the rules.

MICA

The use of expanded mica, known under such names as "Vermiculite" and "Terralite," as a laboratory substratum has only been experimental. It is widely used in greenhouses as a covering for seeds when grown in soil flats, and for such purposes as the propagation of cuttings. The advantages for laboratory use appear to be that it is (1) relatively inexpensive, (2) sterile, (3) inert in nature, (4) light in weight, (5) spongy and porous, and has a tremendous water-holding capacity. Its disadvantages are twofold: (1) It is very "flaky" and will stick to the hands of workers and to the surfaces of the tools used in mixing and placing it for test; and (2) it may hold too much water for the proper development of normal seedlings of certain kinds. For instance, "watery seedlings" have been reported on beans grown in mica but when tested in other substrata the seedlings were normal. This objection might be overcome by mixing measured amounts of dry mica with sand or soil. In any event, although not now generally used, it may have future possibilities when used alone or in combination with other materials as a substratum for laboratory tests.

PETRI-DISH TESTS

In the rules the capital letter P indicates "covered Petri-dish tests," which may contain as the germination substratum one of the following: (1) Two layers of blotters; (2) one layer of absorbent cotton; (3) 5 layers of paper toweling; (4) 5 layers of filter paper; or (5) 5/8-inch layer of sand or soil. Except as provided for those kinds of seeds requiring a substratum with high moisture, the substrata in the Petri dishes should never be so wet that a film of water is formed around the seeds. Rewatering must be done very carefully, preferably squirted under the edges of the substrata with a medicine dropper.

PREPARING THE TEST

NUMBER OF SEEDS

The rules specify that at least 400 seeds shall be tested for germination except that in mixtures, 200 seeds of each of those kinds present to the extent of 15 percent or less may be used in which case an additional 2 percent is to be added to the regular germination tolerances. The seeds shall be tested in replicates of 100 seeds or less.

SOURCE OF SEEDS

Special care must be taken to select the 400-seed subsample exactly in accordance with the requirements of the rules, which are as follows:

(*a*) When both purity and germination tests are required, seeds for germination shall be taken from the separation of the kind, variety, or type considered pure seed and shall be counted without discrimination as to size or appearance.

(*b*) When only a germination test is required and the pure seed is estimated or determined to be at least 98 percent, the pure seed for the germination test may be taken indiscriminately from a representative portion of the bulk.

(*c*) When only a germination test is required and the pure seed is found to be less than 98 percent the pure seed shall be taken indiscriminately from a pure seed separation made according to the provisions of these rules and regulations which govern the separation of the kind, variety, or type considered pure seed except that other crop seeds, inert matter, and weed seeds need not be separated.

When a purity analysis is not made and the sample is large, the use of a mechanical divider is recommended for obtaining the germination subsample. Small bulks may be poured directly into a small mixing pan and stirred by hand. Large seeds, such as beans, which may be injured by dropping through a mechanical divider, may be poured out on a flat surface and repeatedly subdivided with the aid of a flat board or ruler into a small subsample.

COUNTING THE SEEDS

The counting of the 400 seeds without discrimination as to size or appearance may be done by hand, by the aid of a counting board, or with the aid of a vacuum seed counter. It should be emphasized that only free-flowing, smooth seeds lend themselves readily to the vacuum method and only large seeds can be successfully counted with counting boards. However, if a laboratory handles a volume of kinds, such as cereals, vegetables, legumes, or certain of the grasses, that can be successfully counted by the vacuum method, the rapidity of placing the seeds in test and the even spacing of the seeds on the substratum will more than justify the use of a vacuum counter. Vacuum counters are now regarded as standard seed-laboratory equipment. The vacuum counter is designed to avoid personal bias in selecting seed, but it may be misused to defeat this purpose. It is important to spread the seed well over the face of the counter. If uneven seed, such as alfalfa with some immature flat seed, is placed on one edge and the counter tipped, the rounded seeds will move across the face of the counter more rapidly and be held on the holes not in proportion to their presence in the sample.

SPACING THE SEEDS

The proper spacing of seeds to reduce to a minimum the contact of seedlings with each other during germination cannot be emphasized too strongly. This is especially important for large-seeded kinds and seed stocks infected with storage or other fungi. There have been no regulations with respect to spacing of seeds included in the rules but the Standardized Test Committee, in 1949, made the following recommendation:

> Careful attention should be given to the spacing of seeds in blotters, towels, or sand. The distance between seeds should be not less than 1½ to 5 times the width or diameter of the seed, the basis of spacing being the size of the seed to be tested.

Since certain seeds, such as beans and peas, may double in size after the absorption of water, and others, such as spinach and bluegrass, do not become appreciably larger, proportionate allowances for their expected increase in total area must be made when they are spaced on the substratum.

PROVISION AND MAINTENANCE OF ENVIRONMENTAL CONDITIONS

MOISTURE AND AERATION

The analyst is cautioned in the rules for seed testing that the substratum must be moist enough at all times to supply the needed moisture to the seeds, and that there is always danger of supplying excessive moisture which may restrict aeration. Except as provided for those kinds of seeds requiring very moist substrata, the blotters, towels, or other substrata should never be so wet that a film of water is formed around the seeds. For most kinds of seeds, blotters or other paper substrata should not be so wet that, by pressing, a film of water forms around the finger. The analyst should give particular attention to the explanatory notes in the column headed "Remarks" in the germination table of the rules, regarding the care of substrata for the kinds of seed that require special attention with regard to maintenance of proper moisture conditions during the test period.

The necessity of adding water to the substratum subsequent to placing the seeds in test will depend on the evaporation from the substrata in the germination chambers. Since the rate of evaporation will depend, among other factors, on the relative humidity of the air, it is desirable to keep water in the germination chambers or to provide other means of maintaining a high relative humidity. In 1949, the Standardized Test Committee recommended that the relative humidity around tests should be approximately 95 percent and that great care should be taken to insure that the methods and equipment used will maintain approximately this level of moisture. All tests should be examined daily to insure that the moisture content of the substratum is near optimum. Such mechanical aids as small rubber florist's bulbs and medicine droppers have been found to be very useful in enabling the analyst to rewater tests without danger of overwetting the substratum.

TEMPERATURE

Temperature is one of the most critical factors in the laboratory germination of most of the seeds listed in the rules. It is not possible to control temperature without special equipment designed for that purpose. In 1949, the Association of Official Seed Analysts adopted the provision that a permissible variation of only 1° C. be allowed from the temperature specified in the rules for laboratory germination of seeds. Daily observations and records should be made of the temperature inside each germinator to insure attention to this detail. It cannot be emphasized too strongly that correct temperature controls must be maintained at all times.

When referring to the rules the worker should keep in mind that a single numeral indicates a constant temperature and two numerals separated by a dash indicate an alternation of temperatures in which the test is held at the first temperature for approximately 16 hours and at the second temperature for approximately 8 hours per day. If temperatures cannot be conveniently alternated over week-ends and on holidays, the seeds are to be held at the lower temperature during such time, unless otherwise indicated under "Remarks." The daily alternation of temperature is either brought about by manually transferring the tests from one germination chamber to another or by

changing the temperature of the chamber in which the seeds are placed. Some germinators are equipped with time clocks which switch the electrical circuits at preestablished time intervals, causing the alternations of temperature.

LIGHT

Light is required for the germination of most of the grasses and for some vegetable seeds. Relatively little research has been done with respect to the effects of specific wave lengths and intensities of light required for the commonly tested agricultural and vegetable seeds. There are some data to show that freshly harvested seed is more likely to be benefited by light than older seed and that light may compensate for certain unfavorable germination conditions. Fluorescent light has been used successfully in lieu of natural daylight and is preferred in testing because the wave lengths and intensity can be standardized, within limits. Available evidence indicates that daylight fluorescent light is as effective in stimulating germination as natural daylight. There are two principal objections to using fluorescent lights placed inside the germination chambers: (1) Fluorescent lamps produce considerable heat which must be counterbalanced by a cooling system; and (2) they tend to cause drying of the substrata.

The Association of Official Seed Analysts has accepted the recommendation that light should be evenly distributed over the tests, with a range of intensity from 75 to 150 foot-candles. A variation of plus or minus 25 foot-candles on the tests is not considered important at optimum intensity. Seed technologists should check their equipment and if necessary make the necessary adjustments to comply with this recommendation. Weak light will not provide the necessary stimulus to cause some seeds to germinate while intense light retards and depresses the development of aerial organs of the seedling.

Tests should be subjected to light for only a part of the test period. The usual procedure is to provide 8 hours of light during the day period. While a somewhat shorter exposure period may be sufficient there are not enough available data to justify a definite statement on this point.

SANITARY CONDITIONS OF EQUIPMENT AND SUPPLIES

The germination substrata and supplies should be kept as clean as possible in order to minimize the growth and spread of fungi and bacteria on tests. Such supplies as blotters, towels, and cardboard boxes for sand or soil tests, which will be discarded after a single use should be stored in a dry place protected from dust. Permanent supplies, such as Petri dishes or aluminum containers for soil tests, should be thoroughly washed with hot water and soap or other detergent after each use and thoroughly rinsed and dried. It is not necessary to wash metal germination trays after each use unless they appear to have mycelia of molds clinging to them.

Germinators should be cleaned periodically by flushing with hot water to which a detergent, or formaldehyde may be added. It is not usually necessary to fumigate germinators but, if such a procedure is deemed essential, a solution of potassium permanganate and formaldehyde has been used and recommended as follows: Place 25 grams of potassium permanganate in a quart can and add 50 cc. of

40-percent formaldehyde solution. The permanganate should be shaken into a pile on one side of the can and the formaldehyde solution gently poured into the bottom of the can. Place the can in the germinator, close the door immediately and leave it closed overnight. Remove the can the next day and thoroughly air out the germinator before it is used for germination tests so that the toxic effects of the fumes will not affect the seedlings.

INTERPRETATION OF THE GERMINATION TEST

DATES OF PRELIMINARY AND FINAL COUNTS

The rules specify the days on which the first counts and the final counts are to be made for the different kinds of seeds. The date stated for the first count is approximate and a deviation of 1 to 3 days is permitted. Counts made between the first and final counts are at the option of the analyst and will frequently vary with different samples. In general, soil or sand tests may be left for the final count only, whereas tests on artificial substrata should be examined every 2 or 3 days, especially during the first 10 days of test. Grasses needing longer than 10 days to completely germinate usually need counting only once a week after the fourteenth day of test. A convenient schedule for grasses having a test period of 21 or 28 days is to count on the tenth, fourteenth, twenty-first, and twenty-eighth days.

When samples are prechilled, the length of time they are prechilled is to be added to the usual test period unless otherwise specified in the rules. For instance, a sample of Kentucky bluegrass seed that requires prechilling must be held in test for a total of 33 days, which is the sum of a 5-day prechill period and a 28-day regular test period. Experience has shown that it is not always necessary to hold the samples in test for the additional prechill period as the conditioning of the seed during prechilling greatly accelerates the speed of germination when the tests are placed at the higher temperatures. Consequently, as more information is accumulated on the speed of germination subsequent to prechilling, it may be possible to reduce the total germination test period from that now required by the rules.

GUIDES FOR CLASSIFICATION OF SEEDLINGS

Germination is defined in the rules under the Federal Seed Act as follows:

> A seed shall be considered to have germinated when it has developed into a normal seedling. Broken seedlings and weak, malformed, and obviously abnormal seedlings shall not be considered to have germinated.

This is in agreement with the definition of germination in the first paragraph on page 86.

The rules of the Association of Official Seed Analysts and the rules promulgated under the Federal Seed Act provide that the photographs of normal and abnormal seedlings prepared by the Federal laboratory and approved by the Association shall be used as standard guides for classification of seedlings. The negative numbers of the photographs are listed in the rules in the column under the heading "Remarks" following the respective kinds of seedlings to which they apply. In addition, the Association rules provide that soil or sand tests are to be used as a standard guide for the evaluation of germina-

tion tests made on approved artificial media in determining the classification of questionable seedlings. This technique is intended to provide a method of checking the reliability of tests made on artificial substrata when there may be doubt as to the proper evaluation of such tests. It does not mean that all samples are to be tested in sand or soil. Means of distinguishing between normal and abnormal seedlings are set forth for specific groups under the heading "Application of Germination Procedures to Specific Groups."

The analyst should keep in mind that normal seedlings should have a well-balanced symmetrical growth pattern of all their essential parts and that when one part shows stunting or weakness in respect to the growth of another part, some abnormality should be suspected. In conducting the germination test it is very important that all seedlings be allowed to develop to a stage at which it can be determined whether the essential plant parts are present. The interpretations of normal and abnormal seedlings in this manual are those followed in the Federal seed laboratories and are based primarily on the photographs of seedlings approved as standard guides for germination by the Association of Official Seed Analysts.

CAUSES OF ABNORMAL SEEDLINGS

Declining vitality.—Seeds which are aged, or have been subjected to unfavorable storage conditions are usually slow to germinate. Some of the essential plant parts are frequently stunted or lacking and saprophytic fungi may interfere with the growth of the seedlings. In regard to samples that are slow in sprouting but which produce normal seedlings the Standardized Test Committee recommends that a notation should be made on the report as follows: "This sample shows evidence of declining vitality."

Infection with pathogenic organisms.—Although seed infected with certain pathogenic organisms may initiate growth, one or more of the essential seedling structures frequently may become damaged or destroyed by the fungi or bacteria. Since the manifestations of disease on the seedlings are largely dependent on the environmental conditions during the test period, results may be erratic unless the germination conditions are carefully controlled. The following kinds of seeds are usually troublesome in this respect: Velvetbean; broadbean; lima beans; soybeans; peanuts; crotalaria; cowpeas; garden peas; chickpeas; sweetclover; alfalfa; cotton; oats; corn; sorghum; wheat; barley; rye; rhubarb; beets; celery; radish; and flax. Should a seedling decay as a result of infection from an adjacent seed it should be regarded as normal.

Mechanical injury.—Mechanical breakage of seeds may occur during the harvesting, threshing, handling and processing operations such as scarification, and the milling processes designed to remove certain accessory seed structures. Injuries of this type are found principally on the following kinds: Beans; peas; cowpeas; lupines; peanuts; soybeans; vetches; clovers; alfalfa; black medic; trefoil; crotalaria; sericea lespedeza; rye; flax; onion; cardoon; sunflower; beets (by the shearing process); timothy; reed canary grass; tall oatgrass; and certain of the native range grasses. Mechanical injury to grass seeds usually occurs during combining or the special milling processes designed to remove certain accessory seed structures.

Considerable research on mechanical injury to beans of the field, garden, and lima types has proved that the breakage occurs principally during the threshing process. Thresher injury has been suspected as the cause of breakage in samples of crimson clover. In some cases it has also been attributed as the cause of injury to hairy vetch, peas, blue lupine, and clover seeds. The mechanical scarification employed to reduce the hard seed content in certain legume seeds is a frequent cause of breakage.

Mechanical injury to seeds may interfere with normal seedling development or it may completely prevent development, depending on the extent and place on the embryonic plant where injury occurs.

Insect injury.—Seeds that have been infested with insects may produce seedlings which lack some essential part or structure, or the seedlings may be severely stunted or weakened. The principal problems which analysts will encounter are: Weevil damage to field peas and cowpeas; Bruchus damage to vetch; chalcid fly damage to alfalfa and red clover; and damage to certain of the cereals, such as corn, rice, sorghum, and rye, which have been in storage for a long period of time. A condition known as "honey-dew" has been found on alsike clover seed. It is an aphid secretion which forms a sticky mass on the outside of the seeds causing them to cling together in clumps. Although it detracts from the appearance of the seed, it has not been reported as harmful to germination.

Chemical treatment of seeds.—Seeds which have been overtreated with toxic fungicides, such as the organic mercurial compounds, have been known to produce abnormal seedlings. The symptoms include stunting of the growth in length of roots and thickening of the roots and hypocotyls on artificial substrata. Development may or may not be normal in soil, apparently depending on the dosage, types of soil, and possibly other factors. In some cases observed, the treatment had been so severe as to permanently kill certain of the essential seedling organs.

Seeds that have been treated or accidentally subjected to certain of the new chemical insecticides and herbicides such as DDT and 2–4–D may yield abnormal seedlings. Exposure to the fumes of the latter may produce abnormalities. Check tests in soil or sand will be necessary for proper evaluation of seedlings exhibiting any great amount of treatment injury when grown on artificial substrata. Unless the seedling organs have been destroyed by the treatment, a greater number of normal seedlings may develop in soil than on an artificial substratum where the toxic substances may come in direct contact with the germinating seedling.

Metal germination trays.—Seed germinated on paper substrata placed directly on metal germinator trays may produce seedlings with shortened, thickened, or discolored radicles. Such abnormalities are apparently caused by soluble zinc compounds dissolved from galvanized trays, galvanized trays given a thin copper finish, or from copper trays coated with acid during the soldering process. Injury to the roots of common vetch seedlings grown directly on old copper trays has been observed in the Federal laboratory. A sheet of waxed paper placed under the towel substrata has been found to protect the seedlings from such injury. Galvanized trays may be protected with lead-free paints but the paint must be replaced from time to time as it wears off.

Toxicity of substrata.—Seedlings grown on or in artificial substrata containing certain toxic materials, such as sulfuric acid or toxic pigments, may exhibit root inhibition or injury. Injury to the roots of timothy seedlings grown on blue blotting paper has been reported, and similar effects from growing seedlings on white paper toweling treated with sulfuric acid have been observed.

Chemicals in tap water.—Seeds germinated in tap water containing injurious chemicals may fail to germinate or produce abnormal seedlings. Retarded germination of *Hypericum* seed due to calcium in the tap water has been reported. It has been suggested that chlorine in tap water may be harmful, but this is not supported by published data. Tap water is used in most laboratories rather than distilled water except when solutions of potassium nitrate are prepared. The analyst should be on the alert for any possible contamination of the tap water. If in doubt, the water can be checked against a control test set up with distilled water.

Frost damage.—Seedlings grown from frost-damaged seeds are especially difficult to evaluate. Growth is initiated in most of the frost-damaged seed but the resultant seedlings are too weak to produce normal plants. Sand or soil tests are very highly desirable, especially on frost-damaged cereals.

Mineral deficiency.—It has been found that deficiencies of certain minerals in the soil on which seeds are produced will cause specific types of abnormal development of the cotyledons or plumules in some varieties of peas and beans. Manganese deficiency is characterized by the appearance of sunken, brown, and slightly pithy areas in the center of the flat surfaces of the cotyledons, and sometimes with browning of the plumule in beans. Peas appear to be particularly susceptible to this type of injury which has also been reported as occurring on broadbean and runner bean.

Boron deficiency has been reported for peas and is characterized by injury to the plumule which may be stunted, multiple branched, or undeveloped. The seed analyst can determine whether the injury is owing to lack of boron by germinating the sample with and without added boron. Leggatt (*34*) found that a 0.01-percent borax solution may be used to moisten the germination medium or the seed may be dusted with pure borax or in one-tenth dilution with talc.

FUNGI INTERFERING WITH THE GERMINATION TEST

The control of saprophytic fungi developing on the seeds or substrata is a major problem to seed analysts, necessitating special care in the spacing, watering, selection of substrata, and care of the seeds while in test. The Committee on Standardized Tests made a recommendation in 1949 regarding this, as follows:

> All ungerminated seeds which are decayed, mouldy, and obviously dead, should be removed from samples in which saprophytic moulds are a problem at the time the initial and subsequent counts are made.

Besides the saprophytic fungi and various bacteria which may develop and spread easily in germination tests, there are parasitic fungi which are associated with certain kinds of seeds. The latter may occur on fresh, strong samples with the infection often being clear-cut and confined to individual seeds. Should a seedling become decayed as a result of infection from an adjacent decayed seed, it

should be considered as normal. Laboratory practices which will minimize the spread of molds include proper spacing of seeds, control of temperature, removing decayed seeds, proper aeration, and keeping the tests as dry as possible and yet providing adequate moisture for germination. Questionable samples should be checked by testing in soil or sand.

DISTINGUISHING BETWEEN DORMANT AND DEAD SEEDS

Frequently the analyst must resort to means of distinguishing between dormant and dead seeds. All samples suspected of being dormant must be subjected to the conditions for breaking dormancy as set forth in the rules. Sometimes one can tell by the condition of the seed, after it has been in test for a few days, whether it is dead or dormant. Dead seeds often decay, become covered with fungi, become soft, or the embryos become soft and discolored, whereas dormant seeds are more apt to remain firm and relatively free of mold. Sometimes when erratic sprouting occurs on samples with dormant seeds, a retest put in under conditions calculated to be more optimum for overcoming the dormancy will result in uniform germination. This has been observed especially on certain samples of tomato seed. Samples with dead seeds are not likely to exhibit such erratic sprouting.

DISTINGUISHING BETWEEN HARD SEED, SWOLLEN SEED, FIRM UNGERMINATED SEED, DEAD SEED, AND GERMINATED SEED

In laboratory practice, hard seeds are defined as follows:

> Seeds which remain hard at the end of the prescribed test because they have not absorbed water, due to an impermeable seed coat, are to be counted as hard seed.

The kinds of seeds recognized as often having hard seeds are indicated by a footnote in the table on germination in the rules. The rules provide that if at the end of the germination period stated for legumes, okra, and asparagus there are still present swollen seeds or seeds of these kinds which have just started to germinate, all seeds or seedlings except the hard and swollen seeds and seeds which have just started to germinate shall be removed and the test continued for 5 additional days. Any normal seedlings which develop during this period shall be included in the percentage of germination.

The percentage of hard seeds occurring in the germination test will vary with the age, kind, variety, and moisture content of the samples. There are some data to show that the hard seed content of some freshly harvested legumes such as red clover, lespedeza, and field peas may decrease rapidly within the first few weeks or months of dry laboratory storage. Seeds of okra, vetch, and certain other legumes may increase in hard seed content during dry laboratory storage. It has been found that hard seededness in beans is increased as the beans become desiccated and that the relative humidity of the air in which they are stored will cause rapid moisture changes within the seeds. These changes are reversible. Some of the differences in reported percentages of hard seeds on certain samples may be explained by these facts.

Usually the analyst can easily distinguish between a swollen seed and a hard seed. In cases of doubt, especially when testing large

seeds such as beans or peas, the questionable seed may be dropped on a hard table top or china plate. Swollen seeds will produce a low-pitched thud whereas hard seeds will produce a higher-pitched ping.

If there is doubt as to whether a seed is swollen or dead, it should not be destroyed by pressing with forceps but left in test with other swollen seeds for 5 additional days. At the end of that period, the dead seeds have usually decayed and the swollen seeds germinated.

Grasses such as Sudan grass often have firm, ungerminated seeds left on the substrata at the end of the test period. These are not to be confused with or reported as hard seed. It is possible that as our knowledge of seed behavior increases such seeds may be treated in some way to cause them to germinate. However, at the present time, since these seeds do not respond to laboratory treatments under the conditions now recommended in the rules, or to greenhouse soil tests, they cannot be reported as having planting value.

METHODS OF OVERCOMING DORMANCY

SELECTING THE APPROPRIATE METHOD

Special treatments for overcoming dormancy are listed for many kinds of seed in the rules for seed testing under "Remarks." Other methods may be used by the analyst in cases where the method indicated for a particular kind does not work. However, if the result of such a test is reported the pretreatment should be indicated and the report should also show the result obtained when tested in accordance with the rules. It is necessary that the rules be kept as elementary as possible and that the conditions of test be standardized. It would be very desirable if only one germination condition could be specified for each kind of seed, but owing to the complicated physiological problems involved in seed germination, this is impossible for many kinds. It has been found that as seeds age they frequently will not only respond to different temperatures but they will lose the ability to germinate rapidly at a temperature that was optimum when the seed was fresh. It has also been found that seeds will often respond to several combinations of conditions, and that one set of conditions may be substituted for another. For example, light may compensate for unfavorable temperatures, and potassium nitrate may stimulate germination equally as well as light or soil.

LOW TEMPERATURES

Prechilling means placing the seed on a moist substratum at an indicated low temperature for a specified period of time before placing it at the higher temperature for the duration of the regular test period. The temperature used most frequently in seed laboratories for prechilling is 10° C., although occasionally samples will be found requiring as low as 5° C. This is especially true for some of the native grasses. Alternate methods in the rules of the Association of Official Seed Analysts provide that certain of the cereals which may not exhibit deep dormancy may be germinated satisfactorily at 15° C. The proponents of this method claim that the prechill period is eliminated and the 15° temperature is satisfactory for nondormant seeds and will catch most dormant samples as well. This presents a problem to the analyst to determine at which temperature to place

such samples. The age, origin, condition of samples, and other historical information will frequently help in determining the method to be used.

HIGH TEMPERATURES

Exposure to high temperatures has been found necessary for overcoming dormancy of some freshly harvested seeds. For example, a constant temperature of 30° C. is specified in the rules for dormant citron. There are some data which show that fresh seeds of other cucurbits, peanuts, and tobacco may also respond favorably to high temperatures. A constant temperature of 35° C. is specified in the rules for Alyce clover, although data show that as the seed ages it will respond to lower temperatures.

TEMPERATURE COMBINATIONS

Combination of low-high temperature alternations, with and without light, have been found to bring about as prompt germination of some of the grass seed as can be obtained by prechilling. Freshly harvested seeds of Canada bluegrass and *Agrostis tenuis* will germinate more promptly at low-high temperature alternations, such as 10°–30° C. or 15°–30° C., than at 20°–30° C. Combinations of temperatures such as 10°–25° C. and 15°–25° C. without light have been found to be optimum for dormant seeds of some of the fescues.

LIGHT

Light is specified in the rules for seeds of most of the grasses and some of the vegetables. In the rules no distinction is made between the light requirements of dormant and nondormant seeds. This is because it is believed that moderate light exposure has no deleterious effect on germination of nondormant seed, thus avoiding the necessity of distinguishing between dormant and nondormant seed. There is a wealth of data which show that light will overcome dormancy in certain kinds of seeds. There are also some data to show that the beneficial effects of light are tied up with the temperature at which the moist seeds are held during the test period.

POTASSIUM NITRATE AND SOIL

Potassium nitrate solutions are known to stimulate the germination of certain dormant seeds. Its use on particular kinds of seeds is indicated in the rules in the column under the heading "Remarks." A 0.2-percent solution is used in moistening the substratum except that when testing Kentucky bluegrass and Canada bluegrass seed a 0.1-percent solution is used. A 0.2-percent solution is prepared by dissolving 2 grams of potassium nitrate crystals in 1,000 cc. of distilled water; a 0.1-percent solution is prepared by dissolving 1 gram of the crystals in 1,000 cc. of distilled water. In rewatering the substrata either tap water or distilled water should be used, and not a solution of potassium nitrate.

Soil may sometimes be a better germination medium than an artificial substratum for the germination of certain dormant seeds. Its use for particular kinds of seeds is indicated in the rules under the column headings "Substrata" and "Remarks." In some cases either potassium nitrate or soil may be used. Although it is known that soil is sometimes a better substratum than an artificial medium mois-

tened with a dilute solution of KNO_3 the reason is not clearly understood. Germination of rescue grass (*Bromus catharticus*) is definitely higher when germinated in Petri dishes on soil than when placed in Petri dishes on blotters moistened with a potassium nitrate solution. There are some data to show that certain dormant oats may germinate higher in soil than when placed between folded towels. Germination of orchard grass seed is usually more rapid in soil. Germination of some of the grasses such as Western wheatgrass may be higher and more uniform when soil is used as the substratum.

MODIFICATION OF THE SEED COAT AND OTHER STRUCTURES

Clipping the seeds of alfilaria, piercing the seed coat of Alyce clover, degluming seeds of Bahia grass, and removing the pulp from seeds (fruits) of New Zealand spinach are accepted methods of initiating germination in these kinds of seed. These operations must be done very carefully in order to avoid injury to the resultant seedlings. It is known that other kinds of seeds listed in the rules will respond to similar treatments but the analyst should not use such procedures in service testing or on regulatory samples until such methods are uniformly adopted.

STEEPING IN WATER

The rules provide that citron seed shall be soaked in water for 6 hours before testing and that dormant endive seed shall be "flooded" for 24 hours after which time the excess water is drained off. Also, seeds of *Beta vulgaris* are to be soaked or washed in running water for at least 2 hours to remove any toxic nitrogenous substances which may be present. There are provisions in the rules for maintaining a high moisture level of the substratum when testing certain other kinds of seeds. The analyst should observe these specific directions and follow them closely.

PREDRYING

Drying prior to testing is not included in the rules but has been very effective in overcoming dormancy in grains with high moisture content. The method used in the United Kingdom for cereal seed provides for drying at a temperature of 40° C. for 3 days. In the Federal laboratory cereal seed has been dried at 35° for 5 days with good results.

SPECIAL PROCEDURES

FLUORESCENCE TEST ON RYEGRASS

The rules provide that when a fluorescence test is made on ryegrass the seedlings shall be grown on filter paper and the number of fluorescent seedlings determined under the ultraviolet light at the end of the germination period. The fluorescence test is used as a means of measuring the presence and proportion of Italian ryegrass in samples of perennial ryegrass seed. There is fairly conclusive evidence that the roots of genetically pure perennial ryegrass do not fluoresce, whereas the roots of Italian ryegrass do. The only reported exception to this is that the roots of the annual, Wimmera ryegrass, do not fluoresce. Wimmera ryegrass is of little or no economic value in the United States. Hybrids of Italian and perennial ryegrass may or may not fluoresce.

The present formula for calculating the results of fluorescence tests makes an allowance of 5 percent for long-lived hybrids which may fluoresce. The detailed procedure for placing the ryegrass seeds for fluorescence test and the subsequent treatment and counting of the seedlings is of utmost importance if uniform results are to be obtained. Since the fluorescence occurs in the roots of the seedlings, enough space must be allowed for growth of the roots without contact with each other, or if planted close together arrangements must be made to confine the roots of each seedling to a limited area. Filter paper has been found to be a satisfactory substratum for development of the fluorescent lines. The fluorescence not only shows on the roots of the seedlings but also appears on the filter paper, outlining the roots of each fluorescent seedling.

The exact placement and method of testing for fluorescence varies considerably in laboratories, since the problem of space is often a limiting factor. There are several methods in use which consist in placing the seeds on: (1) Small strips of filter paper which are laid flat on the germination tray; (2) strips of accordionlike folded filter paper or on flat pieces of filter paper which are then placed sidewise in a daylight germinator so that all roots will grow in the same direction; (3) filter paper pressed into cuplike depressions in a flat plastic board, with the aim of restricting the roots of each seedling to a single depression; (4) filter paper in Petri dishes; and (5) squares of filter paper laid flat on germination trays.

In Petri-dish tests there is a tendency to crowd the seeds too close together. The fluorescent seedlings are removed daily or as soon as the fluorescent lines become apparent. This usually occurs about the sixth day of test and may continue to appear until the sample has fully germinated.

The method employed in the Federal laboratory at Beltsville is identified as method (5) above and is used as follows: The seeds are tested in 8 replicates of 50 seeds each. The substratum for each replicate consists of 2 square pieces of filter paper cut approximately 9 by 9 inches placed directly upon 2 pieces of blotting paper cut the same size. Four of these replicates fit on the standard germination tray, thus making it necessary to use 2 trays for the complete test. The seeds are placed on the substratum with the aid of a vacuum counter which insures a spacing of approximately 1 inch between seeds. The trays are placed in a 20°–30° C. daylight germinator.

The tests are examined for fluorescence at the end of the 14-day test period. The dead seeds are circled with an indelible pencil before the tests are placed under the ultraviolet light. Time is allowed for the analyst's eyes to become accustomed to the ultraviolet light and then the roots on each seedling showing fluorescence are outlined on the filter paper with an indelible pencil. Any seedlings not showing fluorescence are pulled off the filter paper while being held under the ultraviolet light in order to detect fluorescence from roots which may have grown into the substratum. A blue line or faint trace of fluorescence will often be evident when the seedlings are thus examined. The percentages of fluorescence, nonfluorescence, germination, and dead seeds should be ascertained and recorded on the record card. The procedure for calculating the results, with examples, is given on page 64. The percentages of fluorescence and germination are both obtained from the same test.

TESTING COATED OR PELLETED SEED

The methods of pelleting and coating seeds and problems incident to testing such seed have been discussed under the heading "Procedures for Determining Purity Composition."

Whether the inert "covering" would have to be removed from the seeds before a germination test is made has not been determined. Probably such "pellets" can be germinated according to the present provisions for temperature, but it is questionable whether artificial substrata can be used successfully. There are some data which suggest that a more natural medium such as sand or soil will be necessary for proper germination and seedling evaluation. Other data indicate that injury to the seed, as reflected in its germination, may occur during the "pelleting" process. Also, the inert covering appears to retard germination of some kinds of seed.

THE COLD TEST

The rules for testing seeds aim to provide optimum conditions for the germination of each kind to be tested. It has been advocated that in addition to the standard germination test another test should be made under adverse growing conditions similar to the unfavorable conditions which may prevail in the field subsequent to planting. This method, commonly known as the "cold test," is intended to detect weaknesses and measure the seeds' response to these unfavorable field conditions. At the present time the cold test is limited essentially to corn, although it is understood that the method is being used for beans and peas on a small scale. Briefly, the method for corn consists in planting the seeds in unsterilized soil or a mixture of soil and sand, with high-moisture content, at a temperature of approximately 10° C. for 5 to 7 days and then transferring the tests to a temperature of approximately 30° C. for completion. Some laboratories use loam soil from a cornfield without further inoculation whereas other laboratories inoculate the soil with ground seed which previously failed to germinate. The difficulties of standardizing such tests are apparent, and their future use as regular laboratory methods is unpredictable.

SPECIAL METHODS OF DETERMINING VIABILITY

The use of biochemical methods as rapid measures of determining seed viability are still in the experimental state. Their use is based on the principle that certain compounds such as selenium and tetrazolium are reduced to colored forms by enzymatic action in living cells and that no staining will occur in dead cells.

The use of selenium salts has been discouraged because of their toxicity to the individual carrying out the test. The use of tetrazolium compounds as a regular method of determining viability has apparently been limited to certain laboratories in Germany, where it was first developed. Investigations are currently being conducted in the United States, England, and perhaps other countries, but present indications are that the method can be used only as a rough measure of seed viability. Apparently, very high germinating seed will stain easily and dead seed will not stain, but the correlation between staining and germination of seed of intermediate viability and of low vigor is very poor. Obviously, a staining test does not directly measure the plant-producing power of seeds which may be diseased, mechanically injured, or insect-damaged.

The activity of such enzymes as catalase and oxidase as a measurement of seed viability has been reported by numerous workers. The conflicting data and the fact that the determinations require special equipment have made their application to seed testing of no practical importance.

The growth of excised embryos, as a rapid method of measuring seed viability, is of more practical application to nurserymen and foresters than to seed analysts. Because of the difficulty of removing embryos without injury, the small size of most of the seeds subject to the rules for testing, and the relatively short periods required for a regular germination test this method has found no place in the testing of agricultural and vegetable seeds. There is no provision for the excision of embryos in the present rules.

APPLICATION OF GERMINATION PROCEDURES TO SPECIFIC GROUPS

AIZOACEAE (CARPETWEED FAMILY) AND CHENOPODIACEAE (GOOSEFOOT FAMILY)

KINDS OF SEED

Aizoaceae—Carpetweed family.

New Zealand spinach—*Tetragonia expansa.*

Chenopodiaceae—Goosefoot family.

Beet—*Beta vulgaris.*
Sugar beet—*Beta vulgaris* var. *saccharifera.*
Swiss chard—*Beta vulgaris* var. *cicla.*
Mangel (field)—*Beta vulgaris.*
Spinach—*Spinacia oleracea.*

OCCURRENCE AND LABORATORY TREATMENTS FOR OVERCOMING DORMANCY

New Zealand spinach.—New Zealand spinach seed is frequently dormant. Exposure of the fruits to low temperatures or removal of the pulp from around the ends of individual seeds in each fruit will cause prompt germination. The laboratory treatments for breaking such dormancy are: Germination of the fruits on top of soil at alternating temperatures of 10°–30° C., or removal of the pulp from the fruits and then placing them for germination between blotters at 15°. Extreme care must be taken when the pulp is removed so as not to injure the seeds. The rules also specify that the substratum should be kept somewhat drier than it is maintained for the average kind of seed. It has been claimed that the absorption of excess water by the pulp of the fruit can cause "water-logging" or restriction of the aeration necessary for germination. The Federal laboratory has had success in regulating the moisture on New Zealand spinach by pressing the seeds about half their length into the top of soil, keeping the substratum fairly dry, alternately rewatering, stirring the soil, and turning the fruits during the course of the test period.

Spinach.—Spinach, *Spinacia oleracea*, may exhibit dormancy if germinated at too high a temperature, or if the seeds are kept too wet during the test period. No difficulty with dormancy should be experienced if the provisions of the rules with respect to temperature and moisture are followed. The seeds should be placed on top of blotters at 10° C. and kept slightly dry. In no case should water be allowed to accumulate around individual seeds. Germination has been found to be accelerated if the seeds are placed at 15° C., but as yet there is no provision in the rules for such treatment.

Beta vulgaris.—Slight dormancy frequently occurs in the different varieties of *Beta vulgaris.* This has been attributed to the mechanical restriction of the enveloping seed structures and the presence of germination inhibitors in the seed balls. Treatments with sulfuric acid, soaking in water, and germinating in soil have been recommended

for such samples. Soaking in water is specified in the rules as the laboratory treatment for all the varieties of beet. The procedure is as follows: Soak in water for 2 hours, using at least 250 cc. per 100 balls; rinse in running water and blot the surface of the balls dry. After the seeds have been soaked, rinsing may be accomplished by dumping them into a fine meshed colander or sieve and washing them under running water in a sink. They can then be placed on a piece of absorbent toweling and the excess moisture blotted off. Then they may be rolled up in a dry towel and left for a few minutes, unrolled and put in test with the aid of a mechanical counter.

After germination is initiated in beets the seedlings may become black and die, owing to the presence of toxic substances from the seed balls coming in contact with the young sprouts. The soaking process as described above ordinarily removes most of these substances or germination inhibitors from the seed balls. However, occasional samples may be found which will have darkened radicles or hypocotyls, or both, in blotter tests. In soil tests there is very little blackening of seedlings since the toxic substances are apparently adsorbed by the soil particles. For these occasional samples with blackened seedlings in the blotter tests, the following treatments are recommended in the rules: Retest either in sand or soil or by washing in running water for 3 hours and then placing the seed balls on creped cellulose paper wadding, keeping the seed covered with slightly moist blotters. Special equipment as that described on page 35 is necessary if the seeds are washed in running water.

SUBSTRATA, SPACING, AND SPECIAL TREATMENTS

Blotters.—The different varieties of *Beta vulgaris* are tested between blotters and also New Zealand spinach when the pulp has been removed. No more than 50 seeds should be placed on a blotter folded to 4¾ by 6 inches in size.

If the fruits of New Zealand spinach are to be tested between blotters, the pulp should be scraped off in a manner that will not cause injury to the seeds which lie near the surface of the large end of the fruit. To facilitate removal of the pulp soak the fruits in water for a few hours. No particular precautions need be observed in scraping the base and sides but the broad end should be observed with a hand lens occasionally to determine whether there is injury to the seeds or whether some have been accidentally removed.

Spinach seed is tested on top of blotters. No more than 100 seeds should be placed on a blotter 4¾ by 6 inches in size. The edges should be turned up approximately ¼ inch to prevent the seeds from rolling.

Sand and soil.—Sand or soil is indicated as an alternate method for seeds of *Beta vulgaris* exhibiting darkened radicles in blotter tests. It has been found that testing in sand or soil is an invaluable guide for proper interpretation of seedlings from balls infected with *Phoma*, overrun with mold, or mechanically injured by the shearing process. In no case should more than 100 beet balls be placed in a container 8½ by 8½ by 1¾ inches in size. Separators constructed to provide a separate section for each seed ball should be used when soil or sand tests are made.

The rules provide for testing New Zealand spinach seed on top of soil or sand. Since the test period for intact fruits is of long dura-

tion, a substratum that will retain moisture over a long period of time and yet not pack with rewatering is desirable. Equal amounts of sand, soil, and peat moss have been found very satisfactory. The fruits should be firmly pressed into the substratum for at least one-half their length. No more than 25 fruits should be placed in a container 4½ by 4½ by 1½ inches in size. This requires 16 replicates for a complete test.

Creped cellulose wadding.—Kimpak is indicated as an alternate method for *Beta vulgaris* and varieties if they exhibit darkened radicles in blotter tests. No more than 50 seeds should be placed on a piece of creped cellulose paper wadding 9 by 9½ inches in size. Seventy-five cc. of water should be added to a piece of Kimpak this size. A moist blotter the same size should be placed over the seeds.

SEEDLING INTERPRETATION

Since the seed unit in beet, sugar beet, mangel, Swiss chard, and New Zealand spinach usually contains more than one seed, the germination percentage is based on the number of viable seed balls or fruits and not on the number of viable true seeds. Even though two or more seedlings develop from each seed unit, only one is counted. The only exception is when a sprout count is requested for beets. In this case both the germination of each fruit or seed "ball" and of the seedlings per "ball" are recorded and reported.

A completely normal seedling on the above kinds should have a long slender root with root hairs, a long, well-developed hypocotyl, two attached leaflike cotyledons and an intact but small epicotyl. It is not possible to observe the condition of the epicotyl in routine testing. The condition of the cotyledons must be observed, especially when mechanical injury to the seed is apparent. (Figs. 24, 25, 26.)

Normal seedlings include those that have: (1) A well-developed, long, slender root with root hairs; (2) a stubby primary root, provided the secondary roots are strong and the hypocotyl is near normal length, as in spinach; (3) at least one attached cotyledon, provided the seedling is otherwise normal; (4) slight infection by fungi, provided none of the essential seedling structures have been damaged; (5) normal seedling structures of *Beta* but discolored from toxic substances in the seed balls or other causes; (6) at least one normal seedling from a seed ball, regardless of whether abnormal seedlings also emerge from the same fruit.

Abnormal seedlings include those that have: (1) No root or a stubby primary root with poor secondary root development, usually associated with a shortened hypocotyl; (2) a malformed, shortened, twisted, watery, or stubby hypocotyl, usually associated with a stubby root but not necessarily so; (3) deep grainy lesions or cracks in the hypocotyl if they appear to interfere with the conducting tissues; (4) both cotyledons absent as in samples of "sheared" beets and occasional samples of spinach; (5) two large cotyledons, but a malformed, short hypocotyl, usually with a stubby root; (6) decayed cotyledons or hypocotyl, provided they are not the result of improper test conditions (if there is decay of beet seedlings in blotter tests the results from a properly conducted soil or sand test should be accepted as correct); and (7) various combinations of the above abnormal types.

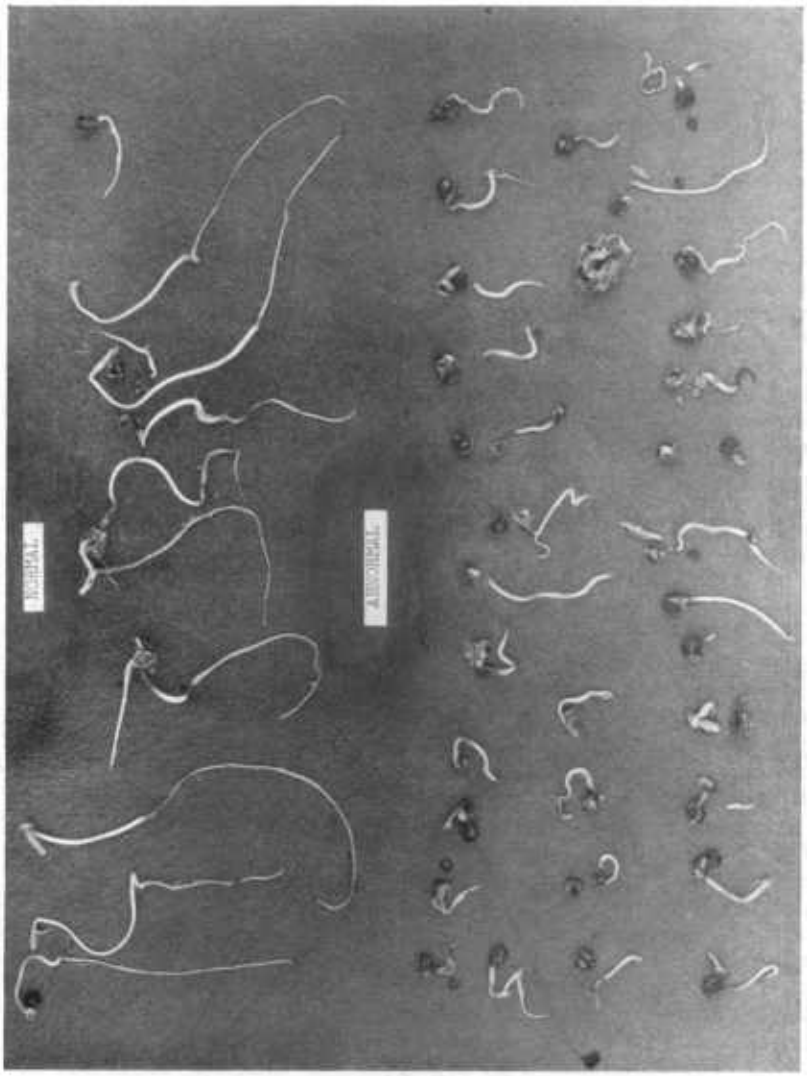

FIGURE 24.—Beets (*Beta vulgaris*). Normal and abnormal seedlings from 14-day tests between blotters

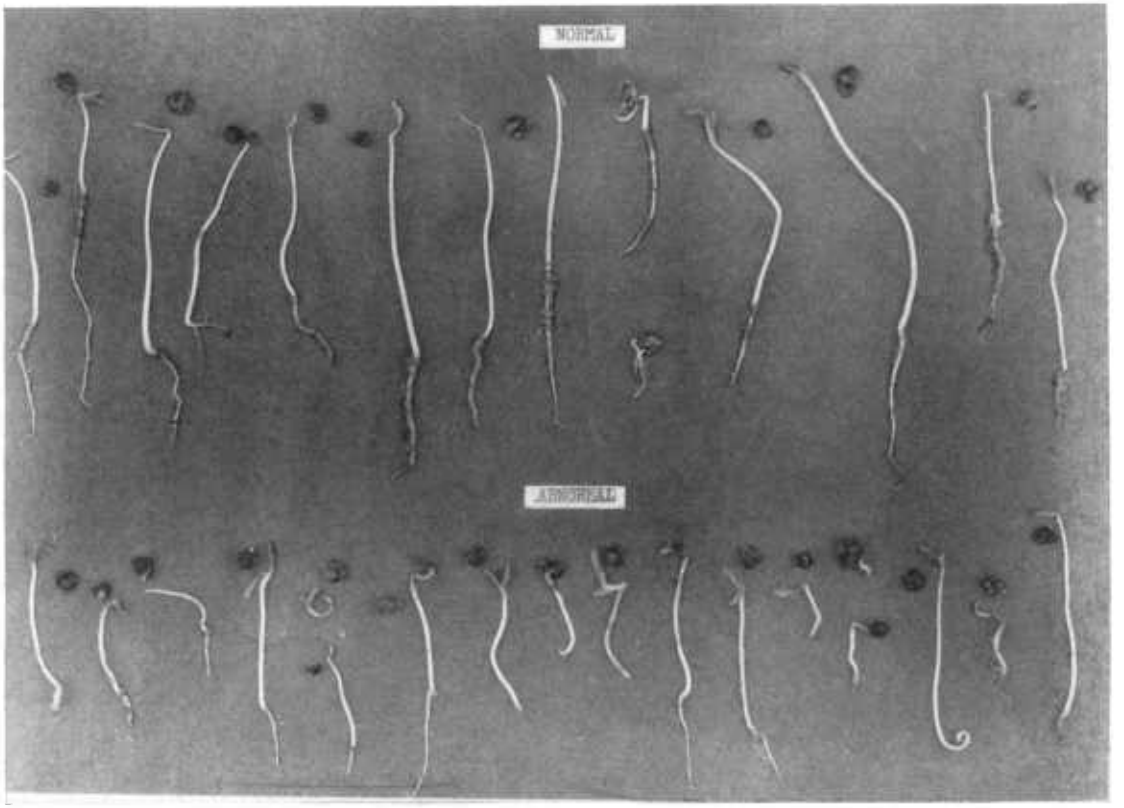

FIGURE 25.—Beets (*Beta vulgaris.*) Normal and abnormal seedlings from 14-day tests in soil.

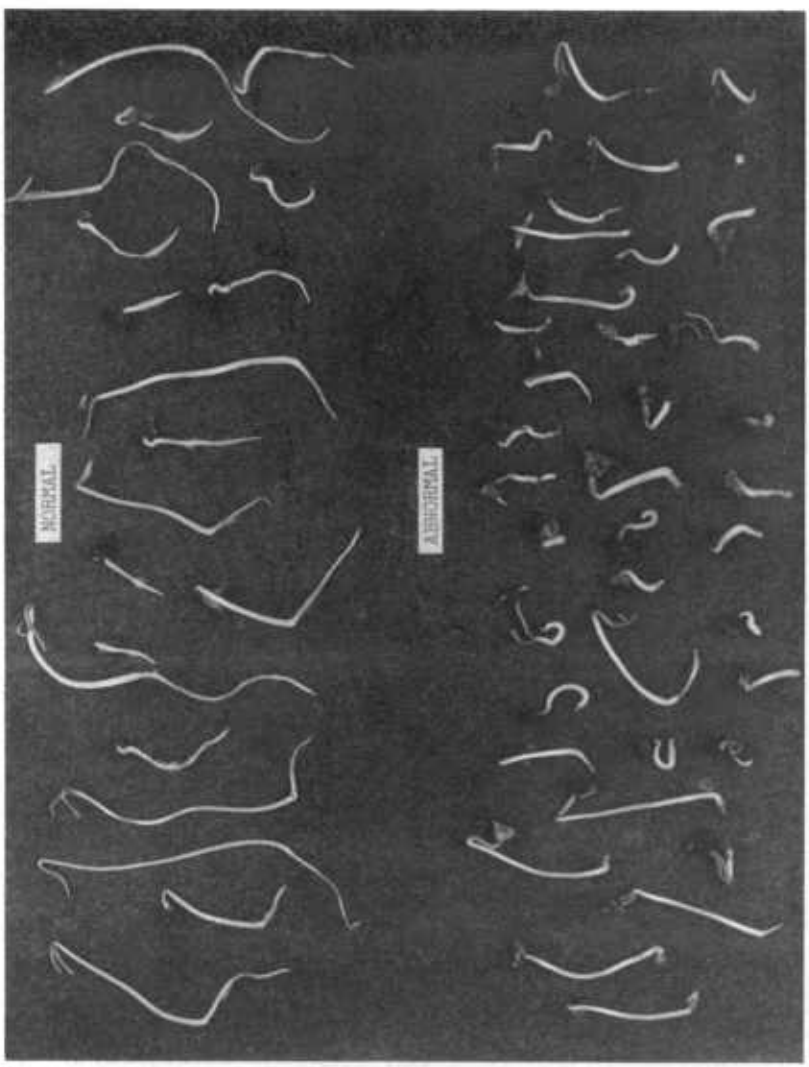

FIGURE 26.—Spinach (*Spinacia oleracea*). Normal and abnormal seedlings from 21-day tests on top of blotters.

COMPOSITAE (COMPOSITE OR SUNFLOWER FAMILY)

KINDS OF SEED

Artichoke—*Cynara scolymus.*
Cardoon—*Cynara cardunculus.*
Chicory—*Cichorium intybus.*
Dandelion—*Taraxacum officinale.*
Endive—*Cichorium endivia.*
Lettuce—*Lactuca sativa.*
Salsify—*Tragopogon porrifolius.*
Sunflower (cult.)—*Helianthus annuus.*

OCCURRENCE AND LABORATORY TREATMENTS FOR OVERCOMING DORMANCY

Since the pure seed units of the composite family may include empty "seeds" or fruits, analysts must distinguish between low germination owing to unfilled seeds and that owing to dormancy. It is recommended that at the end of the germination test all ungerminated seeds should be examined to determine whether they are empty, dead, or dormant. Empty fruits occur more frequently in samples of endive and chicory than in the other kinds.

Dormancy may be encountered in the laboratory testing of endive, chicory, lettuce, salsify, and possibly dandelion. It is unlikely that it will occur in artichoke, cardoon, or sunflower. Although the seeds of endive and chicory are practically indistinguishable, endive will often exhibit extreme dormancy whereas chicory will not. Data on germination of endive show that the seeds will respond favorably to treatment with excess moisture and solutions of thiourea. Germination in the laboratory is usually higher when the substratum is moistened with a dilute solution of potassium nitrate or when the seed is germinated on top of soil, both of which are specified as regular methods for endive and chicory. In addition, dormant seeds of endive should be subjected to an excess of water during the first part of the test period. Care must be taken not to submerge the seeds but to carefully add about one-eighth inch of water to the substratum. This can be accomplished by lifting off the upper layer of artificial substratum which contains the seeds, adding the water to the Petri dish, and then carefully replacing or "floating" the top layer of substratum with the seeds on the water. Certain varieties of lettuce may be extremely dormant and will usually respond to such treatments as light, soaking in water, and prechilling. Exposure to light and prechilling of dormant seeds are specified as regular laboratory germination procedures.

Light is specified in the rules for dandelion although no dormant samples have been observed in the Federal laboratory. Dormancy in salsify has been shown to be broken by prechilling, the method specified in the rules.

SUBSTRATA, SPACING, AND SPECIAL TREATMENTS

Folded towel tests are indicated in the rules for artichoke, cardoon, salsify, and sunflower, although indications are that upright rolled tests would be more satisfactory. In no case should more than 50 seeds of any of the above kinds be placed in a folded towel approximately 5½ by 7 inches in size. If upright rolled towels of approximately 11 by 14 inches in size are used, no more than 50 seeds of artichoke, cardoon, or sunflower or 100 seeds of salsify should be placed

in each towel. If sunflower seed is tested between folded blotters, no more than 50 seeds should be placed in a blotter folded to 4¾ by 6 inches in size.

The rules list Petri-dish tests as standard for endive, dandelion, chicory, and lettuce, but dandelion may be tested on top of blotters and endive and chicory on top of soil or sand. No more than 100 seeds of the above kinds should ever be placed in 100- or 120-mm. Petri dishes or in boxes 4½ by 4½ by 1½ inches in size.

SEEDLING INTERPRETATION

By the end of the germination test, a perfectly normal seedling belonging to the composite family should have a well-developed root with root hairs, a long and well-developed hypocotyl, two leaflike cotyledons, and a small but visible epicotyl. It will not be possible or practical to observe the epicotyl development on any of these kinds of seeds except those tested in soil and abnormal seedlings on artificial substrata (such as result from mechanically injured sunflower seed) that are not removed until the final count is made. The epicotyl development on lettuce is still very small at the end of 7 days. (Figs. 27–30.)

Lettuce.—The interpretations of lettuce seedlings are made only at the end of the test period. (Figs. 27, 28, 29.)

Normal seedlings include those that have: (1) A well-developed, long, slender root with root hairs; (2) a well-developed long hypocotyl with no deep lesions which might interfere with the conducting tissues; (3) two green cotyledons with some blackened or reddish-brown areas, provided the hypocotyl and roots have developed normally or approximately so; and (4) slight infections by fungi, provided none of the essential seedling structures have been damaged.

Abnormal seedlings include those that have: (1) No roots, or very stubby or shortened roots, which are usually associated with shortened hypocotyls; (2) shortened hypocotyls which are usually associated with stubby roots; (3) malformed hypocotyls, severely twisted or having grainy areas or cracks extending into the conducting tissues; (4) cotyledons with large areas of blackish or reddish-brown tissue, usually appearing along the midrib, associated with a short hypocotyl and root (the seed coats are often attached to the cotyledons, adhering to the darkened areas and they may be removed by sprinkling them with water and then manually pulling or brushing them off); (5) cotyledons with a gray cast over their entire area, usually darker at the midrib section (hypocotyls and roots invariably shortened and seed coats usually attached to the cotyledons); (6) swollen, blackened cotyledons with only vestiges of hypocotyl and root, the seed coats usually remaining attached to the cotyledons; (7) decayed cotyledons.

Other composites.—This group includes artichoke, cardoon (fig. 30), sunflower, salsify, dandelion, chicory, and endive.

Normal seedlings include those that have: (1) A well-developed, long, slender primary root with root hairs; (2) a stubby root if there are one or more strong secondary roots, provided the seedling is otherwise normal; (3) a well-developed, long, hypocotyl with no prominent breaks or deep lesions which might interfere with the conducting tissues; (4) at least one uninjured cotyledon, provided the epicotyl is also present; (5) slight infection of the roots or hypocotyl with

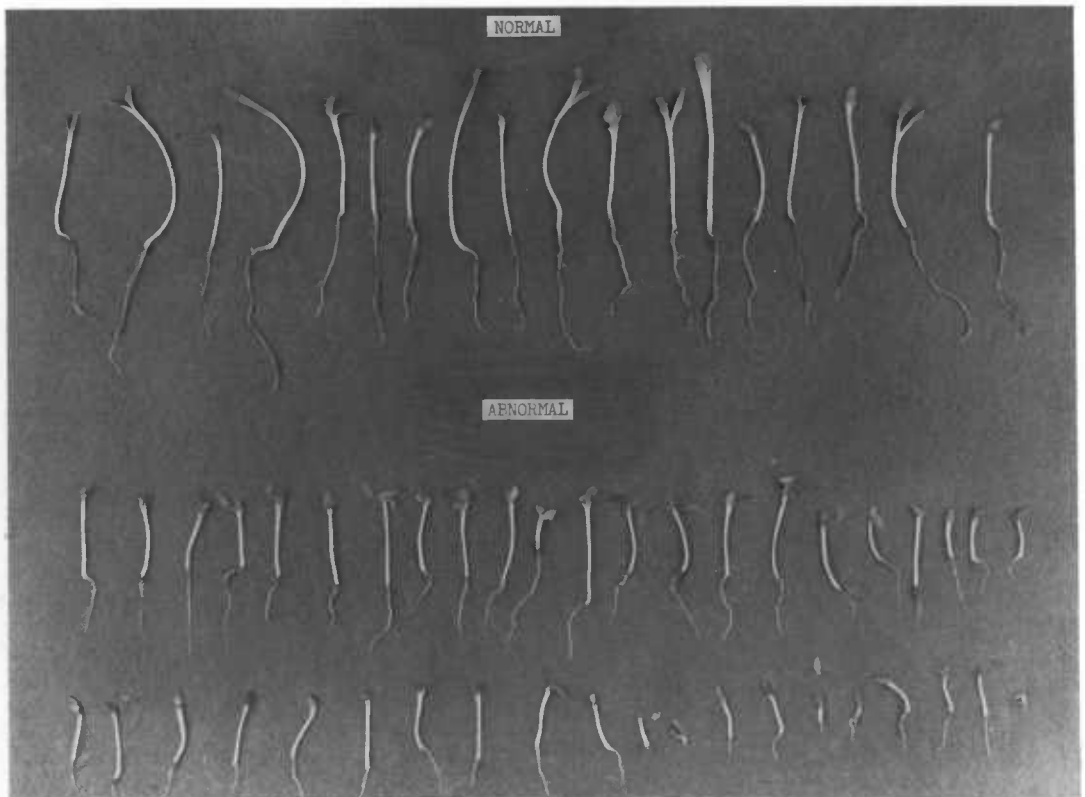

FIGURE 27.—Lettuce (*Lactuca sativa*). Normal and abnormal seedlings from 7-day tests in soil.

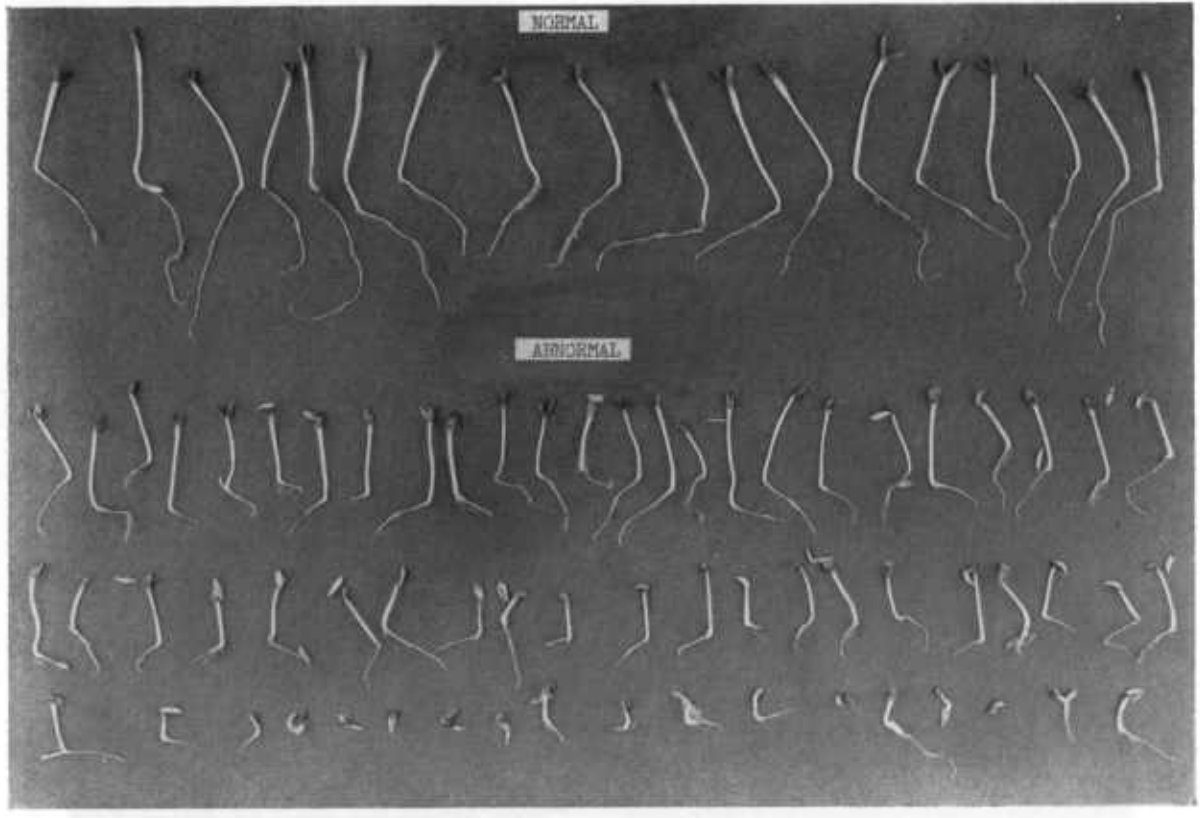

FIGURE 28.—Lettuce (*Lactuca sativa*). Normal and abnormal seedlings from 7-day tests in Petri dishes.

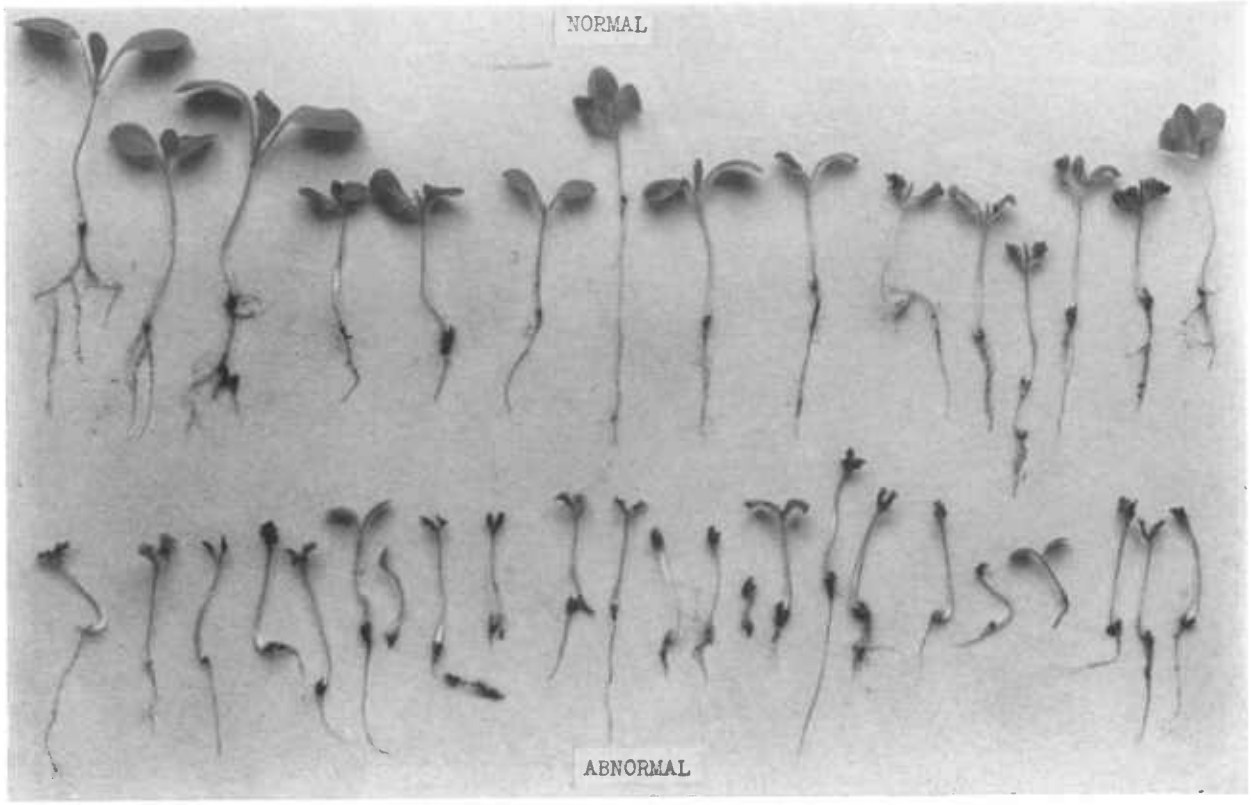

FIGURE 29.—Lettuce (*Lactuca sativa*). Normal and abnormal seedlings from 10-day tests in greenhouse.

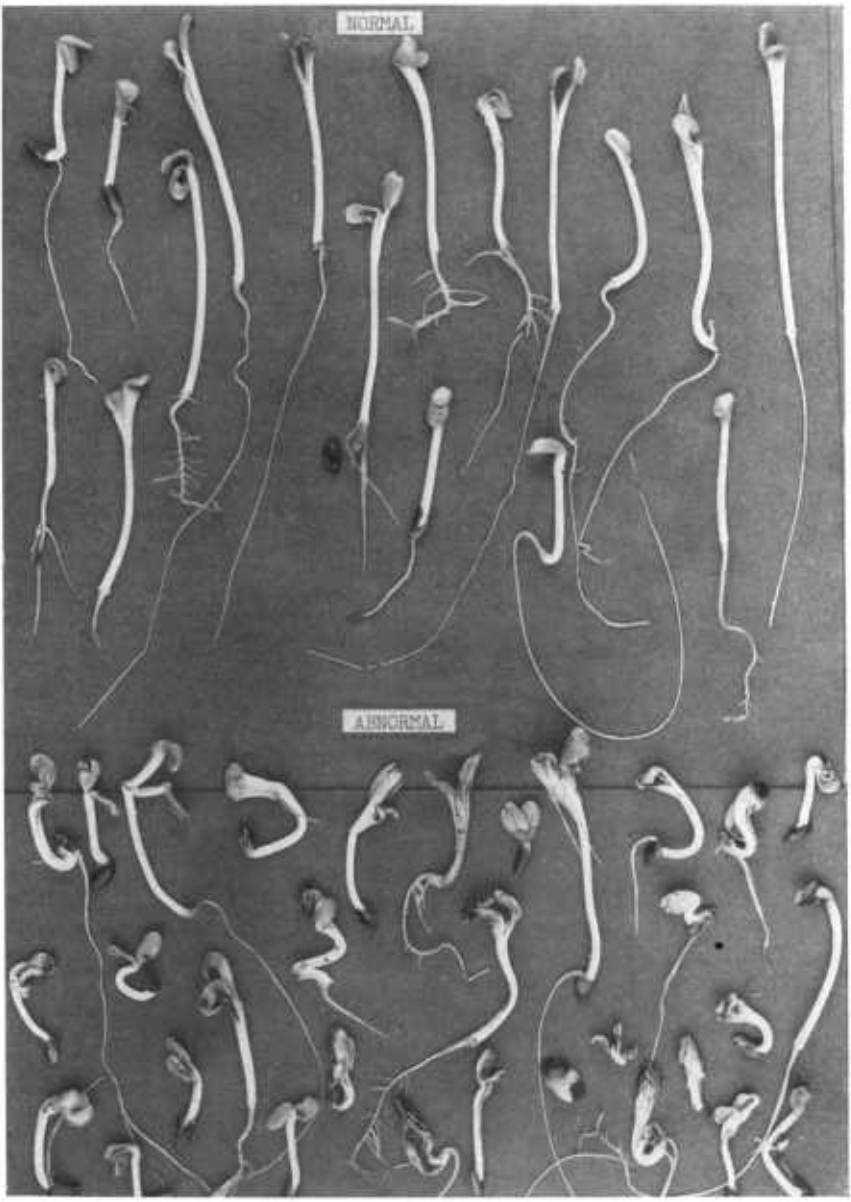

FIGURE 30.—Cardoon (*Cynara cardunculus*). Normal and abnormal seedlings from 14-day tests in towels.

fungi, provided none of the essential seedling structures have been damaged.

Abnormal seedlings include those that have: (1) No root or a stubby root with weak secondary roots, usually associated with a shortened hypocotyl; (2) a malformed hypocotyl, which may be curled, shortened, or thickened, usually associated with a stubby root; (3) deep, unhealed cracks or grainy areas on the hypocotyl, extending into the conducting tissues; (4) both cotyledons entirely broken off; (5) one cotyledon broken off, provided the epicotyl is also absent; (6) two normal cotyledons with a short malformed hypocotyl, usually with a stubby root; (7) decayed cotyledons, provided the infection is not caused by improper test conditions; and (8) various combinations of the above-named abnormal types.

CRUCIFERAE (MUSTARD FAMILY)

KINDS OF SEED

Broccoli—*Brassica oleracea* var. *botrytis.*
Brussels sprouts—*B. oleracea* var. *gemnifera.*
Cabbage—*B. oleracea* var. *capitata.*
Cauliflower—*B. oleracea* var. *botrytis.*
Collards—*B. oleracea* var. *acephala.*
Cress, garden—*Lepidium sativum.*
Cress, water—*Rorippa nasturtium-aquaticum.*
Kale—*Brassica oleracea* var. *acephala.*
Kohlrabi—*B. oleracea* var. *gongylodes.*
Mustard:
- Black—*Brassica nigra.*
- White—*B. hirta.*
- India or Southern curled—*B. juncea.*
- Spinach—*B. perviridis.*

Pakchoi—*B. chinensis.*
Pe-tsai—*B. pekinensis.*
Radish—*Raphanus sativus.*
Rape:
- Annual—*Brassica napus* var. *annua.*
- Bird—*B. campestris.*
- Turnip—*B. campestris* vars.
- Winter—*B. napus* var. *biennis.*

Rutabaga—*B. napus* var. *napobrassica.*
Turnip—*B. rapa.*

OCCURRENCE AND LABORATORY TREATMENTS FOR OVERCOMING DORMANCY

Dormancy may occur in many of the kinds in this group, especially those of the genus *Brassica.* Proper identification of the species being tested must be made and the appropriate treatment selected for germination. Low germination results may be obtained if seeds are incorrectly identified and subsequently not placed under recommended conditions for breaking dormancy.

Of the mustards, *B. juncea* (Southern curled or India), and *B. nigra* (black mustard) are apt to be dormant, whereas *B. hirta* (white mustard) and *B. perviridis* (Spinach mustard) are not. Seeds of the *B. oleracea* group (broccoli, brussels sprouts, cabbage, cauliflower, collards, kale, and kohlrabi) are occasionally dormant. The use of potassium nitrate, light, and prechilling are recommended in the rules for overcoming dormancy in these kinds.

Dormancy may also be encountered in *B. campestris* (bird rape). Treatment with potassium nitrate only is recommended in such in-

stances. It is unlikely that dormancy will be found in *B. napus* var. *annua* (annual rape), *B. campestris* vars. (turnip rape), *B. napus* var. *biennis* (winter rape), *B. napus* var. *napobrassica* (rutabaga), *B. pekinensis* (pe-tsai), *B. chinensis* (pakchoi), or *B. rapa* (turnip).

There is a provision in the rules for treating dormant samples of garden cress (*Lepidium sativum*) by placing them at 15° C. in light. There is no provision for breaking dormancy of water cress, *Rorippa nasturtium-aquaticum*, although it has been observed in some samples.

SUBSTRATA, SPACING, AND SPECIAL TREATMENTS

Seeds of most of the crucifers or members of the mustard family may be tested between blotters. In no instance should more than 50 seeds of radish or 100 seeds of any of the other kinds be placed in a blotter folded to 4¾ by 6 inches in size. Since these seeds roll easily, the edges of the blotters should be turned up about ¼ inch. No more than 100 seeds of any species of the Cruciferae should be tested in a 100-mm. Petri dish.

SEEDLING INTERPRETATION

By the end of the germination test, a perfectly normal crucifer seedling should have a well-developed root, usually with root hairs, a long hypocotyl, two intact green, leaflike cotyledons and a small but visible epicotyl or growing point. Except for diseased seedlings of radish and *Brassica* it is not practical to observe the epicotyl development, unless samples are tested in soil, in which case the cotyledons will open and the growing point become clearly visible. However, the cotyledons of diseased radish and *Brassica* seedlings must be observed, in which case the seedlings should not be removed until the extent of the decay can be determined. It is usually necessary to use a hand lens for these close observations. (Figs. 31, 32, 33.)

Radish (Raphanus sativus) and Brassica spp.—It is not practical to observe the epicotyl except in soil tests or on diseased samples of radish. (Figs. 31, 32, 33.)

Normal seedlings include those that have: (1) A well-developed, long, slender primary root with root hairs; (2) a well-developed, long hypocotyl with no prominent breaks or deep lesions which might interfere with the conducting tissues; (3) one or two cotyledons not decayed at the point of attachment to the hypocotyl, provided the epicotyl is also present; (4) slight decay at the base of one cotyledon, provided the epicotyl is not infected; (5) less than 50 percent of the area of the cotyledons covered with spots or darkened areas; and (6) slight infection of roots or hypocotyl with fungi, provided none of the essential seedling structures have been damaged.

Abnormal seedlings include those that have: (1) No root or a stubby root, usually associated with a shortened hypocotyl; (2) a malformed hypocotyl, which may be curled, shortened, or thickened and usually associated with a stubby root; (3) deep, unhealed cracks or lesions (often grainy) on the hypocotyl, extending into the conducting tissues; (4) decay at the point of attachment of both cotyledons to the hypocotyl which may or may not involve the terminal bud; (5) decay at the point of attachment of one cotyledon to the hypocotyl, provided the terminal bud is also decayed; (6) 50 percent or more of the area of the cotyledons covered with spots or darkened areas; (7) decayed

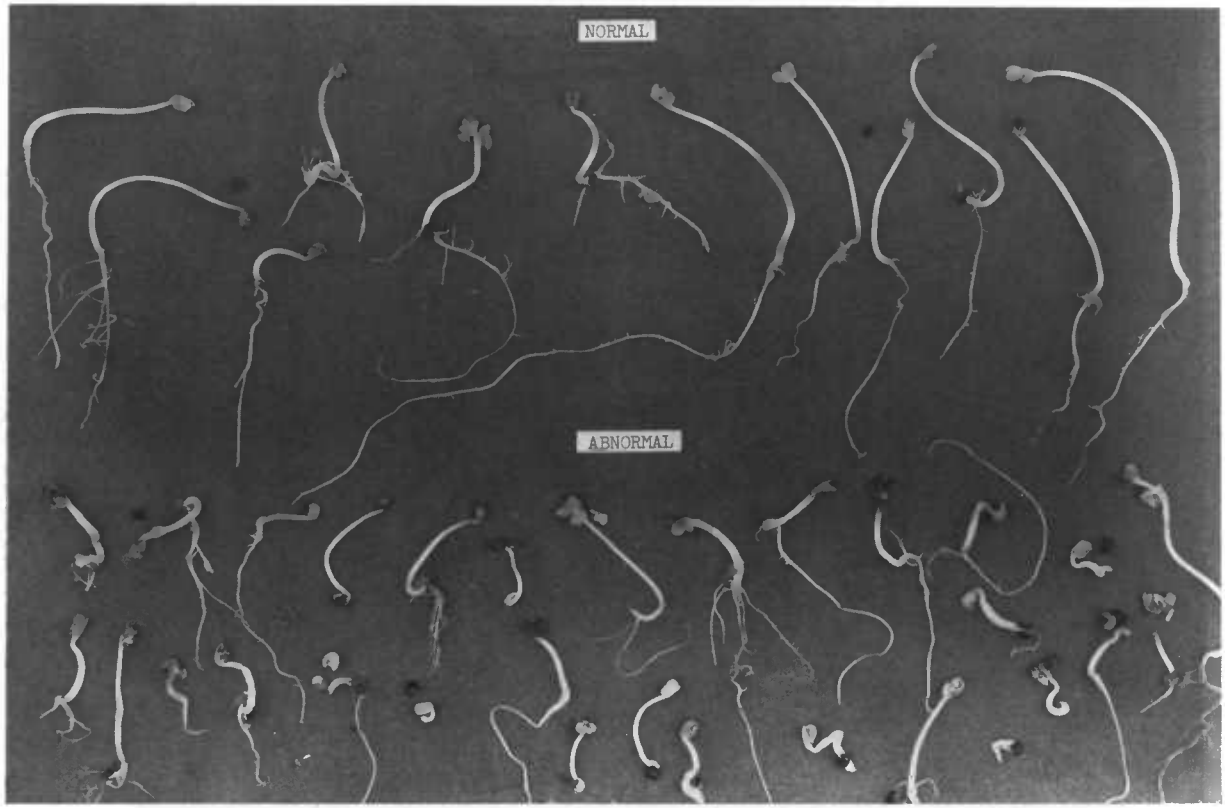

FIGURE 31.—Cabbage (*Brassica oleracca* var. *capitata*). Normal and abnormal seedlings from 10-day tests in blotters.

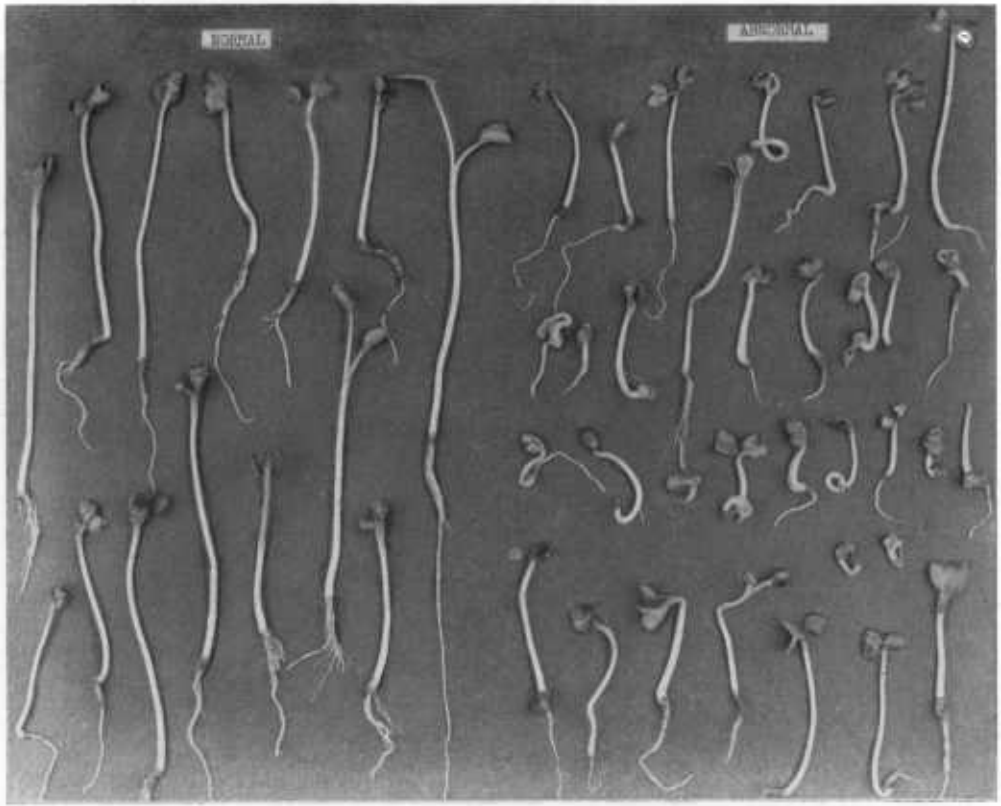

FIGURE 32.—Radish (*Raphanus sativus*). Normal and abnormal seedlings from 6-day tests in soil.

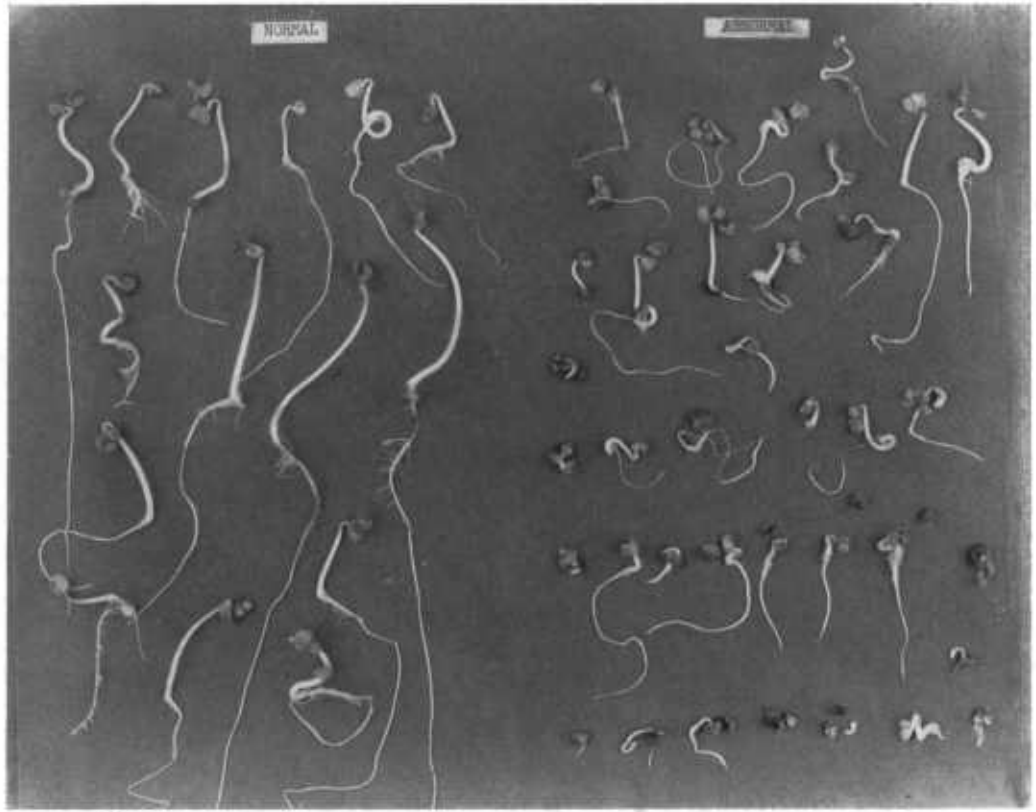

FIGURE 33.—Radish (*Raphanus sativus*). Normal and abnormal seedlings from 6-day tests between blotters.

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roots or hypocotyls, provided the infection was not caused by improper test conditions; (8) watery hypocotyls (usually associated with some other abnormality of the seedlings), provided this condition is not caused by excessive moisture of the substratum; and (9) various combinations of the above-named abnormalities.

Garden cress (Lepidium sativum) and water cress (Rorippa nasturtium-aquaticum).—There appears to be very little difficulty in distinguishing between normal and abnormal seedlings of garden cress and water cress.

Normal seedlings include those that have: (1) A well-developed, slender root with root hairs; (2) a long, well-developed hypocotyl with no prominent breaks or deep lesions which might interfere with the conducting tissues; (3) intact cotyledons; and (4) slight infection with fungi, provided none of the essential seedling structures have been damaged.

Abnormal seedlings include those that have: (1) No root, or a stubby root, usually associated with a shortened hypocotyl; (2) a malformed hypocotyl, which may be curled, twisted, shortened, or thickened and frequently associated with a stubby root; (3) deep, unhealed cracks or grainy lesions on the hypocotyl, extending into the conducting tissues; (4) watery hypocotyls, usually associated with stubby roots or decayed cotyledons; (5) cotyledons entirely broken off; (6) decayed cotyledons, provided the infection was not caused by improper test conditions; and (7) various combinations of the above-named abnormal types.

CUCURBITACEAE (CUCURBIT FAMILY)

KINDS OF SEED

Citron—*Citrullus vulgaris.*
Watermelon—*Citrullus vulgaris.*
Cucumber—*Cucumis sativus.*
Muskmelon or cantaloup—*Cucumis melo.*
Pumpkin—*Cucurbita pepo.*
Squash—*Cucurbita moschata* and *C. maxima.*

OCCURRENCE AND LABORATORY TREATMENTS FOR OVERCOMING DORMANCY

Dormancy may occur in freshly harvested seeds of cucurbits although there is no provision in the rules for the laboratory treatment of this condition except for citron. It has been observed that the extent of dormancy varies not only with the kinds but also with the varieties. Exposure of seeds to a higher constant or alternating temperature than provided in the rules and removal of the seed coats have been used successfully to overcome dormancy in certain of these cucurbits.

Unless the substrata for watermelon, cucumber, muskmelon or cantaloup, pumpkin, and squash are kept drier than they are maintained for the average kind of seed, secondary dormancy may occur. The seeds are very sensitive to excess moisture.

The rules provide that citron should be soaked 6 hours before being placed for test and that dormant samples should be placed at 30° C. for the duration of the test period.

SUBSTRATA, SPACING, AND SPECIAL TREATMENTS

Cucumber and muskmelon or cantaloup are tested between blotters. No more than 50 seeds should be placed in a blotter 4¾ by 6 inches in size.

Folded towels are used for citron, watermelon, pumpkin, and squash and also as an alternate substratum for cucumber and muskmelon or cantaloup. Upright rolled towels may be just as satisfactory provided they are kept on the dry side. No more than 50 seeds of citron, watermelon, cucumber, muskmelon or cantaloup and no more than 25 seeds of pumpkin or squash (large seeded) should be placed in towels folded to 5½ by 7 inches in size. If upright rolled towels are used, 50 seeds of all kinds may be placed in rolls approximately 11 by 14 inches in size.

It is permissible to use soil and sand as alternate substrata for watermelon, cucumber, muskmelon or cantaloup, pumpkin, and squash. No more than 50 seeds of the small-seeded kinds should be placed in a container 4½ by 4½ by 1½ inches in size and no more than 50 seeds of the large-seeded kinds in a container 8½ by 8½ by 1¾ inches.

SEEDLING INTERPRETATION

The cucurbits considered herein all exhibit epigeous growth, the cotyledons turning green and serving not only as food storage but as manufacturing organs. By the end of the germination test a perfectly normal seedling should have a well-developed primary root with several secondary roots, a long hypocotyl, two intact cotyledons, and an epicotyl or terminal growing bud. Unless soil or sand tests are made, the analyst will not be able to observe the condition of the epicotyl. (Fig. 34.)

Normal seedlings include those that have: (1) A well-developed primary root with or without secondary roots; (2) a stubby primary root with at least two strong and vigorous adventitious roots, provided the hypocotyl is not shortened very much; (3) a long well-developed hypocotyl; (4) two intact cotyledons; and (5) slight infection by fungi, provided none of the essential seedling structures have been damaged.

Abnormal seedlings include those that have: (1) No primary root, a stubby primary root, or a stubby primary root with weak secondary roots which are usually associated with a short hypocotyl; (2) a malformed hypocotyl which may be shortened or thickened; (3) thickened and shortened hypocotyls and roots owing to injury from chemical treatment, provided the injury is still apparent in a soil or sand check test; (4) decayed cotyledons or other essential seedling structures, provided the decay was not the result of improper test conditions; and (5) various combinations of the above-named abnormal types.

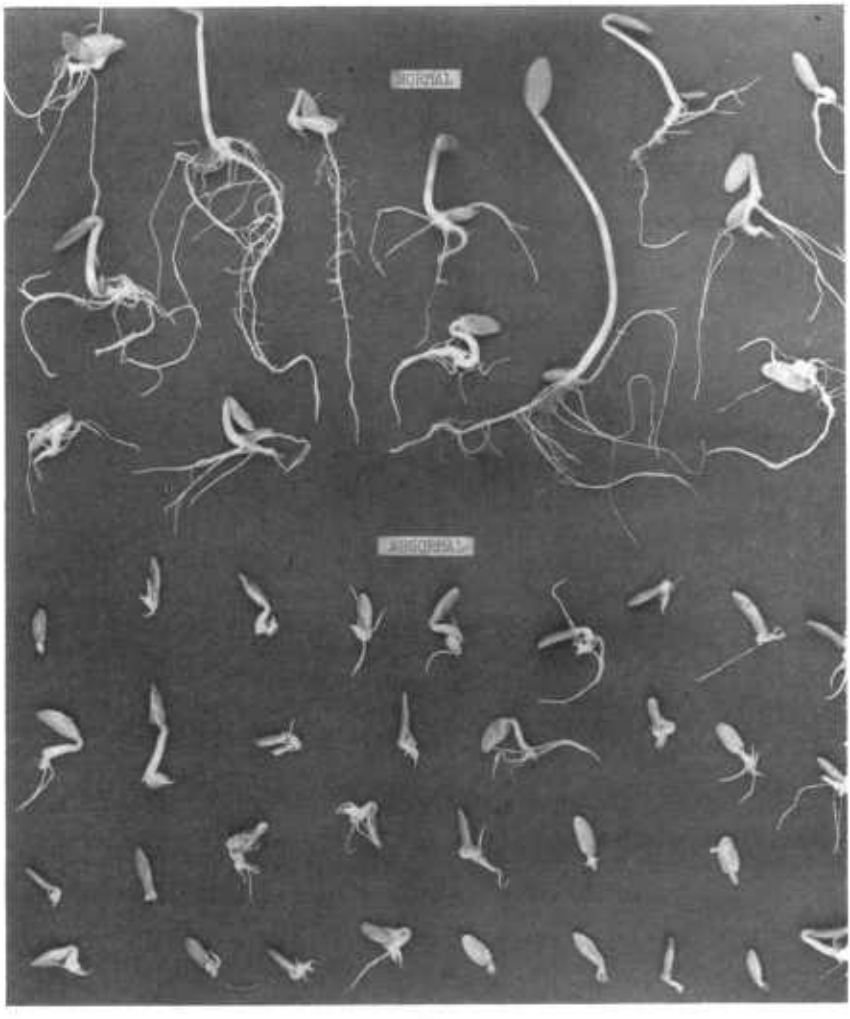

FIGURE 34.—Cucumber (*Cucumis sativus*). Normal and abnormal seedlings from 7-day tests in towels.

GRAMINEAE (GRASS FAMILY)

KINDS OF SEED

The information in the text for groups such as cereals, millets, and grasses will apply to all the kinds herein listed for each group unless otherwise specified.

Cereals:
- Barley—*Hordeum vulgare.*
- Oat—*Avena sativa* and *A. byzantina.*
- Rye—*Secale cereale.*
- Wheat—*Triticum* spp.
- Rice—*Oryza sativa.*
- Corn, field—*Zea mays.*
- Popcorn—*Zea mays* var. *everta.*
- Sweet corn—*Zea mays* var. *saccharata.*

Millets:
- Browntop—*Panicum ramosum* (see footnote, p. 397).
- Foxtail—Common, German, Hungarian, Siberian, or Golden—*Setaria italica.*
- Japanese—*Echinochloa crusgalli* var. *frumentacea.*
- Pearl—*Pennisetum glaucum.*
- Proso—*Panicum miliaceum.*

Sorghums:
- Grain and Sweet (Sorgo)—*Sorghum vulgare.*
- Broomcorn—*Sorghum sudanense* (*S. vulgare* var. *technicum*).
- Sudan grass—*Sorghum vulgare* var. *sudanense.*

Typical grass groups—(More than one species to a genus—mostly small seeded):
- Bentgrass: Colonial—*Agrostis tenuis.*
  - Astoria—*Agrostis tenuis* var.
  - Highland—*Agrostis tenuis* var.
  - Creeping (seaside)—*Agrostis palustris.*
  - Velvet—*Agrostis canina.*
- Bluegrass:
  - Annual—*Poa annua.*
  - Bulbous—*Poa bulbosa.*
  - Canada—*Poa compressa.*
  - Kentucky—*Poa pratensis.*
  - Nevada—*Poa nevadensis.*
  - Rough—*Poa trivialis.*
  - Texas—*Poa arachnifera.*
  - Wood—*Poa nemoralis.*
- Bromes:
  - Mountain—*Bromus marginatus.*
  - Smooth—*Bromus inermis.*
- Bluestems:
  - Big—*Andropogon gerardi* (*A. furcatus*).
  - Little—*Andropogon scoparius.*
  - Sand—*Andropogon hallii.*
- Fescues:
  - Chewings—*Festuca rubra* var. *commutata.*
  - Hair—*Festuca capillata.*
  - Meadow—*Festuca elatior.*
  - Red—*Festuca rubra.*
  - Sheep—*Festuca ovina.*
  - Tall—*Festuca arundinacea.*
- Grama:
  - Blue—*Bouteloua gracilis.*
  - Side-oats—*Bouteloua curtipendula.*
- Ryegrasses:
  - Italian—*Lolium multiflorum.*
  - Perennial—*Lolium perenne.*
- Wheatgrasses:
  - Crested (Fairway and standard)—*Agropyron cristatum.*
  - Slender—*Agropyron pauciflorum.*
  - Western (Bluestem)—*Agropyron smithii.*

Other typical grasses—(Mostly small seeded):
- Bahia grass—*Paspalum notatum.*
- Bermuda grass—*Cynodon dactylon.*
- Buffalo grass—*Buchloë dactyloides.*
- Canary grass—*Phalaris canariensis.*
- Canary grass, reed—*Phalaris arundinacea.*
- Carpet grass—*Axonopus affinis.*
- Crested dogtail—*Cynosurus cristatus.*
- Dallis grass—*Paspalum dilatatum.*
- Dropseed, sand—*Sporobolus cryptandrus.*
- Guinea grass—*Panicum maximum.*
- Harding grass—*Phalaris tuberosa* var. *stenoptera.*
- Indian grass, yellow—*Sorghastrum nutans.*
- Japanese lawngrass—*Zoysia japonica.*
- Johnson grass—*Sorghum halepense.*
- Lovegrass, weeping—*Eragrostis curvula.*
- Manila grass—*Zoysia matrella.*

Other typical grasses—Continued.
Meadow foxtail—*Alopecurus pratensis.*
Molasses grass—*Melinis minutiflora.*
Napier grass—*Pennisetum purpureum.*
Oatgrass, tall—*Arrhenatherum elatius.*
Orchard grass—*Dactylis glomerata.*
Panic grass, blue—*Panicum antidotale.*
Redtop—*Agrostis alba.*
Rescue grass—*Bromus catharticus.*
Rhodes grass—*Chloris gayana.*
Ricegrass, Indian—*Oryzopsis hymenoides.*
Smilo—*Oryzopsis miliacea.*
Sweet vernal grass.—*Anthoxanthum odoratum.*
Switch grass—*Panicum virgatum.*
Timothy—*Phleum pratense.*
Vasey grass—*Paspalum urvillei.*
Velvet grass—*Holcus lanatus.*
Wild rye, Canada—*Elymus canadensis.*

OCCURRENCE AND LABORATORY TREATMENTS FOR OVERCOMING DORMANCY

Dormancy may be encountered in testing most of the Gramineae listed in the rules.

Barley, oats, rye, wheat.—Barley, oats, rye, and wheat respond to the same general temperature conditions, although some samples of oats may exhibit dormancy difficult to overcome in the laboratory. The regular treatment for dormant samples of seeds in the above-listed cereals is to prechill them at 5° or at 10° C. for 5 days, and then place them at 20° C. Since dormancy in the majority of these kinds appears to be easily overcome by subjecting the seeds to temperatures just below 20° C., an alternate method of testing is to place them at 15° C. for the duration of the test period. The selection of the method to use will depend on the kinds and condition of the samples regularly received in each laboratory. If dormant seeds remain at the end of the test period, retests should be made under some other condition. Certain samples of dormant oats may require special treatment, such as placement at 5° C., in a soil substratum, or predrying. The latter procedure is not in the rules, but it is generally accepted that either slow drying at about 35° or 40° C. for 3 to 7 days, or the natural drying after receipt and storage in laboratories, will often overcome dormancy in cereals.

Rice.—Dormancy may be encountered in the testing of rice, although there is no provision in the rules for overcoming this condition. Some available data indicate that a substratum providing more moisture than is provided by folded blotters or folded towels would tend to overcome this dormancy. Upright rolled towel tests with a large initial moisture supply and flooded sand tests have proved very successful.

Millets.—Although dormancy in the millets is not mentioned in the rules, it has been occasionally observed in those of the genera *Panicum* and *Setaria.* Lack of data makes it impossible to suggest a method of overcoming this condition. However, if an analyst is not sure whether a sample is dead or dormant, the glumes may be carefully removed from the seeds and the naked caryopses put back in test. If the seed is dead, the embryos will turn dark and decay within a few days.

Sorghums and Sudan grass.—Dormancy in sorghums may be overcome by prechilling at 5° or 10° C. for 5 days. There are data to

show that slow drying or that testing certain of the sorghums at 20°–35° C. instead of at 20°–30° C. might also have a beneficial effect but these methods should not be used unless the official rules are found inadequate. Common Sudan does not appear to exhibit dormancy, although it is possible that Sweet Sudan might. However, there is little information on this subject at the present time.

Grasses.—In order to standardize and simplify the methods of testing, the least possible choice of treatments and substrata have been included in the rules for the different grass species. Light is specified for all the grasses except Napier grass, canary grass, and certain of the fescues. If red and Chewings fescues are germinated at the specified alternate method of 20°–30° C. instead of the regular method of 15°–25° C., light must be used. It has been found that the lower temperature alternation is more favorable for the germination of freshly harvested seed. When such seed is placed at the higher temperature light appears to compensate for the unfavorable temperature condition.

The temperature alternations and prechilling treatments in the rules are very specific and should need no further explanation beyond stressing that lack of correct temperature control may cause samples of grasses to exhibit erratic germination or no growth at all or to be thrown into secondary dormancy.

The use of potassium nitrate solutions and/or soil for overcoming dormancy in certain grasses is indicated in the rules. Potassium nitrate is preferred and used in most laboratories for routine testing. Soil is better than an artificial substratum moistened with a potassium nitrate solution in the following cases: (1) When there is root injury resulting from the use of potassium nitrate; (2) when certain grasses need an extraordinarily long time for completion of germination; (3) when slow germinating orchard grass seed is encountered; and (4) when rescue grass seed is tested with the glumes remaining on. Rescue grass seed will germinate very rapidly if deglumed, and the caryopses scratched and moistened with potassium nitrate and placed at 15° C. However, this is not an official procedure.

Degluming is specified only for Bahia grass. The operation must be done with care to avoid cracking the caryopsis in any way. A good procedure is to place the seeds flat side down on a damp blotter or cheesecloth, remove the outer thin, papery glume, insert the point of the scalpel between the folded edges of the horny lemma and palea at the pointed end of the seed, and carefully force the glumes open. The naked caryopsis can then be carefully forced out. If there is reason to believe that the seed may be dormant the caryopsis must be scratched lightly on the end away from the embryo, and a 0.2-percent potassium nitrate solution added to the substratum. All seeds considered "pure" must be used, and if more than two or three "inert" seeds are found a retest should be made on the pure seed separations.

The rules for seed testing provide for the testing of free caryopses or burs of buffalo grass but do not indicate whether it is permissible to remove the caryopses from burs as a part of the testing procedure. Owing to the difficulty of obtaining germination of buffalo grass in the bur, the rule has been interpreted as meaning that the caryopses may be removed and tested as a part of the laboratory procedure. Extracting these is a slow and tedious process; it must be done with a sharp

scalpel, and the seeds from each bur kept separate. It has been found practical to make individual sections with blotter strips on top of the substratum in order to keep an accurate count of the germination of seeds from each bur. A 0.2-percent potassium nitrate solution must be added to the substratum.

SUBSTRATA, SPACING, AND SPECIAL TREATMENTS

Cereals and millets.—Folded towel tests are indicated for wheat, barley, rye, oats, and rice. Indications are that rolled towel tests are to be preferred in testing rice. In no case should more than 50 seeds of any of the above-named kinds be placed on a folded towel approximately 5½ by 7 inches in size. If upright rolled towels are used no more than 50 seeds should be placed on an area 11 by 14 inches in size. The usual amount of moisture should be maintained on these tests, except for rice, which should be wetter than average, especially during the initial stages of germination.

Soil or sand tests of rice should have more than the usual amount of water added to them, although this is not specified in the rules. The following procedure is used in one laboratory located in a rice-producing area: After the seeds have been placed on top of normally moistened sand in pans 9 by 9 by 2 inches in size, add an additional 250 cc. of water. On the seventh day of test, at which time the seedlings have become anchored in the sand or soil, add enough water to cover the seed approximately one-fourth inch. Only a final count should be made.

Folded blotters are specified for rice, sorghum, Sudan grass, and the millets. They are not desirable for rice, since they do not provide enough moisture, and are too small to accommodate even 50 rice seeds without undue crowding. They do make a very nice substratum for the millets, sorghum, and Sudan grass. No more than 50 seeds of sorghum or 100 seeds of Sudan grass or millet should be tested in blotters having 25 to 30 square inches of surface after folding. After the seeds have absorbed water, the blotters should be kept slightly dry, especially on tests of sorghums and Sudan grass.

Rolled towel tests are indicated for corn. Rolls placed in the upright position are preferred, and not more than 50 seeds should be placed in towels 11 by 14 inches in size. Care should be taken not to keep tests of corn too wet.

Soil or sand is indicated as an alternate substratum for wheat, barley, rye, oats, corn, sorghum, and Sudan grass. Waxed cardboard soil boxes 4½ by 4½ by 1½ inches in size are satisfactory for all cereals except corn, which should be germinated in boxes 8½ by 8½ by 1¾ inches in size. In no case should more than 50 seeds of any one kind be put in these containers, making eight replicates for a complete test of 400 seeds.

Small-seeded grasses.—These are usually placed in covered Petri dishes, although top-of-blotter tests are indicated as an alternate substratum for a few kinds. Top-of-blotter tests should not be used if (1) a long test period is required and (2) potassium nitrate is specified.

No more than 100 seeds should ever be placed in a 100- or 120-mm. Petri dish or on top of a blotter 4¾ by 6 inches in size. Seeds as large as Rescue grass should not be spaced any closer than 50 seeds in a 100-mm. Petri dish.

SEEDLING INTERPRETATION

The plumule in the grass family appears above the ground and the first foliage leaf is enclosed in a white sheath or coleoptile, the pointed tip of which is broken open as the leaves elongate. As the seedling grows, permanent roots arise from the base of the first foliage leaf, and other whorls of permanent roots arise from the nodes above. The primary root system is temporary and soon dies.

Seedlings are not usually held in test long enough for analysts to observe any development except that of the primary root system and of the first foliage leaf and coleoptile. Since the grass cotyledon serves as the food-absorbing organ, decay of any of its parts may result in weakened and abnormal seedlings.

A perfect grass seedling should have a well-developed primary root system, an intact cotyledon or scutellum, seed free from serious decay, and long, well-developed green leaves within the coleoptile. One or more leaves may have broken through the coleoptile by the end of the test period. Seedlings should not be removed from test until they have developed to a stage whereby the structure, color, and general condition of the plumule and primary root system can be observed. (Figs. 35–43.)

Barley, oats, rye, and wheat.—These four cereals exhibit practically the same growth pattern, although the speed of germination varies with the kinds. Preliminary counts on wheat, barley, or rye should not be made before the fourth to fifth day of test, and on oats before the fifth to sixth day. Since the roots emerge first, analysts may be tempted to remove seedlings before the condition of the shoot can be determined. One advantage of the sand or soil test on cereals is that all seedlings can be left for one final evaluation, at which time they have developed to a stage where their essential structures may be easily seen. The soil test is particularly desirable as an aid in evaluating frost-damaged oats and mechanically injured rye (figs. 35, 36, 37).

Seedlings of barley, oats, rye, and wheat are to be regarded as normal if they have: (1) At least one primary or seminal root, but preferably two or three seminal roots, provided the shoot is well developed and the grain is not badly decayed; (2) well-developed leaves, green in color, and long enough to extend more than half way up into the sheath or coleoptile at the time the seedling is evaluated; (3) spiral twisting or bending of the shoot, provided it is green in color, has normal length, and is not frost damaged; and (4) slight infection by fungi, provided none of the essential seedling structures have been damaged.

Abnormal seedlings are those that have: (1) No primary root; (2) only one or two short or spindly seminal roots which are usually accompanied by weakened shoots and decayed grains; (3) no green leaves, but only the white sheath or coleoptile formed, which may or may not be grainy, spirally twisted, split, or shortened; (4) a shortened shoot, extending no more than one-half the way up through the coleoptile; (5) a thin, spindly, or watery shoot usually accompanied by weak root development and decayed grains; (6) badly shattered or longitudinally split leaves, with or without splitting of the coleoptile; (7) thickened and shortened shoot (leaves and coleoptile), often the result of overtreatment of seed with chemicals; (8) decayed

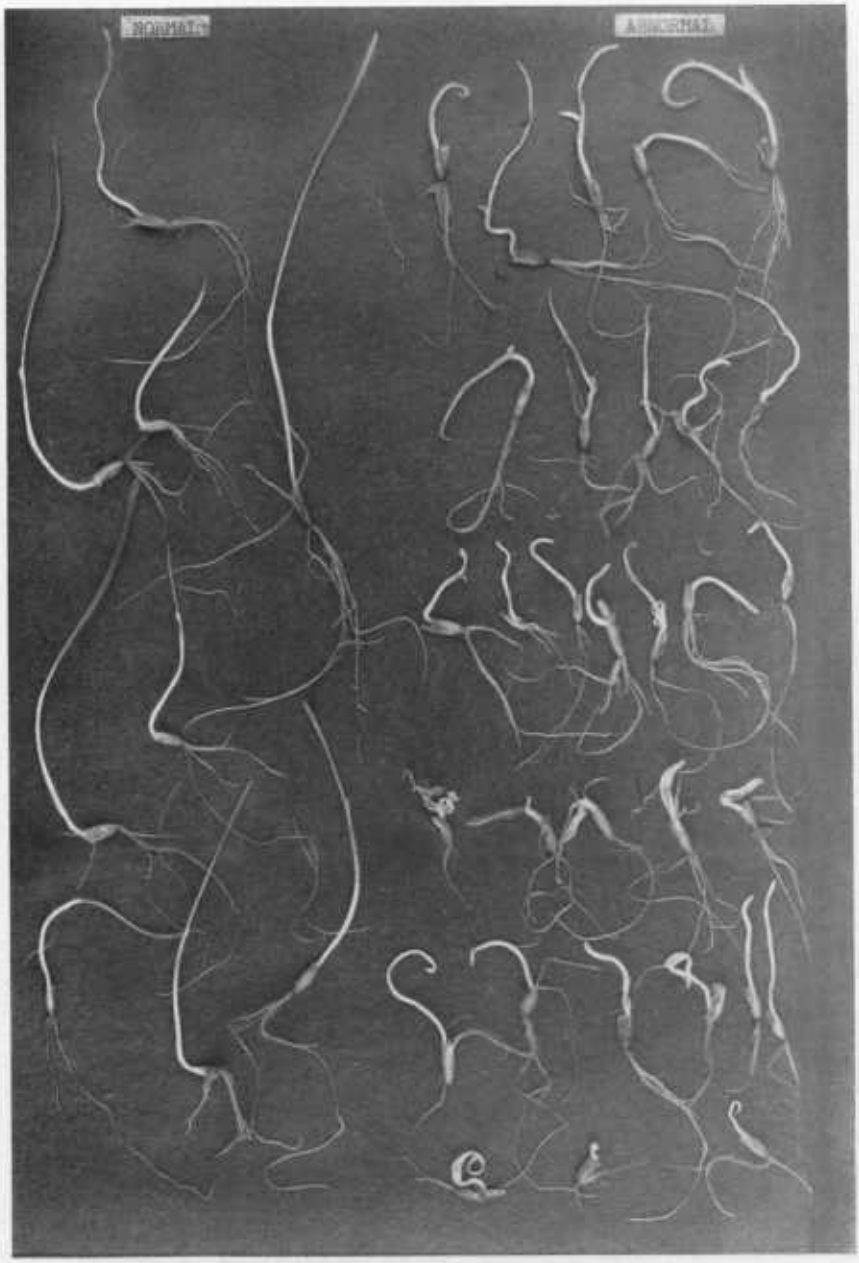

FIGURE 35.—Oats (*Avena sativa*). Normal and abnormal seedlings (exhibiting frost injury) from 10-day tests in towels.

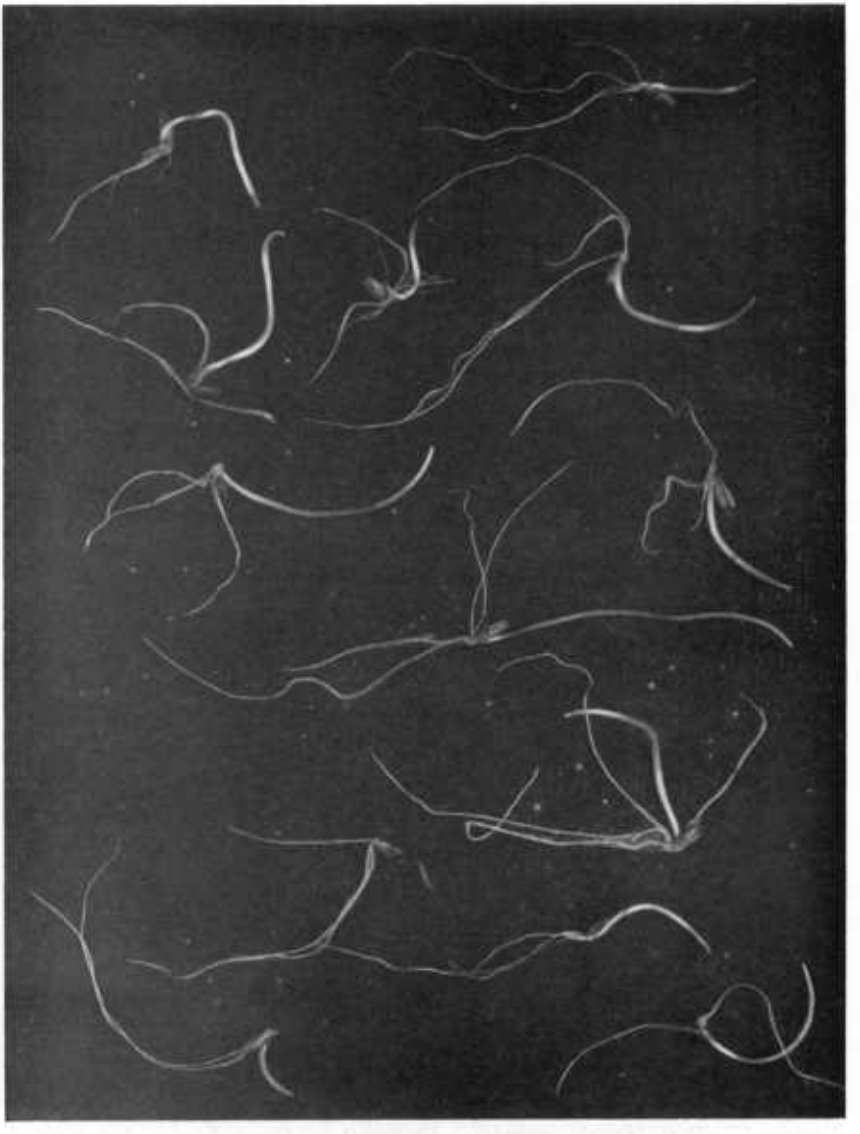

FIGURE 36.—Rye (*Secale cereale*). Normal seedlings from 7-day tests in towels.

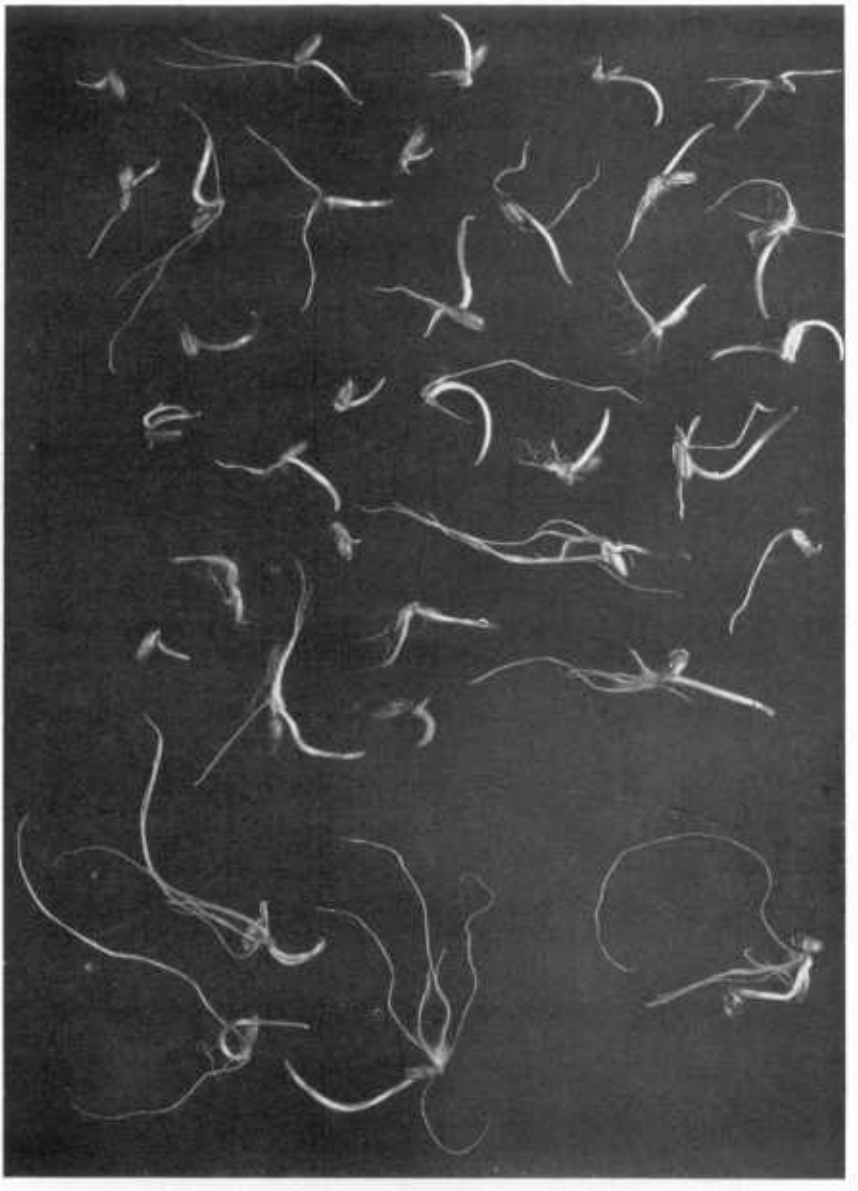

FIGURE 37.—Rye (*Secale cereale*). Abnormal seedlings from 7-day tests in towels.

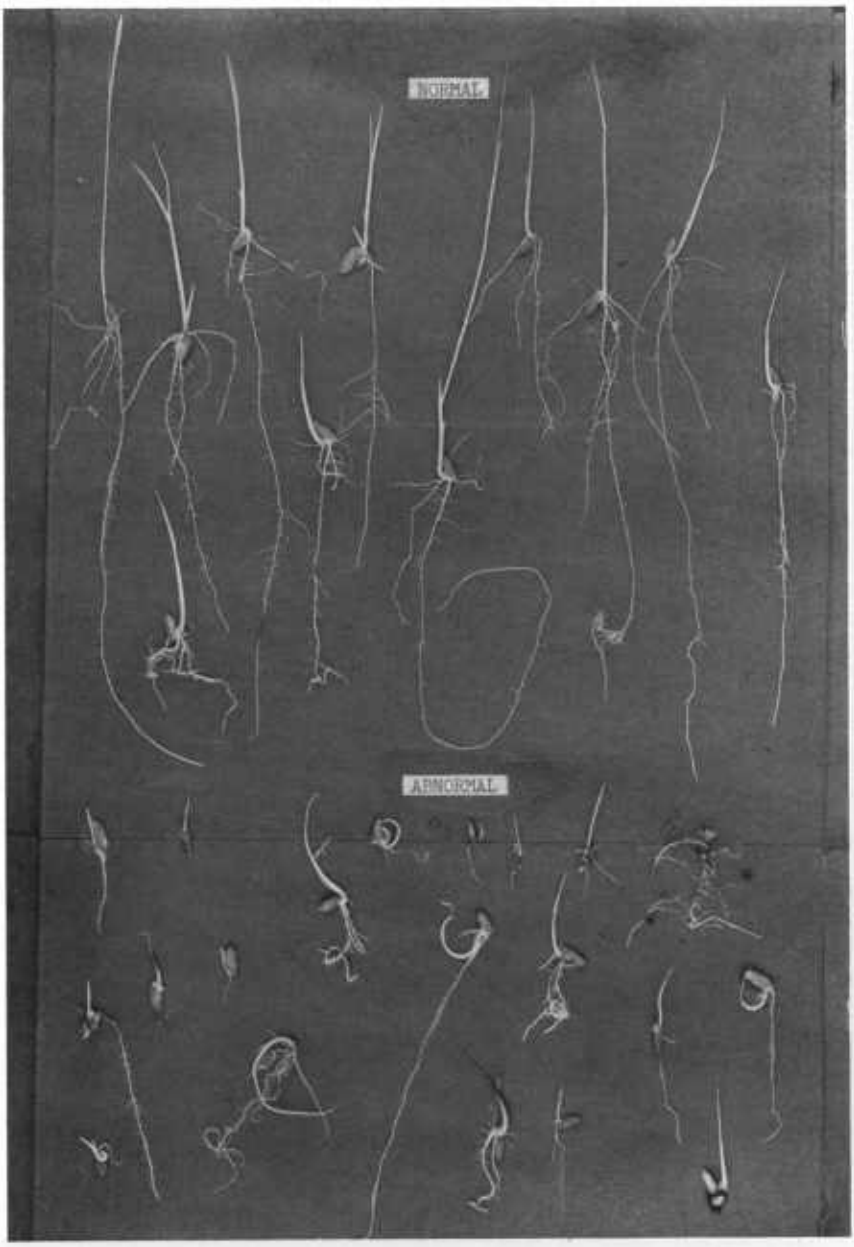

FIGURE 38.—Rice (*Oryza sativa*). Normal and abnormal seedlings from 14-day tests in towels.

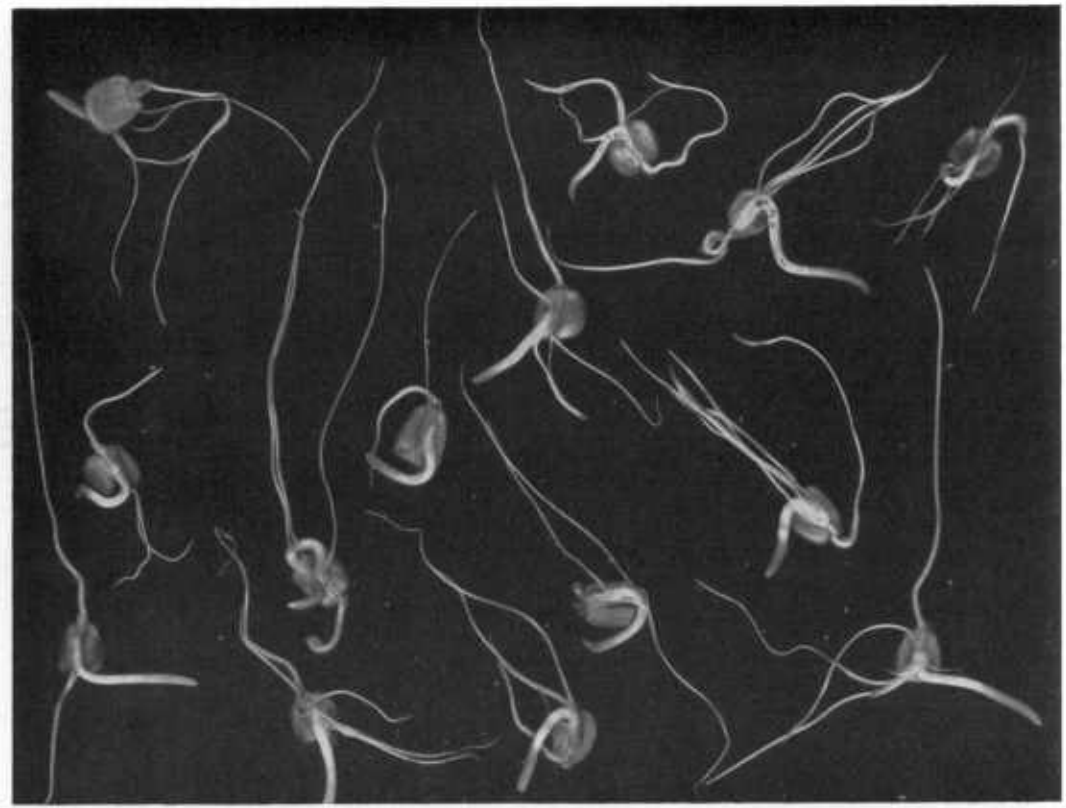

FIGURE 39.—Corn (*Zea mays*). Normal seedlings from 7-day tests in towels.

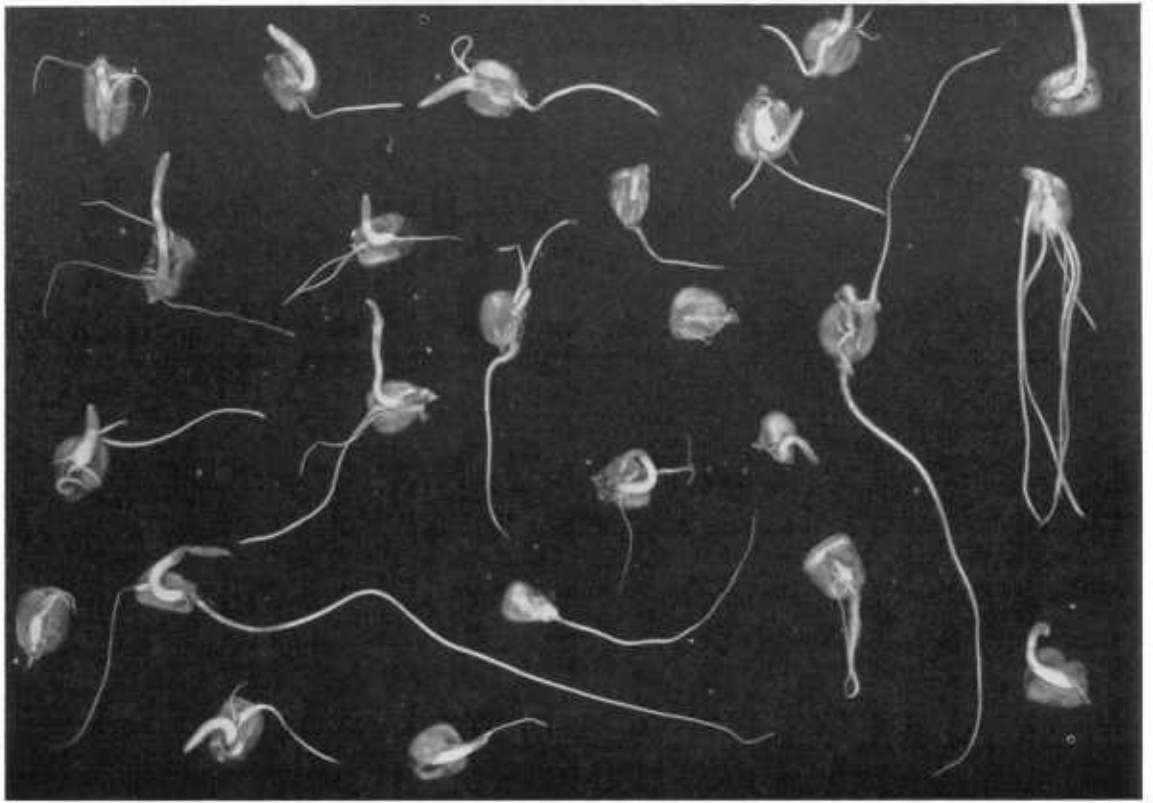

FIGURE 40.—Corn (*Zea mays*). Abnormal seedlings from 7-day tests in towels.

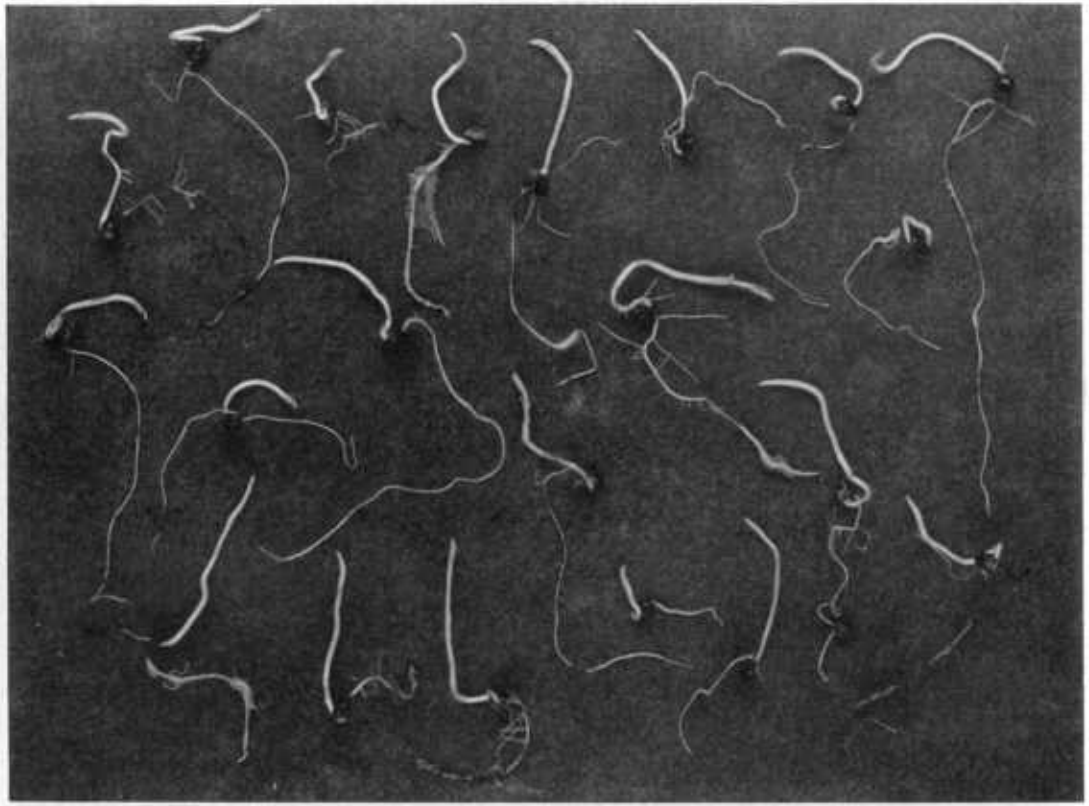

FIGURE 41.—Sorghum (*Sorghum vulgare*). Normal seedlings from 10-day tests in blotters.

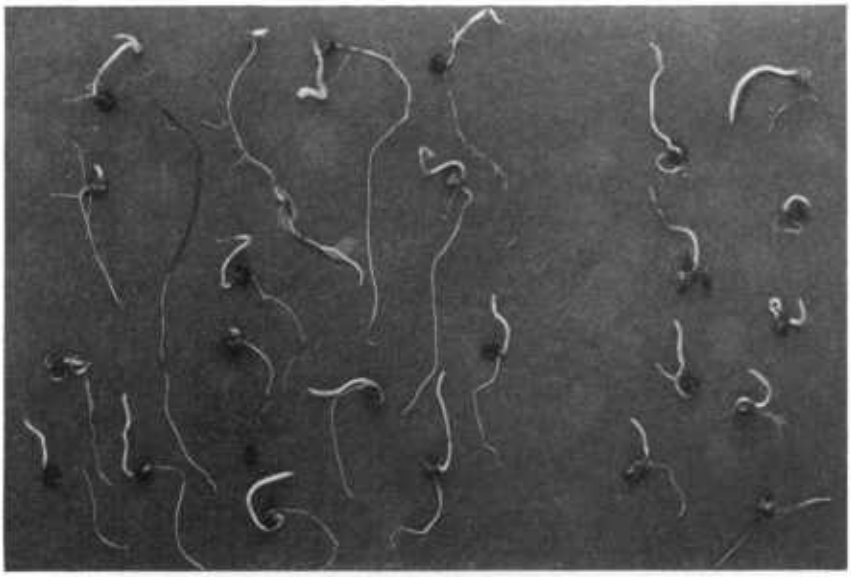

FIGURE 42.—Sorghum (*Sorghum vulgare*). Abnormal seedlings from 10-day tests in blotters.

shoots, provided the decay is not the result of improper test conditions; the shoots usually appear weak and show decay near the point of attachment to the grain which is usually rotten; (9) badly frost-damaged seedlings, characterized by grainy coleoptiles and spirally twisted leaves and coleoptiles; or coleoptile developed without the leaves (in soil tests, some of the longest of the spirally twisted seedlings will appear fairly strong but most of them break off just above the attachment of the plumule and coleoptile to the grain; the shortest of the seedlings do not emerge in soil tests); and (10) various combinations of the above-named abnormal types.

Rice.—Preliminary counts on rice should not be made before at least the fifth to seventh day of test, since the shoots are slower than the roots to develop (fig. 38). Development of fungi on seeds and seedlings may cause extreme variation in test results. More uniform results will be obtained if samples are well spaced and grown in "flooded" sand or soil or placed in upright rolled towel tests, as explained on page 130.

Normal seedlings include those that have: (1) One primary root, usually with numerous lateral roots; several permanent roots arising from the first node should be present if seedlings are not removed until the end of the test; (2) well-developed green leaves which ordinarily should have broken through the coleoptile at the time the seedling is evaluated; and (3) slight infection by fungi, provided none of the essential seedling structures have been damaged.

Abnormal seedlings should be those that have: (1) No roots; (2) a spindly primary root with very little or no branching or secondary development; (3) no green leaves, but only the white sheath or coleoptile; (4) a spindly and sometimes watery shoot which is usually associated with decay of the rice grain; (5) a short leaf, extending

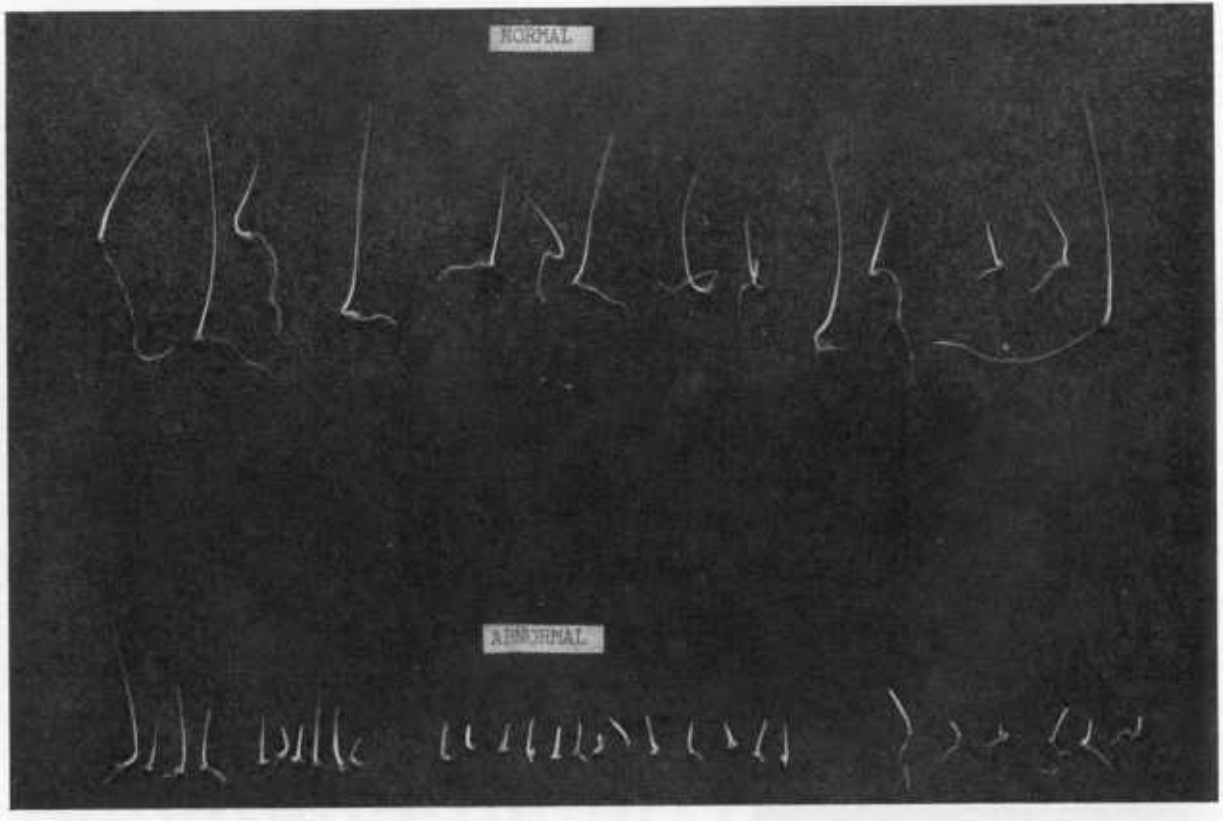

FIGURE 43.—Timothy (*Phleum pratense*). Normal and abnormal seedlings from 10-day tests in Petri dishes.

no more than one-half the distance up through the coleoptile; (6) shattered or longitudinally split plumules with or without splitting of the coleoptile; (7) decayed plumules, provided the decay is not the result of improper test conditions (the plumules usually are weak appearing and show decay near the point of attachment to the grain); and (8) various combinations of the above-named abnormal types.

Corn.—Preliminary counts should usually be made on the fourth day of test or samples may be left for a single count when soil or sand tests are made. (Figs. 39, 40.)

Normal seedlings include those that have: (1) One primary root, usually with secondary roots present; (2) no primary root, but with at least two vigorous secondary roots, provided the grain is not badly decayed, and the shoot is well developed; (3) well-developed green leaves, usually broken through the coleoptile by the end of the test period; (4) twisted and curled shoots bound by the tough seed coat, provided the shoot is not decayed; and (5) slight infection by fungi, provided none of the essential seedling structures have been damaged.

Abnormal seedlings include those that have: (1) No primary or secondary roots; (2) no primary roots but small and weak secondary roots; (3) no plumule, but only the white sheath or coleoptile; (4) a shortened plumule, extending no more than one-half the way up through the coleoptile; (5) a thickened and shortened shoot; often the result of overtreatment of seed with chemicals; (6) a spindly and pale shoot usually associated with moldy seeds; (7) albino (entirely white) seedlings, which will not develop into plants because of lack of chlorophyll; (8) shattered or longitudinally split leaves, with or without splitting of the coleoptile; (9) decayed shoots, provided the decay is not the result of improper test conditions (the plumules usually appear weak and show decay near the point of attachment to the grain and the scutellum is usually rotten); and (10) various combinations of the above-named abnormal types.

Sorghum and Sudan grass.—Preliminary counts should not be made until the fourth or preferably the fifth day of test. It is desirable that only a final count be made for soil and sand tests. (Figs. 41, 42.) Development of fungi on seeds and seedlings may cause extreme variation in test results. More uniform results will be obtained if (1) the seeds are widely spaced in blotter tests, (2) the substratum is kept on the "dry" side, or (3) the seeds are tested in soil or sand.

Normal seedlings include those that have: (1) One primary root, usually with well-developed secondary roots and root hairs if left for final counts in soil tests; (2) well-developed, green leaves, usually broken through the coleoptile by the end of the test period; (3) slight infection by fungi, provided none of the essential seedling structures have been damaged; and (4) red coloration on the roots and on the coleoptile of the shoot, caused by natural pigments, provided the seedling is otherwise normal.

Abnormal seedlings include those that have: (1) No roots; (2) a weak, spindly, and usually shortened primary root, which is often associated with decay of the grain; (3) no plumule, but only the white sheath or coleoptile; (4) a shortened plumule, extending no more than one-half the way up through the coleoptile; (5) a spindly and pale plumule, usually associated with moldy seeds; (6) shattered and longitudinally split plumules, with or without splitting of the coleop-

tile; (7) decayed plumules, provided the decay is not the result of improper test conditions (the plumules usually appear weak and show decay near the point of attachment to the grain which is usually rotten); and (8) various combinations of the above-named abnormal types.

Grasses and millets.—It is frequently necessary to use a hand lens for close observation of abnormal types on the small-seeded grasses and millets. (Fig. 43.)

Normal seedlings include those that have: (1) A well-developed primary root, usually with root hairs; (2) a well-developed green plumule which has usually broken through the coleoptile by the end of the test period; (3) slight infection by fungi, provided none of the essential seedling structures have been damaged; (4) spirally coiled roots held within the tightly enveloping glumes as in certain samples of Bermuda grass; and (5) poor root development resulting from injury caused by use of a potassium nitrate solution; however, if many roots are affected, a retest should be made on top of soil in closed Petri dishes.

Abnormal seedlings include those that have: (1) No root; (2) a weak, stubby, or spindly root, usually short and watery, associated with a decayed seed; (3) no plumule, but only the white sheath or coleoptile which is often short and thick; (4) a shortened plumule, extending only one-half the distance up through the coleoptile; (5) a spindly plumule, usually pale and watery; (6) a shattered longitudinally split plumule with or without splitting of the coleoptile; (7) decayed plumules, provided the decay is not the result of improper test conditions (the plumules usually appear weak and show decay near the point of attachment to the seed, which is usually rotten); and (8) various combinations of the above-named abnormal types.

LEGUMINOSAE (LEGUME OR PEA FAMILY)

KINDS OF SEED

Alfalfa—*Medicago sativa.*
Beans:
- Adzuki—*Phaseolus angularis.*
- Asparagus—*Vigna sesquipedalis.*
- Garden or field—*Phaseolus vulgaris.*
- Horse or broad—*Vicia faba.*
- Lima—*Phaseolus lunatus* var. *macrocarpus.*
- Mung—*Phaseolus aureus.*
- Runner—*Phaseolus coccineus.*
- Velvet—*Stizolobium deeringianum.*

Beggarweed—*Desmodium tortuosum.*
Chickpea—*Cicer arietinum.*
Clovers:
- Alsike—*Trifolium hybridum.*
- Alyce—*Alysicarpus vaginalis.*
- Berseem—*Trifolium alexandrinum.*
- Bur—*Medicago hispida.*
- Bur, spotted—*Medicago arabica.*
- Cluster—*Trifolium glomeratum.*
- Crimson—*Trifolium incarnatum.*
- Ladino—*Trifolium repens.*
- Lappa—*Trifolium lappaceum.*
- Large hop—*Trifolium procumbens.*
- Persian—*Trifolium resupinatum.*
- Red—*Trifolium pratense.*

Clovers—Continued.
Sour—*Melilotus indica.*
Strawberry—*Trifolium fragiferum.*
Sub—*Trifolium subterraneum.*
Suckling (small hop)—*Trifolium dubium.*
Sweet—*Melilotus alba* and *M. officinalis.*
White—*Trifolium repens.*
Cowpea—*Vigna sinensis.*
Crotalaria—*Crotalaria intermedia, C. juncea, C. lanceolata, C. spectabilis,* and *C. striata (mucronata).*
Kudzu—*Pueraria thunbergiana.*
Lespedeza:
Common and Kobe—*Lespedeza striata.*
Korean—*Lespedeza stipulacea.*
Sericea or Chinese—*Lespedeza cuneata.*
Siberian—*Lespedeza hedysaroides.*
Lupine:
Blue—*Lupinus angustifolius.*
White—*Lupinus albus.*
Yellow—*Lupinus luteus.*
Medic, black—*Medicago lupulina.*
Peanut—*Arachis hypogaea.*
Peas:
Field—*Pisum sativum* var. *arvense.*
Garden—*Pisum sativum.*
Rough pea—*Lathyrus hirsutus.*
Sainfoin—*Onobrychis viciaefolia.*
Sesbania—*Sesbania exaltata.*
Soybean (field and vegetable)—*Glycine max.*
Trefoil:
Big—*Lotus uliginosus.*
Birdsfoot—*Lotus corniculatus.*
Vetch:
Common—*Vicia sativa.*
Hairy—*Vicia villosa.*
Hungarian—*Vicia pannonica.*
Monantha—*Vicia articulata (V. monantha).*
Narrowleaf—*Vicia angustifolia.*
Purple—*Vicia atropurpurea.*
Woollypod—*Vicia dasycarpa.*

OCCURRENCE AND LABORATORY TREATMENTS FOR OVERCOMING DORMANCY

Dormancy may be encountered in the laboratory testing of clovers, horse or broad beans, and peanuts, but it is unlikely that it will occur in any of the other legumes listed herein. Dormant legume seeds may absorb water and swell but still fail to germinate. Temperature is the important treatment in the above-mentioned kinds. Impermeable seed coats may occur in all the legumes except peanuts, but scarification treatments to overcome this type of dormancy are not included in the rules for seed testing.

Clovers.—Of the clovers listed in the rules, all except Alyce clover may exhibit primary dormancy or be thrown into secondary dormancy if the germination temperature is too high. In no case should the temperature ever exceed 20° C. and 17° to 18° C. is most desirable. If dormancy is still encountered, the seeds should be placed at 15° C.

Conversely, high temperatures are necessary for the germination of Alyce clover, although as the seed ages it becomes tolerant of lower temperatures. The rules specify 35° C. as the germination temperature and it is imperative that this temperature be maintained when freshly harvested seed is tested, as dormancy may be present at lower temperatures, even at 30°. At the end of the 20-day test period a

few swollen seeds are usually present. The swollen seeds should be carefully pierced with a needle or scalpel (care being taken not to injure the embryo) and then placed back in test for 5 additional days.

Broad bean.—Horse or broad bean should never be germinated at temperatures above 20° C. and 17° to 18° C. is most desirable. If dormancy is encountered, the seeds should be placed at 10° C. for 3 days and then moved to 20° C. for the duration of the test period.

Peanuts.—There is no provision in the rules for the laboratory treatment of dormant peanuts. There are data to show that dormancy does occur in peanuts, that the extent varies with the varieties, and that moist storage at temperatures as high as 30° to 40° prior to testing favor the germination of freshly harvested seed. A few tests made in the Federal laboratory at Beltsville on dormant peanuts indicate that a constant temperature of 30° C. may be a satisfactory laboratory treatment for overcoming this condition.

HARD SEEDS

In blotter tests, the percentage of hard seeds must be determined for all kinds of legumes except peanuts. In soil and sand tests, it is usually necessary to sieve the substratum in order to determine the presence and number of hard seeds. If swollen seeds are present they may be removed, placed in towel tests, and evaluated after 5 additional days, as provided in the rules. It is impractical to try to recover hard seeds of the smaller legumes such as clovers from soil and sand tests.

SUBSTRATA, SPACING, AND SPECIAL TREATMENTS

The choice of substrata, particularly for the large-seeded legumes, may cause confusion as to which to use. An artificial medium is usually preferred in laboratories handling large volumes of work, although it is impossible for an analyst properly to interpret the results of the germination test without being familiar with the seedling development of the various kinds in soil or sand. The artificial substrata listed for legumes are rolled towels, flat folded towels, folded blotters, and creped cellulose paper wadding. Soil and sand are listed as a choice of substratum on those kinds which may be particularly troublesome to interpret.

Rolled towel tests.—More satisfactory results will be obtained if rolled towel tests are placed in an upright or slanted position during the germination period. The small horse beans can be successfully germinated in upright rolled towels, although this is not indicated in the rules. In the use of paper towels, cut to an approximate size of 11 by 14 inches, no more than the following number of seeds should be placed in each roll: Mung beans, 100; field, garden, runner, adzuki, asparagus, small horse beans, and small lima beans, 50; field peas, garden peas, chickpeas, cowpeas, lupines (blue, white, yellow), peanuts, and soybeans (field and vegetable), 50; and large lima beans and velvet beans, 25. A minimum of 400 seeds should be tested even though this may require as many as 16 replicates per test.

Since the large-seeded legumes will absorb a great deal of moisture during the first stages of germination, the towels should be saturated with water at the time the tests are set up. After the seeds have absorbed water it will not be necessary for the towels to be so wet. In fact, it is best that the towels be only moderately damp, having only

enough moisture to maintain seedling growth without excessive drying, in order to discourage decay and growth of fungi. Observation of the moisture content of the rolls should be made regularly, preferably daily, and water added when needed.

Folded towel tests.—Flat, folded towels are listed for the following kinds of legumes: White and yellow lupines, kudzu, rough peas, sesbania, vetches, and bur clovers. It is entirely possible that upright rolled tests could be used successfully on kudzu, rough peas, sesbania and vetches. Because of the spherical shape and small size of most of these kinds, it would be necessary to guard against the loss of seeds by rolling and the accumulation of excess moisture in the rolls. Advantages observed on common vetch include faster germination and easier interpretation.

Paper towels, 11 by 14 inches, folded to 5½ by 7 inches in size are very satisfactory for the folded towel tests. The following numbers of seeds should be placed in each towel: Sesbania and bur clovers, 100; kudzu, rough pea, and vetches, 50. If white or yellow lupines are germinated in flat towels, they should be placed not more than 50 seeds to an area approximately 11 by 14 inches.

In addition to the first and final count on kudzu, rough peas, vetches, and bur clovers, one or two intermediate counts, spaced 2 or 3 days apart, should be made. At the time of the preliminary counts all decayed seeds should be removed and recorded.

Folded blotters.—Folded blotters are listed for the following kinds of legumes: Beggarweed; crotalarias; lespedezas; sainfoin; alfalfa; clovers; black medic; and trefoil. Both flat-folded towels and blotters are listed for bur clover because the seed is sometimes received in the seed pod, in which case a towel will afford more space for the seeds and will also supply more initial moisture. The following numbers of seeds should be placed in each blotter folded to size 4¾ by 6 inches: Beggarweed, lespedeza, alfalfa, clovers, black medic, and trefoil, 100; and crotalaria, 50 or 25, depending on the size of the seed and the amount of mechanical breakage. Sixteen replicates of 25 seeds each are necessary for proper spacing of some samples of crotalaria.

It will be necessary to make more than a first and final count on tests of more than 7 days' duration. Counts at 2- or 3-day intervals during the test period are usually satisfactory, although such samples as scarified crotalarias should be checked daily after the first count.

Creped cellulose paper wadding.—An alternate substratum for the large horse or broad beans, lima beans, and velvet beans is creped cellulose paper wadding (0.3-inch thick) covered with a single thickness of blotter through which holes are punched for the seeds which are pressed for about ½ their length into the creped paper wadding. In no case should more than the following number of seeds be placed on an area approximately 9 by 9½ inches in size: Small lima and horse beans, 50; and large lima beans, large horse beans, and velvet beans, 25. Four hundred seeds of each kind must be tested, even though 16 replicates are necessary. Since the spread of fungi is very rapid in creped cellulose wadding, the tests should be examined daily for the presence of decayed seeds, which should be removed and recorded. Preliminary counts can be made or the seedlings may be left in test for the final count only.

Soil and sand.—A combination of soil and sand is listed as an alter-

nate substratum for many kinds of legumes and may also be used in making check tests on any of the kinds in case problems of interpretation arise.

The number of seeds to be placed in each container for test will depend on the size of the seeds and of the containers. The kinds and number of seeds to be placed in large containers (8½ by 8½ by 1¾ inches) are as follows: Large lima beans, adzuki beans, runner beans, asparagus beans, small lima beans, broad beans, chickpeas, cowpeas, blue lupines, peanuts, and field and garden peas, 50; and mung beans, 100. The following kinds and numbers should be placed in small containers (4½ by 4½ by 1½ inches) for test: Crotalaria, 50 or 25 (depending on size and condition of the seed); lespedeza, 100; common vetch, 50; and alfalfa, alsike, berseem clover, crimson clover, ladino clover, red clover, sweetclover, white clover, and black medic, 100.

SEEDLING INTERPRETATION

It is recommended that only the final count be made on all soil and sand tests because it is possible to make a more accurate seedling evaluation when a comparison is made between the strong and weak seedlings. (Figs. 44–56.)

Legume seedlings may exhibit either hypogeous or epigeous growth. In epigeous development as in lima beans, and garden beans, the only underground part of the seedling is the root and the lower part of the hypocotyl. The latter lengthens and appears above the ground carrying the two cotyledons with it. The growth above the cotyledons

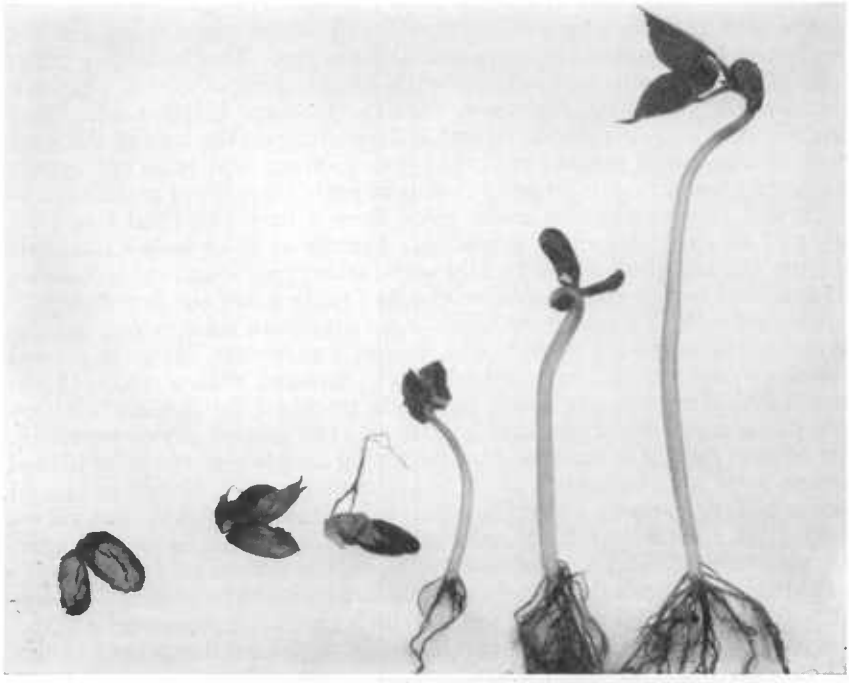

FIGURE 44.—Bean (*Phaseolus vulgaris*). Six seedlings, illustrating from left to right, one decayed, three "other abnormal," one "baldhead," and one normal; from 8-day tests in soil.

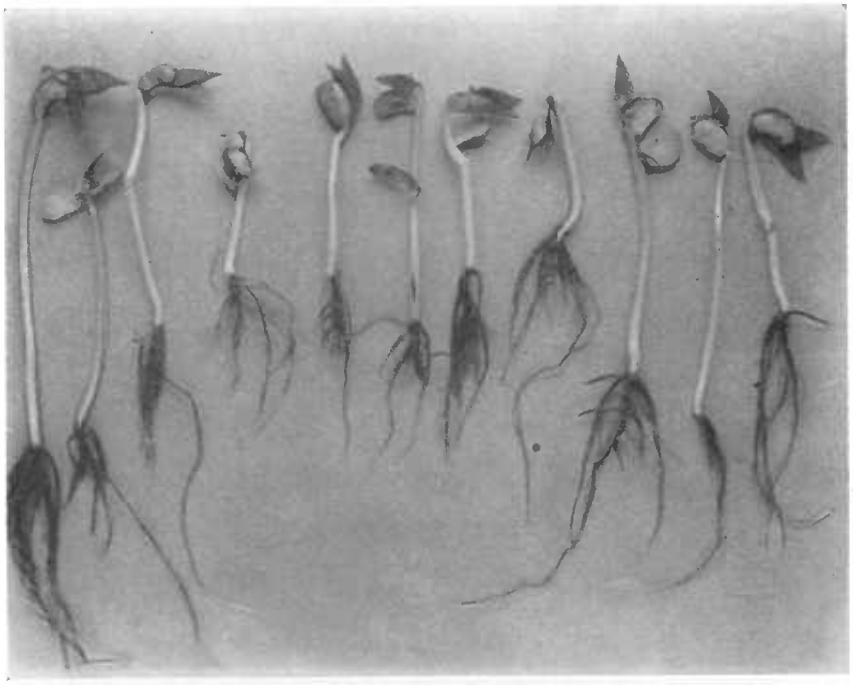

FIGURE 45.—Lima bean (*Phaseolus lunatus* var. *macrocarpus*). Normal seedlings from 9-day tests in sand.

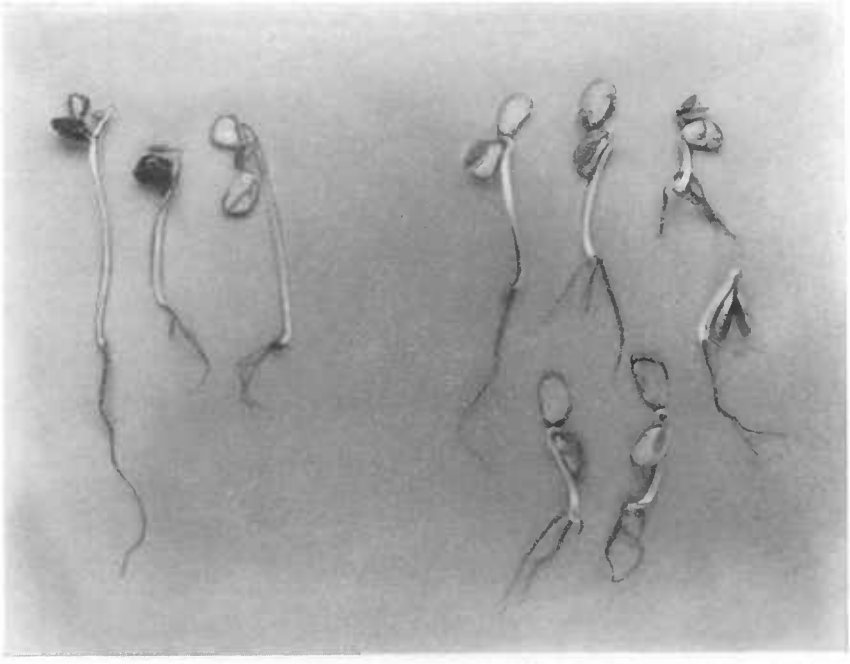

FIGURE 46.—Lima bean (*Phaseolus lunatus* var. *macrocarpus*). Abnormal seedlings from 9-day tests in sand.

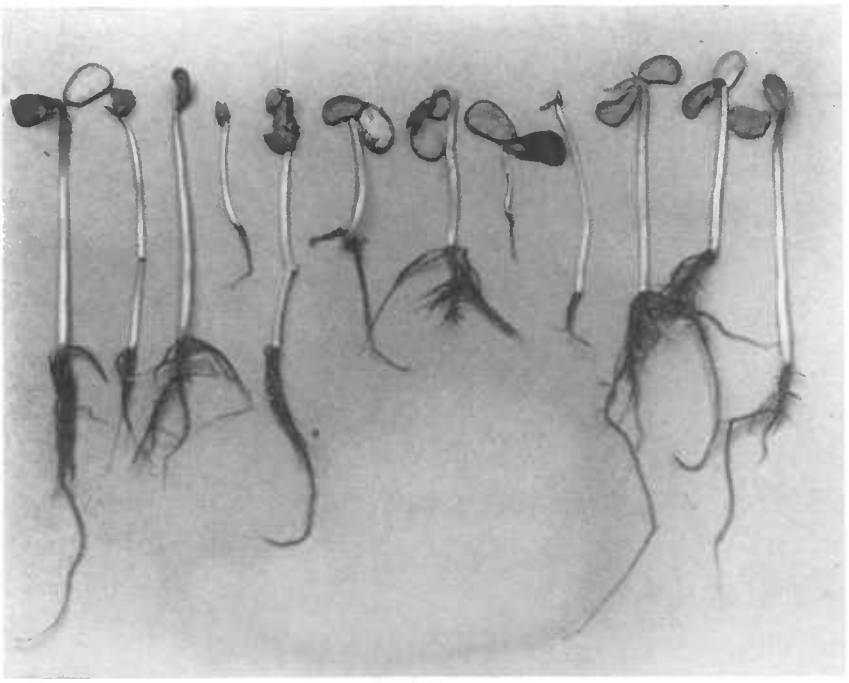

FIGURE 47.—Lima bean (*Phaseolus lunatus* var. *macrocarpus*). "Baldheads," or abnormal seedlings from 9-day tests in sand.

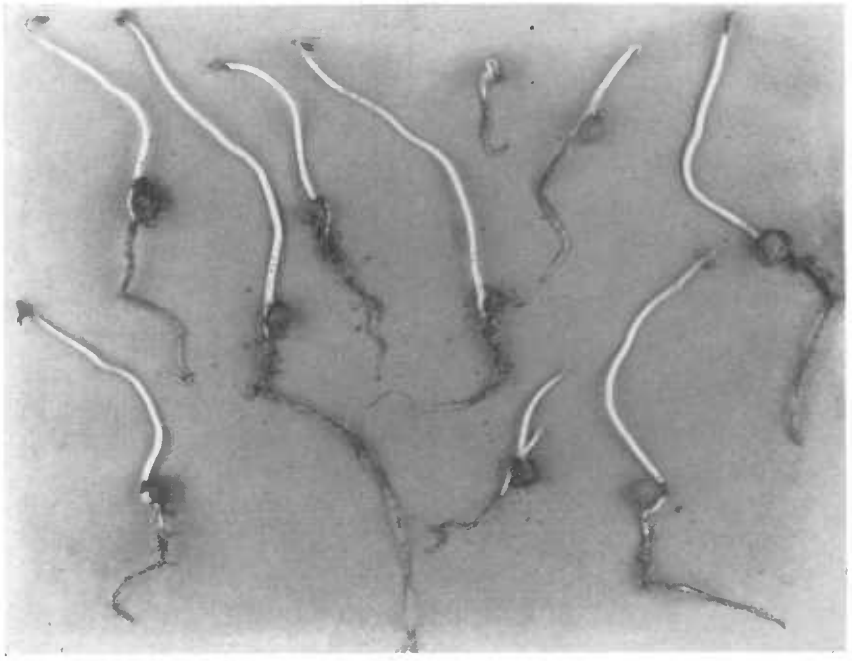

FIGURE 48.—Field peas (*Pisum sativum* var. *arvense*). Normal seedlings from 8-day tests in soil.

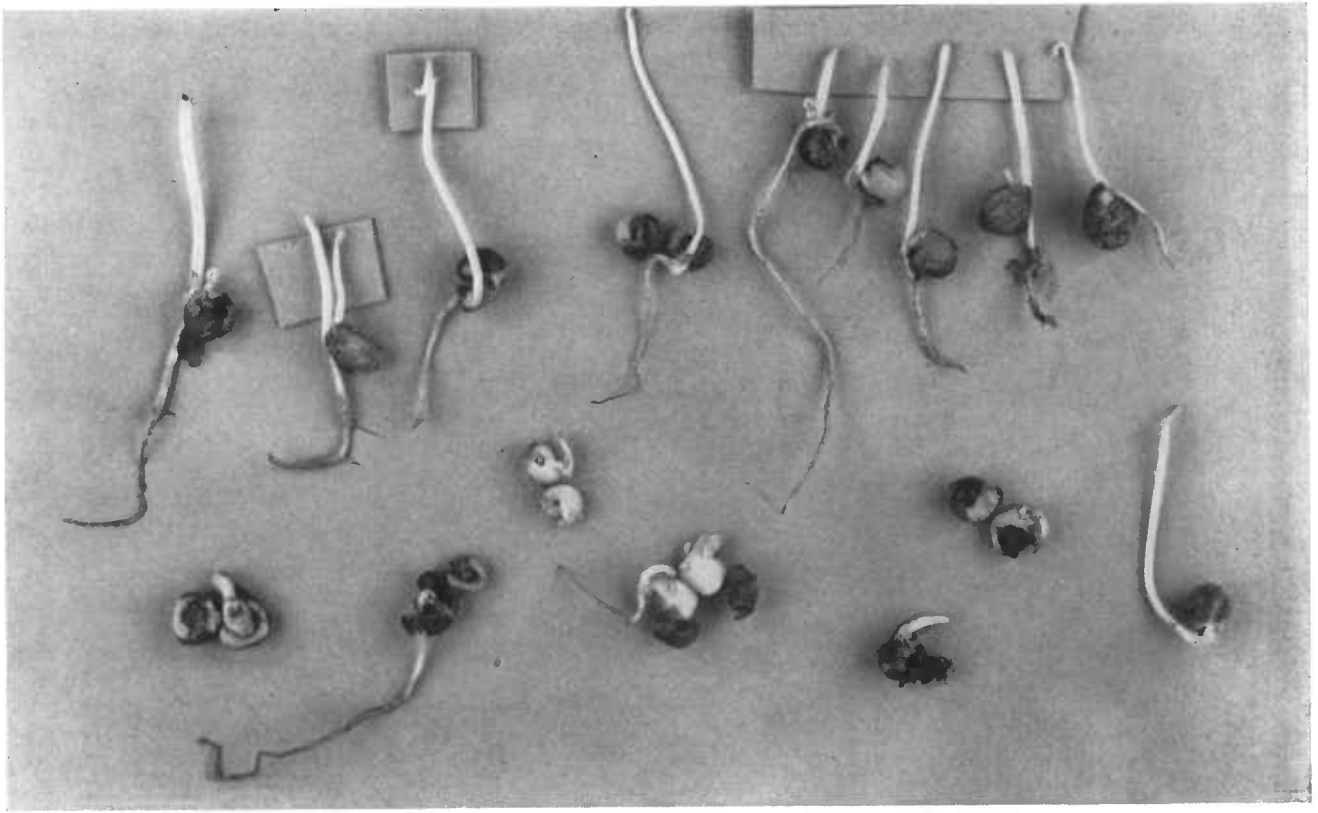

FIGURE 49.—Field peas (*Pisum sativum* var. *arvense*). Abnormal seedlings from 8-day tests in soil.

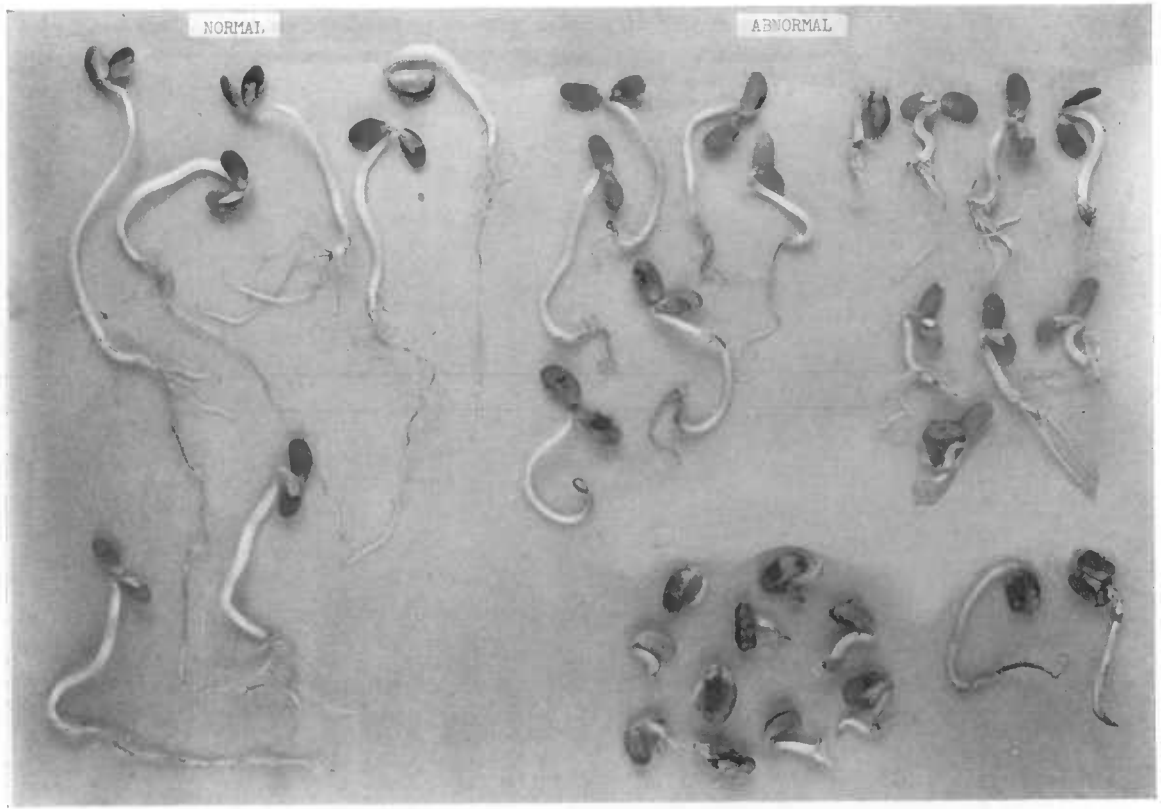

FIGURE 59.—Soybeans (*Glycine max*). Normal and abnormal seedlings from 8-day tests in towels.

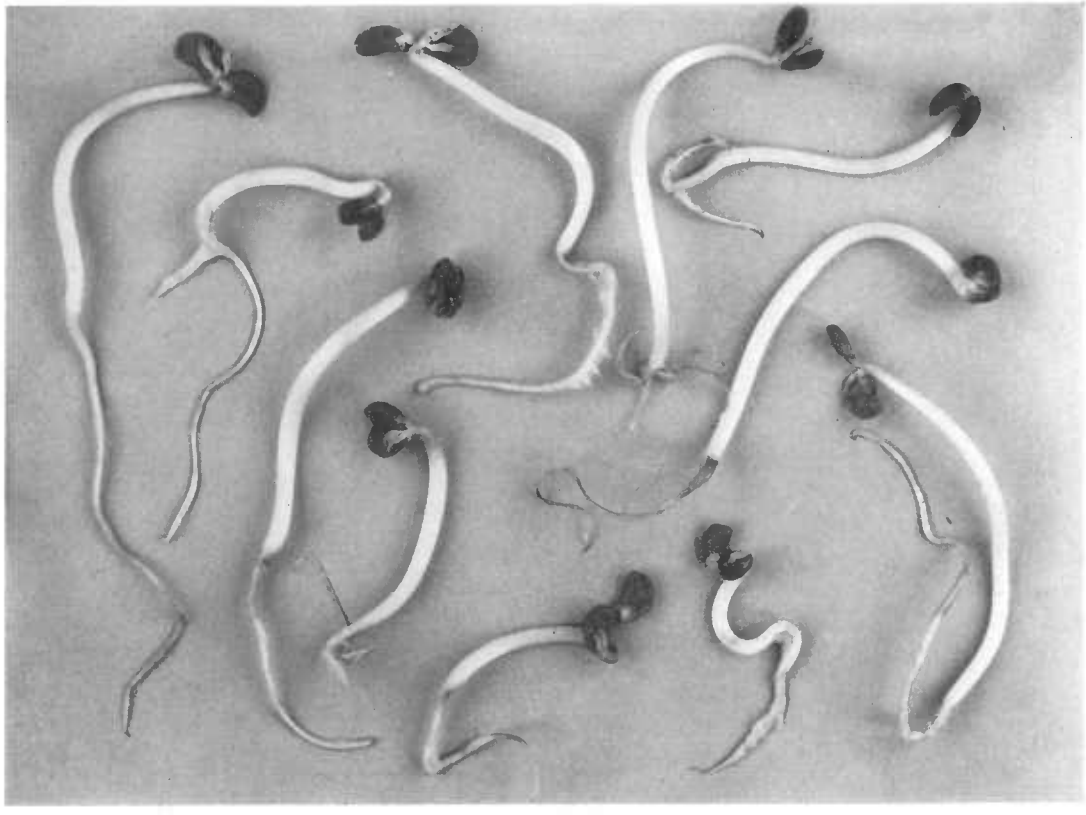

FIGURE 51.—Lupine (*Lupinus angustifolius*). Normal seedlings from 10-day tests in towels.

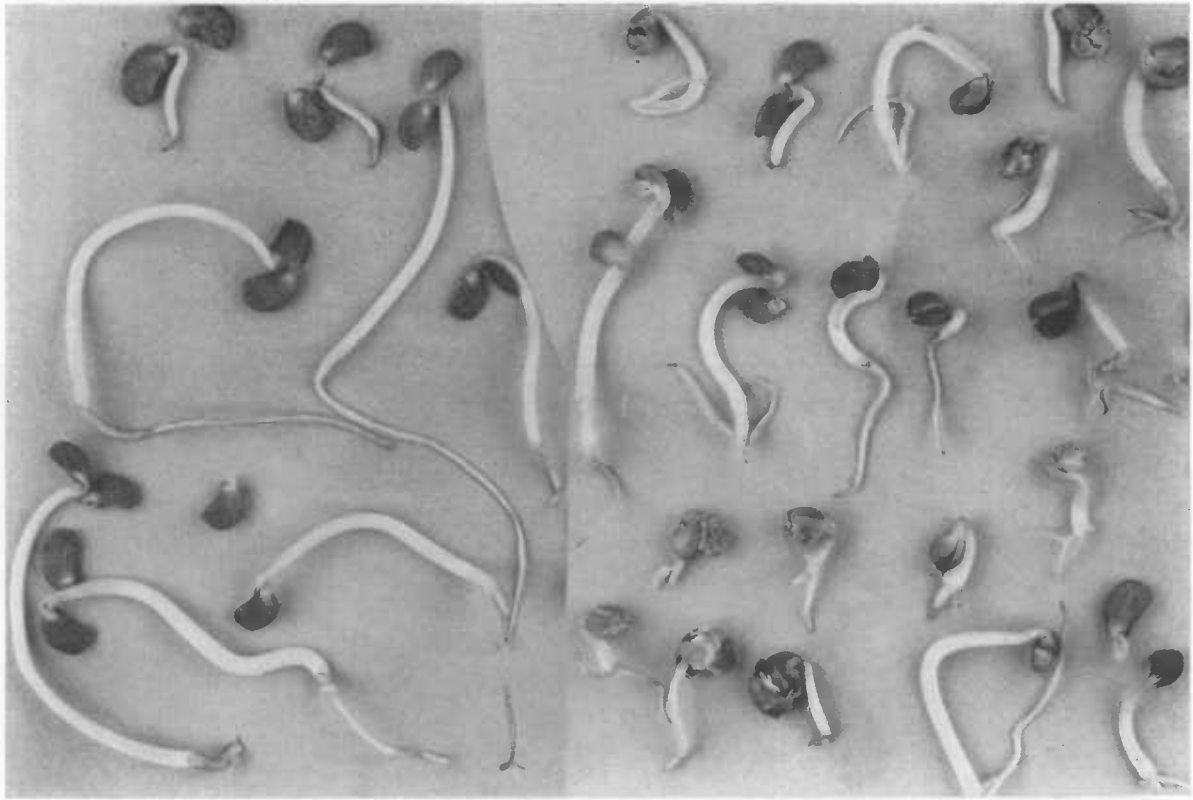

FIGURE 52.—Lupine (*Lupinus angustifolius*). Abnormal seedlings from 10-day tests in towels.

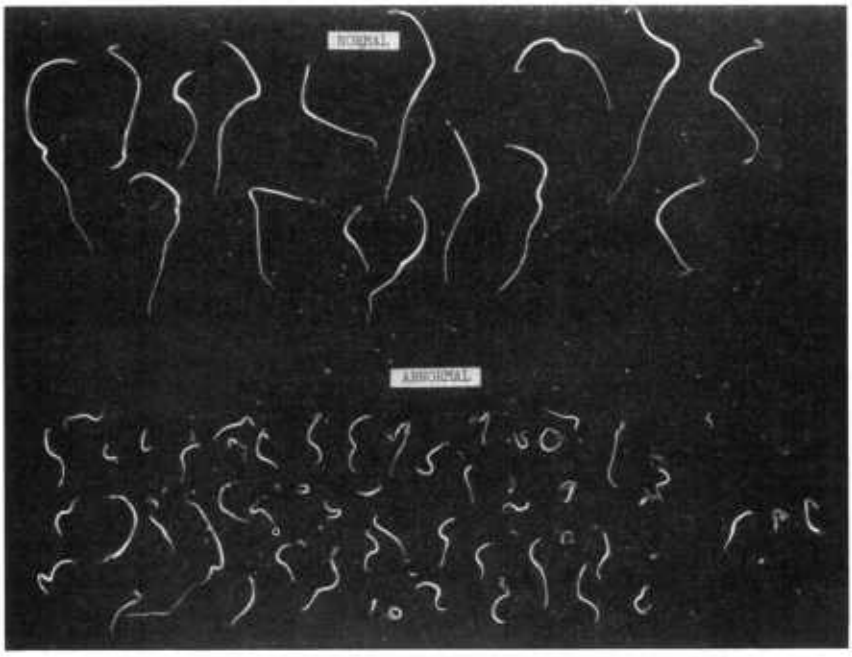

FIGURE 53.—Alfalfa (*Medicago sativa*). Normal and abnormal seedlings from 7-day tests between blotters.

forms the epicotyl consisting of a stem with terminal bud and two primary leaves. In hypogeous development as in peas, the underground parts of the seedling are the root, the very shortened hypocotyl, and the two cotyledons. The epicotyl elongates above the cotyledons and emerges from the ground forming the stem and leaves.

Beans—garden, field, lima, adzuki, mung, and asparagus.—Seedling interpretation for adzuki, mung, and asparagus beans may be considered as being similar to that discussed for garden, field, and lima beans for they all have the same type of epigeous development. (Figs. 44–47.)

If preliminary counts are made before the cotyledons have opened, the analyst must part them manually in order to determine the condition of the primary leaves and the terminal bud. By the end of the germination test, a perfectly normal seedling should have a well-formed root, with or without secondary or adventitious development; a strong, fairly long stem or hypocotyl with two attached cotyledons, and two well-developed first or primary leaves and an intact terminal bud. Injury to the epicotyl is very common on garden, field, and lima beans. Considerable research on the growth and development of these kinds has resulted in a more or less standardized classification of seedlings into normal and abnormal groups for seed-testing purposes. Types of bean seedlings to be regarded as normal are discussed as follows:

1. The seedling must have two primary leaves, or at least one primary leaf, even though one or both cotyledons are absent. The terminal bud must be present in either case.

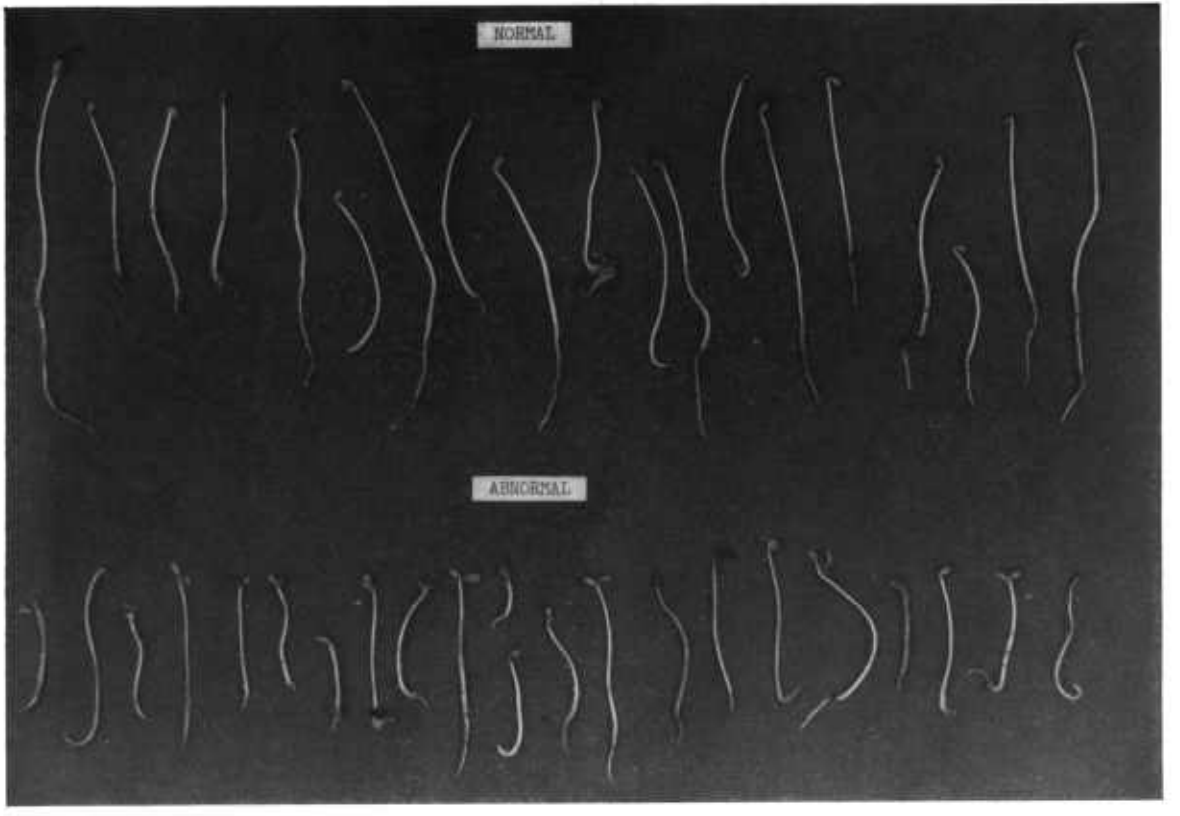

FIGURE 54.—Birdsfoot trefoil (*Lotus corniculatus*). Normal and abnormal seedlings from 7-day tests in soil.

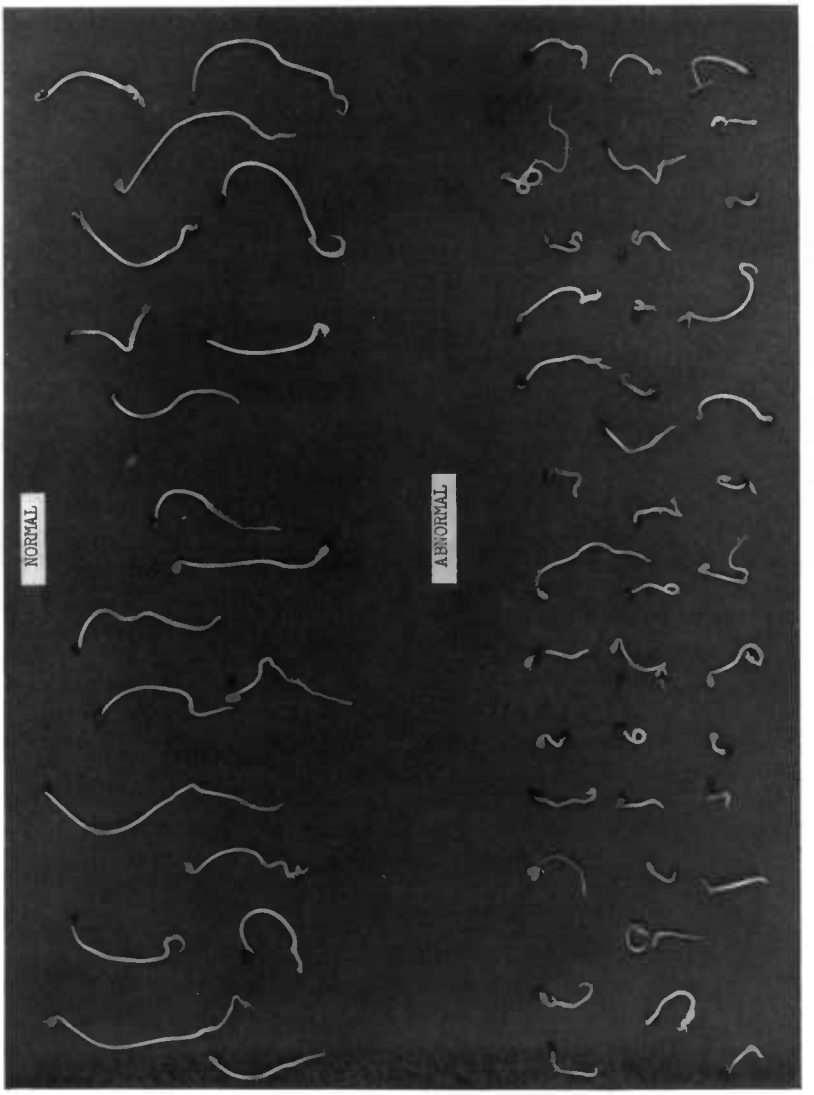

FIGURE 55.—Birdsfoot trefoil (*Lotus corniculatus*). Normal and abnormal seedlings from 7-day tests in blotters.

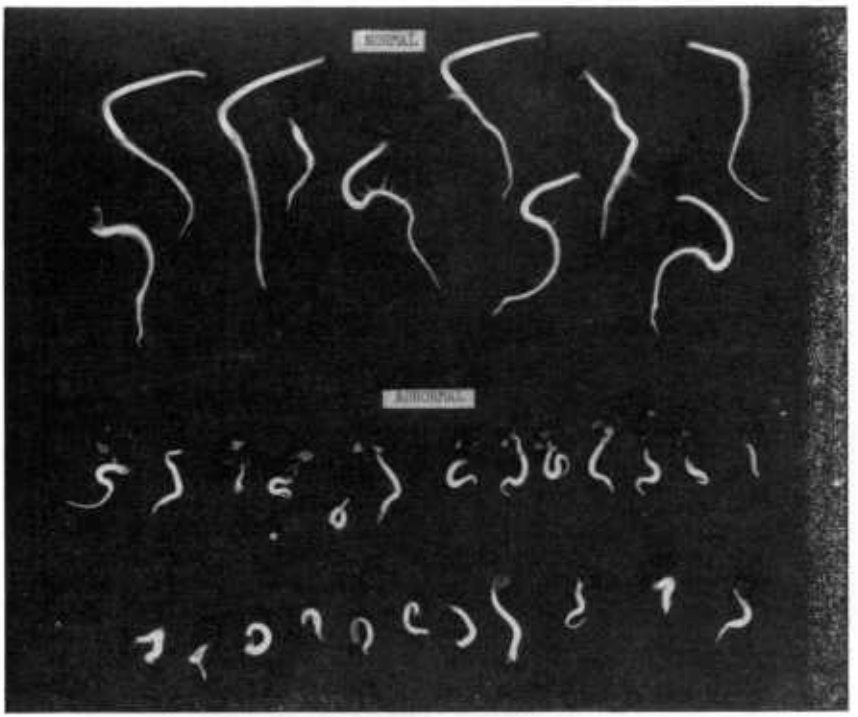

FIGURE 56.—Crotalaria (*Crotalaria spectabilis*). Normal and abnormal seedlings from 8-day tests in blotters.

2. The seedling must have a primary root or a set of adventitious or secondary roots sufficient to anchor it when grown in soil or sand, provided the hypocotyl is not badly shortened.

3. The normal seedling must have a fairly well-developed hypocotyl with no prominent breaks or deep lesions. Healed breaks, sometimes referred to as "knees," are to be considered as normal, provided the seedling is not spindly.

4. Normal seedlings may include those with slight infection from fungi, provided the essential structures have not been seriously damaged and appear to be able to carry on their normal functions at the time of evaluation. If a few seedlings with total or partial decay of the plumule are found, they may be counted as normal, provided the hypocotyl and root are well developed. The plumules on such seedlings usually do not decay when grown under greenhouse conditions where the cotyledons open up naturally and are exposed to a dry environment and sunlight. However, if there are many seedlings with decayed plumules in a test, a retest should be made and such seedlings evaluated cautiously.

5. Spirally twisted and curled root and hypocotyl held within the tough seed coat, causing delayed development; otherwise normal. At the present time, due to lack of data, analysts may count such seedlings as normal, provided the essential parts are present.

Abnormal bean seedlings include those that have: (1) No primary leaves or terminal bud (baldheads); (2) no primary leaves, but with

a terminal bud (snakeheads or partial baldheads); (3) no primary leaves, but terminal bud present and axillary buds in one or both of the cotyledons (partial baldheads); (4) a malformed hypocotyl, which may be characterized by open splits, or appear curled, shortened, or thickened; (5) no primary root or well-developed set of adventitious or secondary roots; and (6) various combinations of the above-named abnormal types.

Some seeds in badly broken samples will be so injured that growth will not occur beyond enlargement of the primary leaves within the swollen cotyledons and the formation of vestiges of root and hypocotyl. Since these do not emerge in a soil test, such growths are referred to as "seeds too broken to grow" or as "splits."

Velvet bean, broad bean, runner bean, chickpea, field pea, garden pea, rough pea, and vetches.—Because of their hypogeous seedling development it will not be necessary to open the cotyledons to observe the condition of the plumule if preliminary counts are made. However, seedlings should not be removed until the epicotyl has broken through the seed coat and erected itself sufficiently so the analyst may discern whether the epicotyl is intact. (Figs. 48, 49.)

By the end of the germination test a perfectly normal seedling should have: (1) A well-formed root, with or without secondary or adventitious development; (2) a strong epicotyl with fairly long stem; (3) a well-developed epicotyl with the leaves and terminal bud intact; and (4) the seedling should not be broken away from the cotyledons.

Normal seedlings include those that have: (1) A primary root or a set of secondary or adventitious roots sufficient to anchor the seedlings when grown in soil or sand, provided the stem is not badly shortened; (2) a fairly well-developed stem with no prominent breaks or deep lesions which might interfere with the conducting tissues; (3) a terminal bud with at least one first leaf and an intact growing point; (4) two shoots, provided the seedling appears vigorous and at least one of the shoots has a normal epicotyl and root; and (5) slight infection by fungi, provided the essential seedling parts have not been seriously damaged and appear to be able to carry on their normal functions at the time of evaluation.

Abnormal seedlings include those that have: (1) No primary root or well-developed secondary or adventitious roots; (2) a malformed stem, which may be characterized by severe open splits, and curled, shortened, or thickened development; (3) no epicotyl, or an epicotyl without the terminal bud; (4) two shoots, both of which appear weak and spindly, often partially broken away from the cotyledons; (5) decayed seedlings caused by the spread of decay from the cotyledons of the developing seedling; and (6) various combinations of the above-named abnormal types.

Severe mechanical breakage of certain kinds of seeds such as field and garden peas and vetches may result in the development of mere vestiges of seedlings. The embryonic plant may be almost broken away from the cotyledons resulting in only slight development of the different organs. Since such growths do not emerge in soil tests, the seeds are regarded as "too broken to grow."

Severe weevil infestation is frequently found in field peas, which often prevents development except for mere vestiges of seedlings. Sometimes the cotyledons have been devoured to the extent that no

food supply is left for the developing seedling. Such insect injury can be easily detected by examination of the cotyledons.

Cowpeas, lupines, peanuts, and soybeans.—Because of the epigeous seedling development, the cotyledons in this group must be parted manually in order to determine the condition of the primary leaves, and the growing point, if counts are made before the cotyledons have opened. This is very necessary on lupines and peanuts, since mechanical breakage appears to interfere with the leaf development on these more than it does on soybeans and cowpeas where the injury appears to be confined to the hypocotyl and roots rather than to the epicotyl. However, weevil damage to cowpeas may cause serious injury to the epicotyl. It might not be practical to open manually the cotyledons of all samples of soybeans on the preliminary counts, since epicotyl injury is not too common; but a few should be opened in each sample and if there is evidence of mechanical injury it may be necessary to open the cotyledons of all seedlings in that sample. If only a final count is made the epicotyl will usually have emerged from between the cotyledons, and the condition of the first leaves can be easily determined. Preliminary counts should be made on samples which show mold or bacteria that might spread to healthy seedlings. At this time, a normal seedling should have: (1) A well-formed root with or without secondary or adventitious roots; (2) a strong and fairly long hypocotyl with two attached, open cotyledons; (3) two well-developed first or primary leaves; and (4) an intact terminal bud (figs. 50, 51, 52).

Normal seedlings include those that have: (1) A primary root or a set of secondary or adventitious roots sufficient to anchor the seedlings when grown in soil or sand, provided the hypocotyl is normal; (2) a fairly well-developed hypocotyl with no prominent breaks or deep lesions which might interfere with the conducting tissues; (3) a plumule with at least one leaf and an intact growing point; and (4) slight infection by fungi, provided the essential seedling parts have not been seriously damaged and appear to be able to carry on their normal functions at the time of evaluation.

Abnormal seedlings include those that have: (1) No primary root or no well-developed secondary or adventitious roots; (2) a malformed hypocotyl which may be curled, shortened, or thickened or have severe open splits; (3) no epicotyl, or one without the growing point, with or without leaves; (4) decayed epicotyl, provided the decay has spread from the rotted cotyledons of the developing seedling; and (5) various combinations of the above-named abnormal types.

Caution must be taken to insure that the decay is not caused by improper test conditions. Tests made in the relatively dry atmosphere and sunlight of a greenhouse are the best measure of the value of samples having many decayed plumules.

As with beans, mechanical breakage of the seeds may result in only vestiges of seedlings, usually an enlarged plumule within the swollen cotyledons and little or no development of the hypocotyl and radicle. Since such growths do not emerge in soil tests, the seeds are regarded as "too broken to grow." Seeds of cowpeas, lupines, peanuts, and soybeans may exhibit this condition.

Severe weevil infestation is found only in cowpeas, and will often reduce development to only vestiges of seedlings. The embryonic

plant may be entirely or partially destroyed, or the cotyledons may have been so badly devoured that there is no food supply left for the developing seedling. Insect injury can be easily detected by examination of the cotyledons.

Clovers, alfalfa, black medic, trefoil, crotalarias, lespedeza, kudzu, sesbania, beggarweed, sainfoin.—Since these relatively small-seeded legumes all have epigeous seedling development, the development of the epicotyl cannot be discerned until the cotyledons have opened up sufficiently for its emergence. (Figs. 53–56.) Breaks at the point of attachment of the cotyledons to the hypocotyl, with injury to the epicotyl, are very common in seeds which have been mechanically damaged. Therefore, when preliminary counts are made on such kinds, it is very important that seedlings should not be removed until the condition of the cotyledons can be determined. It will not be practical to observe the epicotyl development except on badly broken samples, or when samples are tested in soil, where the cotyledons will open up naturally and the growing point of the epicotyl becomes clearly visible. By the fourth or fifth day of the test the cotyledons of most of the kinds listed herein will have developed to a stage where the breaks can be seen. If the point of attachment of the cotyledons to the hypocotyl cannot be seen at this time, the seed coat may be peeled back far enough to determine whether a break has occurred. A hand lens is usually necessary for the close observations required.

The advantages of sand or soil tests on these kinds of seeds are that the cotyledons open up naturally by the end of the test period, injury to the seedling is clearly visible, badly broken seedlings do not emerge, and the analyst has the advantage of being able to judge the abnormal types by direct comparison with the normals. The seeds most subject to mechanical breakage are: Alfalfa; most of the clovers; black medic; trefoil; sericea lespedeza; and the crotalarias.

By the end of the germination test a perfectly normal seedling should have a long, slender root, usually with root hairs, a long hypocotyl, two attached cotyledons which have opened, and an intact epicotyl or growing point.

Normal seedlings include those that have: (1) A long, slender root, usually with root hairs; (2) slightly stubby roots on blotter tests of sweetclovers, provided the seedling is otherwise normal; (3) roots slightly stubby from being held back by the attached seed coat, provided the seedling is otherwise normal; (4) short splits on the roots, provided the split does not extend into the central conducting tissues of the hypocotyl, and provided further that root hairs are present and the seedling is normal in other respects; (5) a long, well-developed hypocotyl which may have slight cracks or breaks, provided they do not extend into the conducting tissues; (6) at least one cotyledon, provided the epicotyl is also present; and (7) slight infection by fungi, provided none of the essential seedling structures have been damaged.

Abnormal seedlings include those that have: (1) Stubby roots, usually associated with shortened hypocotyls; (2) longitudinal, deep splits on the roots, extending into the conducting tissues of the hypocotyls; (3) deep cracks or breaks in the hypocotyl which extend into the conducting tissues; (4) both cotyledons broken off; (5) one cotyledon broken off if the epicotyl is also absent; (6) rotted cotyledons, provided the decay did not spread to the seedling from an adja-

cent seed or was not the result of improper test conditions; (7) spindly, watery seedlings, provided they are not the result of excess moisture in the substrata (usually seedlings of this type have one or more abnormalities of the essential structures, such as broken cotyledons or deep splits in the hypocotyls); and (8) various combinations of the above-named types of abnormal seedlings.

Mechanical breakage of the seed may result in only vestiges of seedlings, manifested by swollen cotyledons and broken, slightly enlarged hypocotyls or radicles. These seeds are regarded as "too broken to grow," since the resultant growths do not emerge in soil tests. Insect damage may also cause lack of seedling growth.

LILIACEAE (LILY FAMILY)

KINDS OF SEED

Asparagus—*Asparagus officinalis.*
Leek—*Allium porrum.*
Onion—*Allium cepa.*

OCCURRENCE AND LABORATORY TREATMENTS FOR OVERCOMING DORMANCY

Onion, leek, and asparagus apparently present no dormancy problems in routine laboratory testing. Asparagus frequently is slow to germinate, the seeds imbibing water but not growing. Borthwick (7) found that freshly harvested and year-old asparagus seeds germinated promptly when held at a constant temperature within the range of 25° to 30° C. for the duration of the test period.

HARD SEEDS

Although it is permissible to report hard seeds in asparagus, there is question whether the seeds remaining at the end of the germination test are really hard. According to the definition, "hard seeds" are those which have not absorbed water because of an impermeable seed coat. Asparagus seeds do absorb water during the course of the test period. The failure of the seeds to germinate is not due to a seed coat that is impermeable to water, but to some other cause.

SUBSTRATA, SPACING, AND SPECIAL TREATMENTS

Onion and leek are tested between blotters and asparagus between folded towels. Not more than 100 seeds of onion and leek should be placed in a blotter folded to 4¾ by 6 inches in size and no more than 50 seeds of asparagus in a towel folded to 5½ by 7 inches in size. Upright rolled towels have proved to be very satisfactory for asparagus. No more than 100 seeds should be placed in a roll 11 by 14 inches in size. Soil or sand is listed in the rules as an alternate substratum for onions. No more than 100 seeds should be placed in a small container 4½ by 4½ by 1½ inches in size. It is recommended that only one final count be made. Soil or sand tests must be continued for 12 days, whereas blotter tests should be discontinued at the end of 10 days.

SEEDLING INTERPRETATION

Onion and leek.—Onion and leek exhibit epigeous growth, the root emerging first, and the cotyledon appearing above the surface of the ground as a closed loop, its tip still adhering to the seed coat and endosperm (fig. 57). As the seedling grows, the tip of the cotyledon

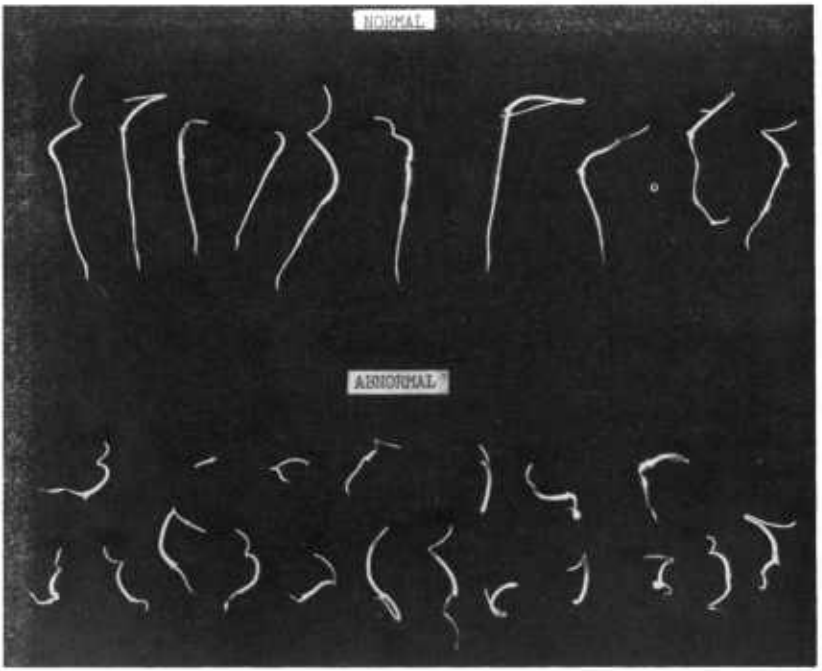

FIGURE 57.—Onion (*Allium cepa*). Normal and abnormal seedlings from 10-day tests in blotters.

shrivels and becomes separated from the seed coat and the first foliage leaf appears through a slit or pore in the cotyledon. Since the foliage leaf does not develop during the laboratory test period, the analyst will be able to observe only the leaflike cotyledon. By the end of the test period a perfectly normal onion or leek seedling should have a long, slender root with a thickened area where it is joined to the base of the hypocotyl, a fairly long hypocotyl, and a long, green cotyledon with a definite loop or bend, often referred to as the "knee."

Normal seedlings include those that have: (1) A well-developed, long, slender root, with or without root hairs; (2) a fairly long hypocotyl; (3) a long, green, leaflike cotyledon, with a well-developed bend or "knee"; and (4) slight infection by fungi, provided none of the essential seedling structures have been damaged.

Abnormal seedlings include those that have: (1) A thickened area at the base of the hypocotyl with no root, or a stubby root; (2) a very short hypocotyl, usually associated with a poorly developed root and cotyledon; (3) a poorly developed leaflike cotyledon without a definite bend or "knee"; (4) spindly, watery seedlings, often slow in sprouting, and with one or more other abnormalities; (5) a rotted cotyledon, provided the decay is not the result of improper test conditions; and (6) various combinations of the above-named abnormal types.

Asparagus.—Asparagus exhibits hypogeous growth, the cotyledon remaining below the surface of the ground. After the seed has absorbed water the embryo enlarges and the immature seedling appears as a swollen protuberance on one side of the seed. The root forms first and then the stemlike epicotyl.

By the end of the test period a normal asparagus seedling should have a long, slender root, a fairly long epicotyl, an intact terminal bud, and the seedling should not be broken away from the cotyledon. It is necessary to allow the seedlings to develop to a stage whereby the epicotyl development may be observed.

Normal seedlings include those that have: (1) A long, slender root; (2) a long, well-developed epicotyl with terminal growing point; (3) the cotyledon attached to the seedling; and (4) slight infection by fungi, provided none of the essential seedling structures have been damaged.

Abnormal seedlings include those that have: (1) No root, or a very stubby root with weak secondary root development; (2) a malformed epicotyl, which may be thickened, shortened, or twisted; (3) no terminal growing point or bud; (4) cotyledon broken away from the seedling; (5) decayed epicotyl, provided the decay is not the result of improper test conditions; and (6) various combinations of the above-named abnormal types.

LINACEAE (FLAX FAMILY)

KIND OF SEED

Flax—*Linum usitatissimum.*

OCCURRENCE AND LABORATORY TREATMENTS FOR OVERCOMING DORMANCY

Certain samples of flaxseed are retarded in germination at temperatures over 35° C. but germinate satisfactorily at alternating temperatures of 20°–30° C. as prescribed in the rules. However, flax is tested at 20° in the Canadian laboratories and it has been suggested that 15° is necessary for germination of certain samples in the region of Calgary, Canada.

SUBSTRATA, SPACING, AND SPECIAL TREATMENTS

The standard procedure is to test flaxseed between blotters, but soil and sand are alternate substrata. No more than 50 seeds should be placed between blotters 4¾ by 6 inches in size, or in soil or sand containers 4½ by 4½ by 1½ inches in size. Soil or sand tests will aid in the interpretation of seedlings of samples which have been mechanically injured or subjected to severe chemical treatment.

SEEDLING INTERPRETATION

By the end of the germination test a normal flax seedling should have a well-developed primary root, a long hypocotyl, two intact cotyledons, and a small epicotyl which does not develop sufficiently during the course of the laboratory test to be examined unless the seedlings are left for final evaluation and the cotyledons manually parted. It will not be necessary to do this except when badly broken samples are being tested. (Fig. 58.)

Normal seedlings include those that have: (1) A long, slender root, usually with root hairs; (2) a short or stubby primary root, provided secondary root development is strong and the hypocotyl is of normal length or approximately so; (3) a long, well-developed hypocotyl with no breaks or lesions extending into the conducting tissues; (4) at least one attached cotyledon, provided the epicotyl is not injured; (5) variously broken or cracked cotyledons, provided the other seed-

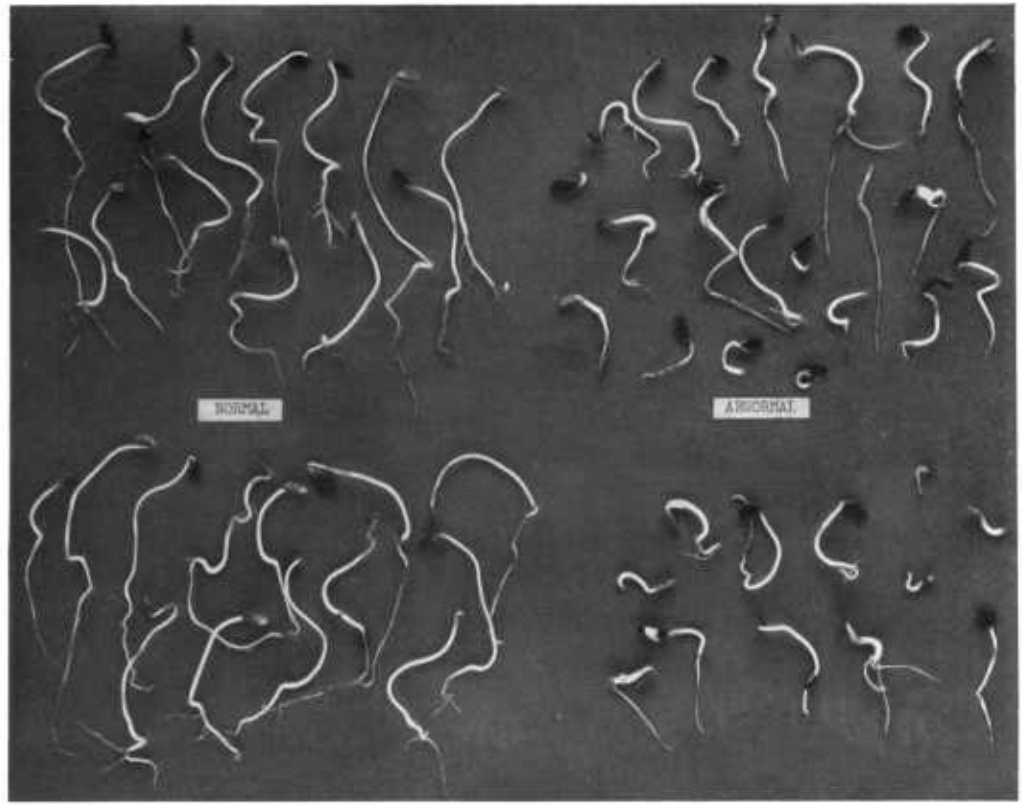

FIGURE 58.—Flax (*Linum usitatissimum*). Seedlings from 7-day tests in blotters. (Left) Normal seedlings; (right) abnormal seedlings.

ling parts appear normal; and (6) slight infection by fungi, provided none of the essential seedling structures have been damaged.

Abnormal seedlings include those that have: (1) A stubby or no primary root, provided the secondary root development is weak, a condition usually associated with a shortened hypocotyl; (2) a malformed hypocotyl, which may be twisted, thickened, or shortened; (3) deep cracks or lesions on the hypocotyl, extending into the conducting tissues; (4) both cotyledons broken off; (5) one cotyledon broken off if the epicotyl is also injured; (6) decayed cotyledons or other essential seedling structures, provided the decay is not the result of improper test conditions; and (7) various combinations of the above-named abnormal types.

MALVACEAE (MALLOW FAMILY)

KINDS OF SEED

Cotton—*Gossypium* spp.
Okra—*Hibiscus esculentus.*

OCCURRENCE AND LABORATORY TREATMENTS FOR OVERCOMING DORMANCY

Impermeable seed coats may occur in okra or cotton but scarification treatments to overcome this type of dormancy are not accepted as routine methods in seed testing.

HARD SEEDS

Although not indicated in the rules, hard seeds may occur in cotton. The same treatment as provided in the rules for legumes, okra, and asparagus should be applied to swollen and hard seeds of cotton. It will be necessary to examine the soil or sand for the presence of hard seeds at the end of the test period. If swollen seeds are present they should be removed, placed in towel tests, and evaluated after 5 additional days.

SUBSTRATA, SPACING, AND SPECIAL TREATMENTS

Rolled towels are specified in the rules for cotton and okra. More satisfactory results will be obtained if the tests are placed in an upright or slanted position during the germination period. When using paper towels cut to approximately 11 by 14 inches in size, no more than 50 seeds of each kind should be placed in a roll. It has been found advantageous to stagger the rows of cotton in each roll so that the germinating seedlings will have a minimum of contact with each other. Because of the fungi carried on the fuzzy seed coats, proper spacing of cottonseed is essential if uniform results are to be expected.

Soil and sand are also listed as substrata for cotton. Soil containers approximately 8½ by 8½ by 1¾ inches are very satisfactory and only 50 seeds should be placed in each.

In addition to the rolled towels and soil or sand the following alternate method is specified for cotton: Shake the seed in a closed container, thoroughly wetting the lint and then blot off the excess moisture. This method will be necessary only on certain "sensitive" samples, which are those exhibiting slow growth and having numerous fungi on the fuzzy seed coats.

Owing to the absorption of the added moisture by the lint on the seeds, faster germination is obtained by the "prewet" method, and the seedlings emerge before the fungi have a chance to develop. It

appears possible that approximately the same results could be obtained by keeping upright rolled tests of cottonseed quite wet for the first few days of test.

SEEDLING INTERPRETATION

By the end of the germination test a perfectly normal seedling should have a long, well-developed root with root hairs, a long hypocotyl, and two attached green leaflike cotyledons, with a tiny epicotyl formed between them. It will not be possible or practical to observe the epicotyl development on any except those tested in soil or on those abnormal seedlings which are left in test for final interpretation at the end of the test period in artificial substrata. (Figs. 59, 60.)

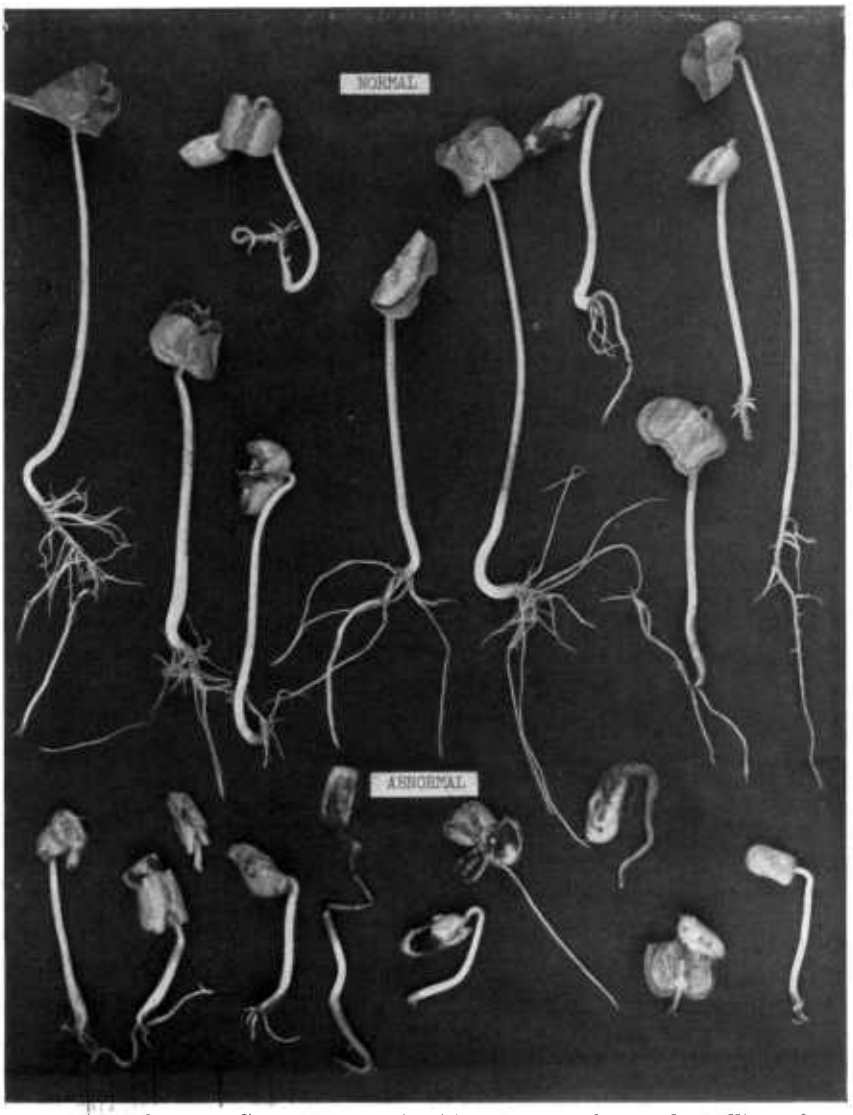

FIGURE 59.—Cotton (*Gossypium* spp.). Normal and abnormal seedlings from 12-day tests in towels.

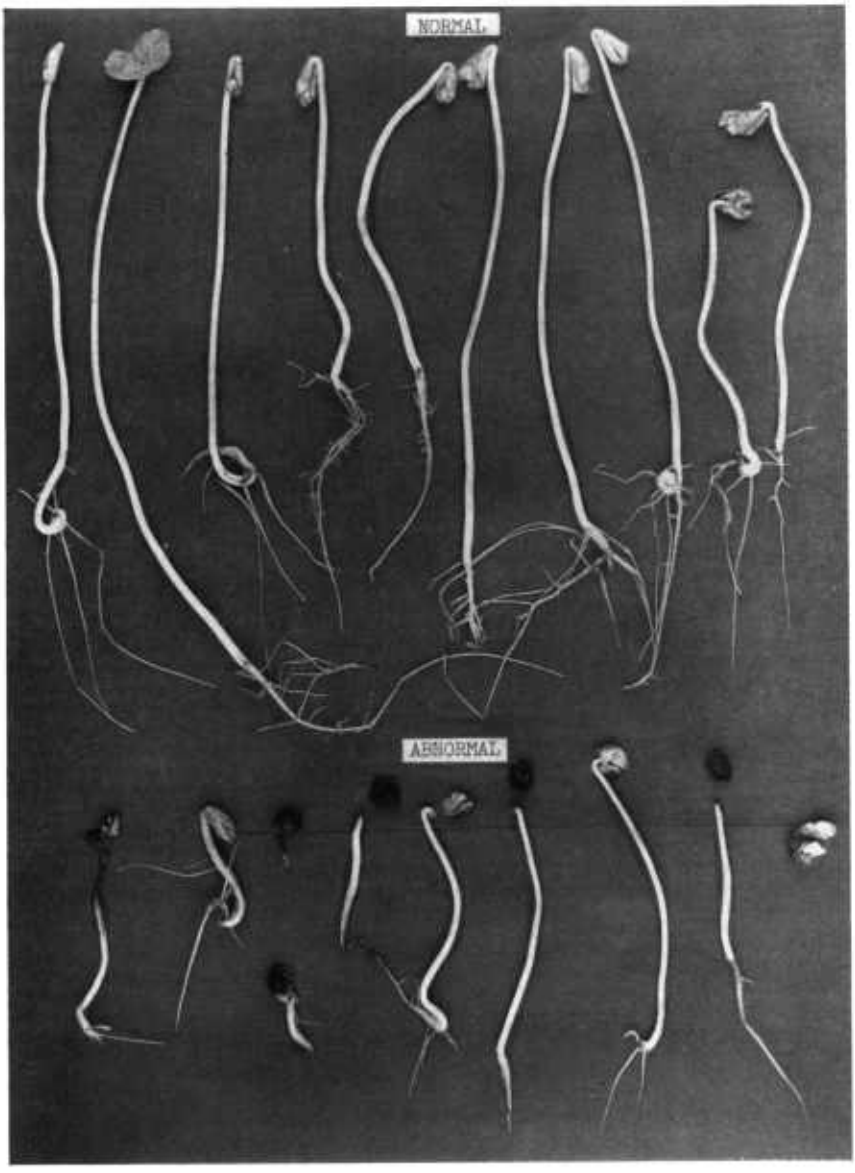

FIGURE 60.—Okra (*Hibiscus esculentus*). Normal and abnormal seedlings from 21-day tests in towels.

Normal seedlings include those that have: (1) A well-developed, long, slender root, usually with root hairs; (2) no primary root but strong secondary roots, provided the hypocotyl is of normal or approximately normal length; (3) a long, well-developed hypocotyl with no breaks or deep grainy lesions which might interfere with the con-

ducting tissues; (4) at least one cotyledon and intact epicotyl; (5) slight infection by fungi, provided none of the essential seedling structures have been damaged; and (6) yellowish hypocotyls or roots of cotton which may appear diseased, provided the cotyledons are free of infection (the seed coat must be peeled back on young seedlings to determine this condition of the cotyledons).

Abnormal seedlings include those that have: (1) No root or very stubby roots, usually associated with a shortened hypocotyl; (2) stubby roots and thickened hypocotyls resulting from chemical treatment of seed, such as often occurs on delinted cottonseed; (3) malformed hypocotyl, which may be curled, thickened, or shortened; (4) deep cracks or grainy lesions on the hypocotyl which appear to interfere with the conducting tissues; (5) epicotyl absent, even though one or both cotyledons are attached; (6) decayed cotyledons and hypocotyls, provided the decay did not spread from another seed or was not the result of improper test conditions; and (7) various combinations of the above-named abnormal types.

POLYGONACEAE (KNOTWEED FAMILY), SOLANACEAE (NIGHTSHADE FAMILY), UMBELLIFERAE (CARROT FAMILY), AND MISCELLANEOUS KINDS IN OTHER FAMILIES

KINDS OF SEED

Knotweed family:
- Buckwheat—*Fagopyrum esculentum.*
- Sorrel—*Rumex acetosa.*
- Rhubarb—*Rheum rhaponticum.*

Nightshade family:
- Eggplant—*Solanum melongena* var. *esculentum.*
- Pepper—*Capsicum* spp.
- Tomato—*Lycopersicon esculentum.*
- Husk tomato—*Physalis pubescens.*

Carrot family:
- Carrot—*Daucus carota.*
- Celery—*Apium graveolens* var. *dulce.*
- Celeriac—*Apium graveolens* var. *rapaceum.*
- Parsley—*Petroselinum hortense.*
- Parsnip—*Pastinaca sativa.*

Valerian family:
- Cornsalad (Fetticus)—*Valerianella locusta* var. *olitoria.*

Hemp family:
- Hemp—*Cannabis sativa.*

Geranium family:
- Alfilaria—*Erodium cicutarium.*

OCCURRENCE AND LABORATORY TREATMENTS FOR OVERCOMING DORMANCY

Umbelliferae.—Dormancy may occur in seeds of any of the kinds of Umbelliferae (carrot family) listed above. However, dormancy should not be confused with low germination owing to the presence of embryoless seeds, which can be determined by dissection of the seeds. Light is specified for the germination of celery and celeriac; potassium nitrate and prechilling are indicated for dormant samples of these kinds. There are no provisions in the rules for treatment of dormancy in carrot, parsnip, or parsley, although there are certain indications that occasional samples may be dormant. Treatment of parsnip seed with potassium nitrate and exposure of parsnip and

parsley seeds to lower constant temperatures, or lower alternations of temperature than those specified in the rules have been suggested as methods of overcoming dormancy.

Solanaceae.—Tomato and husk tomato may exhibit dormancy but dormant samples of pepper and eggplant are rarely, if ever, found. The only treatment specified in the rules for husk tomato is light, although Heit (*28*) has recommended moistening the substratum with potassium nitrate for *Physalis* spp. The provisions in the rules for overcoming dormancy in tomato are probably adequate; however, an alternating low-high temperature has also been found beneficial (Shuck (*42*)). The rules specify that dormant samples of tomato shall be exposed to light and the substratum moistened with a potassium nitrate solution.

Polygonaceae.—Apparently buckwheat seed does not exhibit dormancy, but rhubarb may. The rules provide that rhubarb seed shall be tested on top of soil at an alternating temperature of 20°–30° C., with light. According to Heit (*27*) light is beneficial to some samples and germination is satisfactory on top of blotters. The control of fungi is of major importance in the testing of rhubarb seed. Results may be more uniform when such seed stocks are tested on top of soil rather than on top of blotters. The rules provide that sorrel shall be tested on top of soil or in Petri dishes at an alternating temperature of 20°–30° C., with light. Dormant seed should be placed at 15° C. Some samples may require moistening of the substratum with a potassium nitrate solution.

Valerianaceae.—The provision in the rules to place dormant samples of cornsalad at a low temperature for test appears to be adequate.

Cannabinaceae.—Apparently dormancy in hemp seed is not encountered in laboratory testing.

Geraniaceae.—Alfilaria is usually dormant. Clipping the ends of the seeds (fruits) as provided in the rules is apparently an adequate treatment for overcoming this condition. Care must be taken to clip the fruit on the end opposite the embryo to avoid injuring it.

SUBSTRATA, SPACING, AND SPECIAL TREATMENTS

Celery, celeriac, husk tomato, and sorrel may be tested in Petri dishes. Petri dishes are not listed in the rules for tomato, although it is almost necessary to use them when dormant samples must have light. Not more than 100 seeds of any of the kinds listed above should be placed in a 100- or 120-mm. Petri dish.

Pepper and eggplant may be tested on top of blotters as a regular method, and celery, celeriac, and husk tomato as an alternate method. No more than 100 seeds of any of these kinds should be placed on top of a blotter 4¾ by 6 inches in size.

Buckwheat, carrot, parsnip, parsley, tomato, cornsalad, hemp, and alfilaria are regularly tested between blotters. Not more than 50 seeds of buckwheat and hemp, and not more than 100 seeds of carrot, parsnip, parsley, tomato, cornsalad, or alfilaria should be placed between a folded blotter 4¾ by 6 inches in size. Buckwheat may also be tested between folded towels as an alternate substratum. Not more than 50 seeds should be placed in a towel 5½ by 7 inches in size.

Soil is the only substratum listed in the rules for rhubarb and it

is also an alternate substratum for sorrel. Rhubarb should be placed on top of soil in small open containers. The seeds should be pressed for about one-half their length into the top of soil, 25 seeds placed in boxes 4½ by 4½ by 1½ inches in size. This necessitates 16 replicates for a complete test. Sorrel may be placed on top of soil in a closed Petri dish, not more than 100 seeds being placed in a dish 100- or 120-mm. in size.

Pepper, eggplant, and tomato may be tested between blotters with raised covers as an alternate substratum. Not more than 100 seeds of any of these kinds should be placed in a blotter 4¾ by 6 inches in size.

SEEDLING INTERPRETATION

The only true seeds in this group are pepper, tomato, husk tomato, and eggplant, all of which are members of the nightshade family. The rest are fruits or half fruits, each containing a single seed. The fruits in the Umbelliferae normally occur in two's, splitting longitudinally down the center, forming two single-seeded half fruits when mature. Samples received for test may be half fruits, each containing a single seed, or they may be whole fruits containing two seeds. Only single seeds (fruits) of the carrot family should be placed for test; however, if double seeds are germinated only one seedling from each is to be counted. (Fig. 61, 62.)

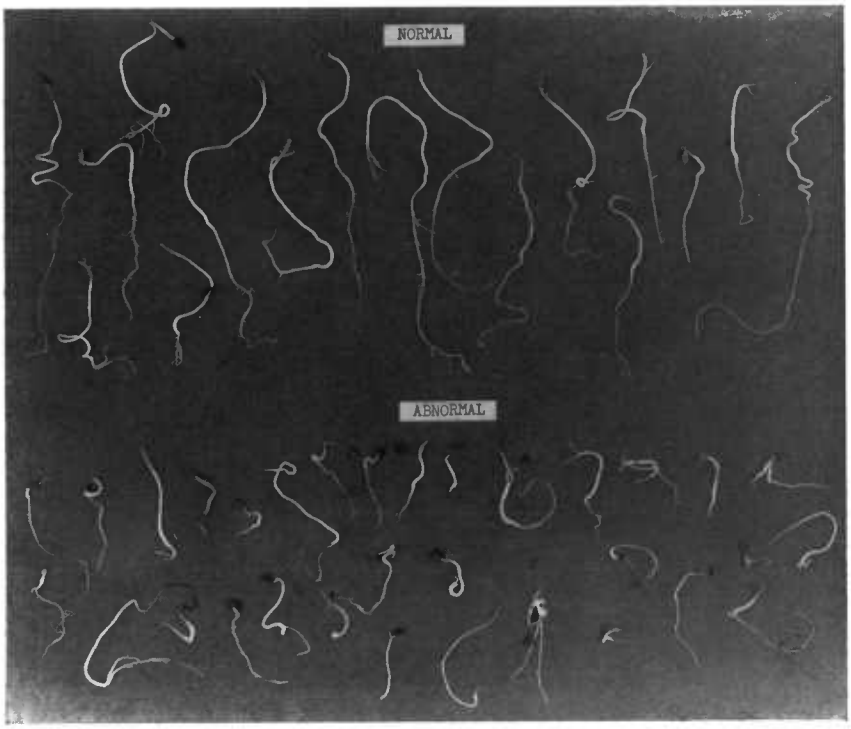

FIGURE 61.—Carrot (*Daucus carota*). Normal and abnormal seedlings from 21-day tests between blotters.

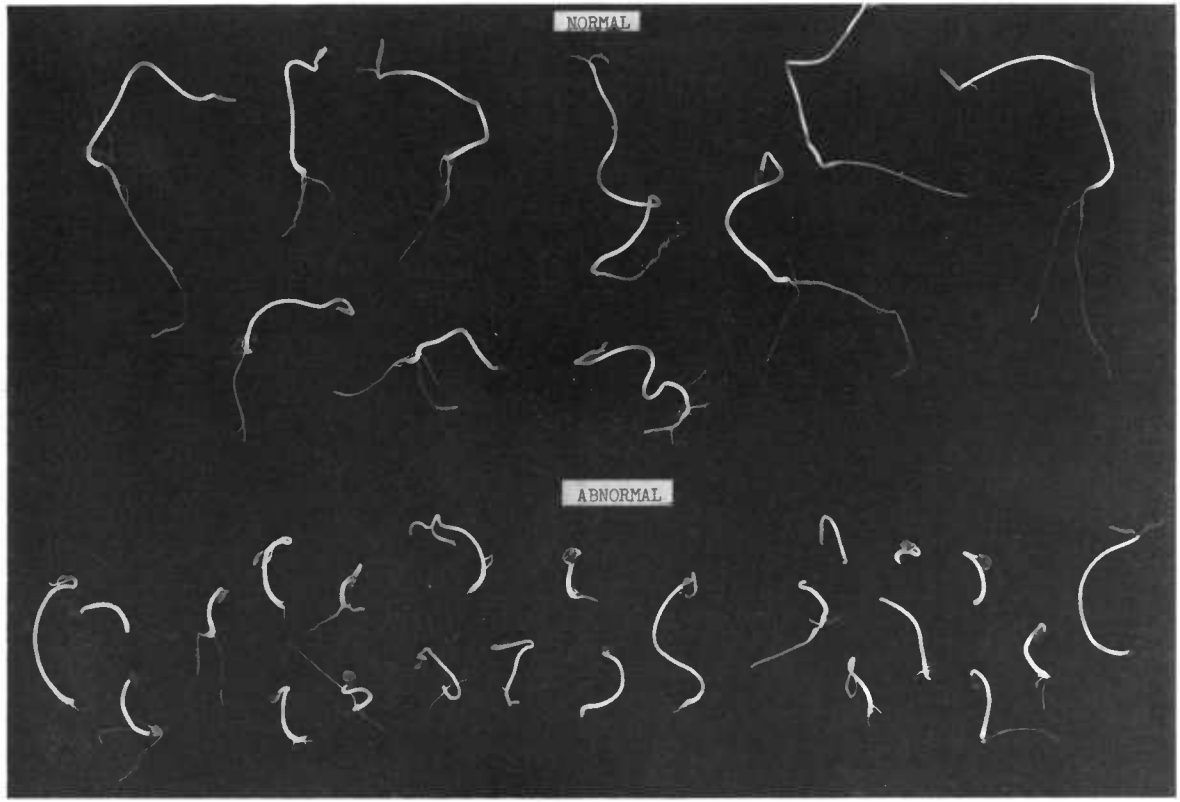

FIGURE 62.—Tomato (*Lycopersicon esculentum*). Normal and abnormal seedlings from 14-day tests between blotters.

Normal seedlings include those that have: (1) A well-developed primary root, usually with root hairs; (2) a stubby root or no primary root, provided the secondary root development is strong and the hypocotyl is near normal length as is frequently encountered in tomato seedlings; (3) a long, well-formed hypocotyl, with no prominent breaks or lesions extending into the conducting tissues; (4) at least one attached cotyledon, provided the epicotyl is intact and the seedling is otherwise normal (a tiny epicotyl may be observed in seedlings left in test for final evaluation); and (5) slight infection by fungi, provided none of the essential seedling structures have been damaged (infection is particularly apt to occur in rhubarb in which case retests may be advisable).

Abnormal seedlings include those that have: (1) A stubby root or no primary root, provided there is weak secondary root development; (2) a malformed hypocotyl, which may be twisted, thickened, or shortened; (3) deep cracks or lesions on the hypocotyl extending into the conducting tissues; (4) both cotyledons, or one cotyledon and epicotyl broken off; (5) two enlarged cotyledons, but hypocotyl short and usually malformed; (6) decayed cotyledons or hypocotyl, provided they are not the result of improper test conditions; and (7) various combinations of the above-named abnormal types.

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EXAMINATION FOR NOXIOUS-WEED SEEDS

OBJECT AND NATURE OF TEST

The object of a noxious-weed seed examination is to correctly identify and determine the rate of occurrence of those weed seeds regarded as noxious or particularly objectionable. In seed testing, the rate of occurrence means the actual number of each named kind of noxious-weed seed that occurs in the sample being examined. For labeling or other purposes, this information is transposed to a "per ounce" or "per pound" basis. The noxious-weed seed examination is often regarded and conducted as a part of the purity analysis, primarily because of the similarity of methods used in conducting the two tests and the fact that the same analysts conduct both tests. However, it is common practice among seed-testing laboratories not to make noxious-weed seed examinations as a part of the purity analysis unless specifically requested to do so.

STATE AND REGIONAL LISTS OF NOXIOUS-WEED SEEDS

Each State as well as the Federal Government has established, by law or regulation or both, a list of noxious-weed seeds. These combined lists show that there are approximately 140 kinds or species of noxious weeds in the United States. Efforts have been made by Federal and some State seed-control officials to set up noxious-weed seed lists on a logical basis by geographical and ecological regions. Although this movement has met with considerable success, there is still much to be desired in bringing about more practical and uniform noxious-weed seed lists. Analysts are often at a loss to know the particular kind of weed seeds to look for when making a noxious-weed seed examination. In State laboratories, analysts who conduct tests for farmers or for control purposes will ordinarily be concerned with the noxious weeds of their own State. State, commercial, and private analysts who perform service testing will usually have to be informed regarding the States into which the seed is to be shipped so that the noxious-weed seed requirements for such States may be met. Since most of the work of Federal analysts relates to seed control activities, information is readily available either from the rules and regulations under the Federal Seed Act or from the noxious-weed seed lists of the States.

SIZE OF SAMPLE

A particular lot of seed may contain many seeds of a certain kind of noxious-weed seed or it may contain only an occasional one. In testing a lot of red clover seed containing only 18 dodder seeds per pound, the 5-gram sample used for purity analysis might possibly contain no dodder seeds and if only this sample were examined for the presence of noxious-weed seeds the lot might be sold as "dodder free." To avoid such possibilities it is necessary to use considerably larger samples for noxious-weed seed tests than for purity determina-

tions. The minimum weight of working samples for noxious-weed seed examinations are shown in the third column of table 3, under Rules for Seed Testing, in the Appendix.

There is no constant ratio between the sizes of the samples used for purity tests and those used for noxious-weed seed determinations. In fact, the ratio decreases gradually from 1 : 50 in the case of sample size for purity of ½ gram to 1 : 1 in the case of sample size for purity of 500 grams. In other words, as the sample size for purity increases (large-seeded kinds) there is less difference in the two sample sizes.

When the noxious-weed seed examination and purity analysis are made at the same time, the amount analyzed for noxious-weed seeds only can be reduced to the difference between the amount given in the rules and the amount used for the purity determination. For example, if a purity analysis is made on crimson clover seed only 40 grams need be examined for noxious-weed seeds, because 50 grams (total required for noxious-weed seed examination) minus 10 grams (amount required for purity analysis) equals 40 grams. The numbers of each noxious-weed seed found in the 10-gram analysis and in the 40-gram examination are added together and the total represents the number found in 50 grams.

The rules for seed testing do not give any guide with respect to the number of decimal places or of significant places to which samples that are to be tested for noxious-weed seed shall be weighed. In the absence of specific instructions, it is recommended that samples be weighed and calculated to the nearest 0.5 gram when the sample size is 25 or 50 grams, and to the nearest whole gram for sample sizes of 100 to 500 grams.

CONDUCTING THE EXAMINATION

The sample is reduced to the proper size by a mechanical divider or other acceptable method described under the heading "Procedures for Determining Purity Composition." The procedure for making the examination is essentially the same as the hand separation procedure described for the purity analysis and the two tests must be carried out in the same meticulous and painstaking manner.

Some analysts choose to use a hand lens for all noxious-weed seed examinations regardless of the size of the seed being examined. It is not essential to use the lens in the examination of large seeds, but it should always be kept close at hand for the critical examination of questionable seeds. A hand lens should always be used in making noxious-weed seed examinations of the kinds of seeds requiring a sample size of 25 or 50 grams. A reading glass may be used for the determinations on those kinds of seeds requiring a sample size of 150 to 500 grams for examination; or, no magnification may be required for the larger seeds if the characters of the weed seeds, for which the sample is being examined, are quite distinct from those of the crop seeds.

If 30 or more noxious-weed seeds of a single kind are found in the purity analysis (or in an amount equal to the sample size for purity analysis when only a noxious-weed seed examination is made) the sample need not be examined further for that kind of seed. At this point, the amount of the crop seed in which the 30 weed seeds were found is weighed and the rate of occurrence is determined on that

basis. However, the analysis must be continued for other noxious-weed seeds. Should 30 seeds of a second or third kind be found before the entire sample is analyzed, examination for each of these kinds of seed may be discontinued in accordance with the above procedure.

INTERPRETATION OF SEEDS

Any sample may contain seeds about which there is question (1) regarding their identity or (2) as to whether they are weed seeds or inert matter. In each instance the seed or seedlike structure must be examined critically with a hand lens or under a stereoscopic microscope, depending on the degree of magnification required.

The rules governing the interpretation of noxious-weed seeds are the same as those applicable to common weed seeds. Likewise, the same interpretations apply to both groups of weed seeds. Consequently, the reader is referred to pages 49 to 52 for a detailed treatment of this subject. Accurate identification and proper interpretation of noxious-weed seeds is so important that the analyst is justified in going to great lengths to attain accuracy. As compared with the purity analysis, relatively more seeds should be dissected, caryopses of grasses removed from glumes, and comparisons made with known seeds, when necessary.

EXPRESSING THE RATE OF OCCURRENCE

Upon completion of the examination the record will show the number of each kind of noxious-weed seed found in the number of grams examined. This can be converted to a "per ounce" basis by dividing the number of grams examined into 28 and multiplying by the number of weed seeds found; to convert to a "per pound" basis divide the sample weight into 450 and multiply by the number of seeds found. Actually, the number of grams per ounce is near 28.5 and the number per pound is near 454, but 28 and 450 are close enough for computations of this kind.

ORIGIN OF SEEDS

IMPORTANCE OF ORIGIN DETERMINATION

Some crops produced in a particular area have characteristics that are a result of the environment as determined by temperature, rainfall, and altitude. Certain varieties are often grown to the exclusion of other varieties because of their adaptation to local conditions. In some cases plants grown from seed produced in one region may be susceptible to a disease that is prevalent in another region; conversely, certain areas may have diseases that would be harmful if introduced into another region. Because of these factors, it is important to know the origin of certain crop seeds.

The importance of origin is recognized in State and Federal seed laws that require the origin of specified seeds to be stated on the label attached to the seed. The Federal Seed Act requires that imported alfalfa and red clover seed shall be stained in certain proportions with colors that indicate the origin or the general adaptation of the seed in the United States.

An experienced seed analyst can usually determine the origin of the seed by a careful examination of extraneous material, such as weed and other crop seeds, that may be present in the sample.

SIZE OF SAMPLE FOR ORIGIN DETERMINATION

The size of sample to be examined for origin cannot be definitely specified. The usual practice is to continue the examination until conclusive evidence is found. This may be found in a very small sample or it may require examination of the entire sample submitted. However, if no evidence is found in about 1 pound (approx. 450 to 500 grams) of seed such as alfalfa or clover, it would appear that little or no useful purpose would be served by further search.

EVALUATION OF IMPURITIES

Many factors must be taken into consideration in making a determination of origin. The general appearance of a seed sample in many cases suggests the possible origin, but this is seldom entirely reliable. Factors such as ability to withstand cold temperature, freedom from disease, and other genetic or varietal characters which are sometimes associated with origin usually cannot be determined from an examination of the seed. The most dependable conclusions may be drawn from the impurities carried by the seed sample, such as weed seeds, other crop seeds, or the character of the inert matter. The weed seed content usually furnishes the most important clue. It must be emphasized that extreme care must be exercised in evaluating the evidence presented by the examination.

The following points should be kept in mind at all times when making an examination:

1. Weed seed impurities are seldom identical in all crops from the same general region. The difference in cultural requirements, time

of harvest, methods of threshing, and cleaning may influence the character of the extraneous seeds carried with the crop seed.

2. The fact that a species is listed as characteristic of one locality does not necessarily mean that the plant does not occur elsewhere. In other regions it may occur only sparingly and the possibility of its appearance in a sample of crop seed is practically negligible. Or, a plant may be fairly abundant in an area but the prevalent cultural practices may prevent its introduction in cultivated fields.

3. It is seldom that all weeds listed as characteristic of a certain region are present in any one seed sample, and conclusions must be based, in part, on the combination of weed seeds represented in the sample.

4. The frequency of occurrence of the different species of seeds may vary from season to season.

5. A new species may become established over a period of time and make its appearance as an impurity in crop seeds. Weed seeds are being constantly distributed into other areas as a result of their being carried with agricultural seeds, feeds, hay and straw, and by birds, wind, water, and other means. Sometimes weeds become established in areas where they have not been found before. When this happens, it is necessary to adjust the list of weeds used as indicators of origin.

6. A new region of seed production is sometimes developed and a new combination of weed seed impurities is introduced.

Some of the incidental seeds found in seed from the Southwestern States occur also in seed from South America. Also, seed of South American origin (Argentina and Chile) sometimes carries impurities identical with those of southern Europe or South Africa. Many of the common weed seeds of central Europe may be found in seed of New Zealand origin, as well as of northern France. In many cases these plants were likely introduced in cultivated fields with imported crop seeds. This possibility should at all times be borne in mind, and the complete picture, rather than the individual kind of seed, should be considered in making a determination of origin.

When the representative impurities have been removed from a seed sample, they may be classified into three general groups: (1) Species that are confined to a limited area and would not be expected to occur from any other source. (2) Species of somewhat wider distribution which, although not typical of any region when considered singly, are very helpful in making a determination when found in combination. (3) Species of such general distribution that they may appear in crops from many sources and consequently have no significance in determining origin.

MAJOR SEED-PRODUCING REGIONS

The seed impurities in groups (1) and (2) above, considered together, may usually be referred to one of six major regions of production: North America, Europe, southwestern Asia, South America, South Africa, and New Zealand.

These general regions, particularly Europe and North America, may then be roughly divided into smaller areas in which the same climatic conditions prevail. Thus, if the incidental weed seeds indicate general European origin, the combination of seeds present may

further suggest either north central and eastern Europe (including Romania, Poland, Hungary, Russia, and Czechoslovakia), or southern Europe (including Italy, southern France, Spain) and Turkestan. Within these more restricted areas considerable overlapping may be expected and seeds of plants of very local distribution have to be relied upon to delimit the smaller areas of production.

The seed-producing regions of North America fall roughly into seven geographic divisions.

The *Pacific Northwest*, including, in general, that portion of British Columbia, Washington, Oregon, and northern California lying west of the Cascade ranges.

The *Southwest*, including middle and southern California, Arizona, New Mexico, and extending into southwest Texas, and southwest Oklahoma.

The *Intermountain* region, including eastern Washington, eastern Oregon, northeastern California, Idaho, Utah, western Montana, western Wyoming, and western Colorado.

The *Great Plains* area, extending from central Canada southward to Texas, and from the Rocky Mountains east to about the ninety-seventh meridian.

The *North Central*, the region east of the ninety-seventh meridian and north of the Ohio River.

The *Northeast*, the general region to the east and north of the State of Ohio.

The *Southeast*, the States east of the ninety-seventh meridian and south of the Ohio River.

It is not always possible to distinguish between the seeds from States within a geographic division. With experience, however, it will be found that the weed impurities of the smaller subdivisions present a rather definite pattern, and fairly reliable conclusions may be drawn as to the place of origin of the seed.

LIST OF SEED IMPURITIES AVAILABLE

A list setting forth the more significant impurities to be expected in both domestic and imported seeds of certain grasses and legumes, particularly alfalfa and red clover, is being prepared and may be obtained from the Grain Branch, Production and Marketing Administration, U. S. Department of Agriculture, Washington 25, D. C., when completed.

TESTING FOR TRUENESS OF VARIETY

SCOPE OF VARIETY TESTING

The term "variety" means a subdivision of a kind which is characterized by growth, plant, fruit, seed, or other characters by which it can be differentiated from other sorts of the same kind; for example, Marquis wheat, Flat Dutch cabbage, Manchu soybeans, Oxheart carrot, and so forth.

At the present time the testing of crop seeds for trueness to variety is carried on to some extent by the Federal seed laboratories and a few State seed control agencies. Variety testing is not carried on by seed control agencies in the United States on as large a scale as that in some European countries.

PURPOSE OF VARIETY TESTING

Since most crops cannot be identified as to variety on the basis of seed characteristics alone it is often necessary to make growing tests for varietal identification.

Federal and State laws require that labeling of seed as to variety shall be correct. It is important to the grower to be able to select and obtain a variety of seed adapted to his needs.

AUTHENTIC SAMPLES FOR CONTROLS

Whenever possible authentic seed of known origin, of the same variety as that being tested, should be grown beside the variety in test for purposes of comparison. The two samples should be planted at the same time and given identical cultural treatment. This authentic seed grown for comparison is commonly referred to as a "check." Seed for check plantings should be obtained from the most reliable sources possible. These sources include the person, firm, or agency that developed or introduced the variety, as well as reliable seed firms and agencies known to have authentic seed of the variety. Sometimes when two or more varieties are very similar, it is desirable to obtain and grow check samples of all the similar varieties with the sample being tested.

NUMBER OF PLANTS TO GROW

The number of plants to be grown for a variety test is a matter which has not been standardized. In variety tests conducted by the Federal seed laboratories an effort is made to obtain at least 200 plants of most crops. Those crops which produce large plants such as tomato, pole bean, and the cucurbits require so much field space that the number of plants grown is usually limited to 100 for each test. The greater the number of plants obtained for judging, the more reliable the results will be.

Clark (*12*) made a study of the number of plants for a variety test and concluded that the magnitude of discrepancies which may occur

when fewer than 50 plants are included is so large that such tests should be avoided if possible. He also concluded that the increase in precision obtained by including more than 100 plants in a test is relatively slight, and that when plants require considerable space and care the expense of larger plantings is not justified. If too few plants are obtained, the planting loses its value as a representative of the lot of seed being tested and therefore is of little value.

TESTING IN THE FIELD

Most variety tests, particularly those carried out on a large scale, are made in the field. It is necessary that the best possible plants be obtained in a variety test so that the characteristics typical of the variety may have optimum conditions to express themselves. This requires (1) growing the plants in areas where the crop is adapted, (2) growing the plants under the best possible accepted cultural practices, and (3) growing the plants during the proper season.

It is necessary to grow the plants under the above-named conditions in order to: (1) Prevent the plants from shooting to seed or "bolting," as spinach, lettuce, and many species of *Brassica* do in hot weather; (2) obtain proper diagnostic color characteristics, such as zoning in beet roots and pigmentation in lettuce leaves; (3) eliminate as far as possible damage due to insects and diseases which are more harmful in certain seasons in some localities; and (4) assure a period sufficiently long for the crop to mature.

In some cases, seed must be planted in a greenhouse and the young plants transplanted to the field at a later date.

Growing of plants under poor cultural conditions, disease conditions, unfavorable environmental conditions, and in areas of heavy insect infestations may alter their development to an extent that would make accurate variety determinations uncertain. An example of failure to exhibit typical characteristics when crops are grown under poor cultural conditions is the suppression of the savoying character in some vegetables, notably spinach, cabbage, and Swiss chard. Savoying is the wrinkling and curling of the foliage of some varieties. When not well grown this characteristic may scarcely develop at all and the variety may not be recognized. Sometimes improperly grown plants may not be typical of the variety, but resemble another variety so closely as to make correct identification difficult or impossible.

An example of this is the Fordhook Giant variety of Swiss chard. Poorly grown and insufficiently fertilized, it may not develop the deep green color which is characteristic of the variety, but may make yellow green leaves and appear identical to the variety Lucullus. Or, it may not only be pale in color, but may lose, to a large extent, the extreme savoying of the foliage and thereby be mistaken for a smooth-leafed variety. Such tests should be discarded and the results disregarded.

When seeds of many crops are planted directly in the field it is necessary to thin the plants to the accepted spacing in order to provide for normal growth. In testing for varietal identification thinning should be done only for proper spacing between the plants. Thinning should not be done on the basis of size, vigor, or appearance of the young plants because, in the case of mixed varieties, selective thinning may decrease the proportion of one or more varieties below its actual

rate of occurrence and increase the rate of occurrence of other varieties.

In such a procedure the mature plants which are to be judged for variety will not be representative of the lot of seed being tested. In order to eliminate possible bias in the thinning operation it is good practice in variety testing to thin the plantings early; if possible, before varietal characteristics begin to appear.

TESTING IN THE GREENHOUSE

Greenhouse testing can be of considerable importance in making variety determinations. A greenhouse is not only necessary for starting plants which are to be set in the field at a later date, but complete tests of some kinds of plants can be made, particularly during seasons when they cannot be grown in the open. Also, special conditions may be provided in the greenhouse which aid in variety testing and which cannot be duplicated in the field.

The length of day or photoperiod may be increased by use of artificial light in the greenhouse. The additional light alters certain characteristics of some plants in ways which permit rapid varietal identification.

An ordinary 100-watt Mazda lamp over one or two flats in the greenhouse is sufficient to induce these changes. Care should be taken that the lamp is not so close to the plants as to damage them or dry the soil. The distance between the plants and the lamp may need to be increased one or more times during the test period. Precaution should be observed in growing plants under continuous light in the greenhouse to be certain that light does not reach other greenhouse plants nearby, as some may be very susceptible to low intensities of supplemental light and possibly develop abnormally. Undoubtedly, regulation of the photoperiod in greenhouse tests may serve as a useful tool in variety testing of many kinds of seeds which are not discussed in this manual.

Biennial sweetclover, which normally does not flower until the second year in the field may be brought into flower in a period of a few weeks in the greenhouse when grown under continuous light, thus permitting an actual count of yellow blossom and white blossom plants. A complete test of sweetclover may be made within a period of 10 to 12 weeks. The lights should be turned on the plants every evening from the time the seedlings emerge. Flowering may take place when the plants are anywhere from 6 to about 12 inches in height. The plants may have single unbranched stems and take up so little space that as many as 200 may be grown in a single greenhouse flat. In a flat 12 by 24 inches at least a dozen rows may be planted, rather thickly. As soon as some of the plants show flower color, they should be pulled out and counted, thus providing more growing space for the remaining plants. Counts should be made every 2 to 4 days until all have flowered.

Although some soybean varieties may be identified by seed characters alone, many cannot. Greenhouse plantings can be helpful in such cases. Seedling characters serve to distinguish some varieties when grown under normal light. Certain varieties can be brought into flower at an early date by increasing the photoperiod with supplementary artificial light, thus making it possible to identify the plants. Others can be held in the vegetative condition by decreasing

the normal daylight period. Characteristics which have been found of value in identifying varieties of soybean in the seedling stage include the following: (1) Size and color of hypocotyl; (2) shade of green of seedling; (3) size and shape of cotyledons 8 days after planting; and (5) pitting or lack of pitting on underside of cotyledons.

Annual rape grown under continuous light in the greenhouse may develop flower buds within 3 weeks. The test period may be reduced even more if the terminal bud is dissected before it opens, to determine whether it is a flower bud or vegetative bud. When grown under the same conditions, winter rape will remain in the vegetative state and not produce flowers. Seeds of the two kinds are difficult to distinguish and the rapidity of the greenhouse test is helpful in differentiating them.

Variety tests of onions may be made in the greenhouse during the winter. However, the short winter photoperiod prevents bulb formation. Continuous supplemental light causes the onion to form bulbs, making it possible to observe their shape and color for varietal determination.

Abruzzi and Rosen rye respond differently when grown in the greenhouse under continuous light. Plants of the Rosen variety do not head out within 90 days after planting, whereas over 70 percent of the Abruzzi plants will head out or will be ready to head out within that period.

Partial tests without obtaining mature plants may be carried on in the greenhouse and may give information indicating that complete tests should or should not be made in the field. Such incomplete tests which do not serve definitely to identify a variety are frequently of value in that they demonstrate that a certain lot of seed cannot be of the variety claimed. An instance of this kind would be a mixture of seed of red and green cabbage. In the seedling stage (before the true leaves have begun to develop) the cotyledonary leaves of the red cabbage will be edged with red and the midvein and stem will be red, whereas in the seedlings of the green cabbage these areas will be green. Varieties of yellows resistant cabbage may be distinguished from nonyellows resistant varieties by inoculating seedlings in the greenhouse and observing them in order to determine the numbers that are killed and not killed.

Some tomato varieties differ from others in their shades of green in the seedling stage. Also, the leaves of the potato-leaf varieties are different in shape from those of other varieties in the seedling stage. Such evidence is of a negative nature, proving that a lot of seed cannot be of a certain variety; however, it is usually not possible to tell to what variety the seed does belong.

Greenhouse seedling tests have an advantage in that large populations may be obtained in very small growing areas in a short time. Sterilized soil should be used whenever possible. It is possible that seedling tests in the greenhouse may be of value in testing many kinds of seed and the benefits to be gained appear to justify more experimental work along these lines.

JUDGING THE CROP

Judging the crop for trueness to variety and making notes on it is commonly called "reading" a test. Readings must be made at the

proper times because some varietal characteristics become indistinct when not observed soon enough, or the characteristics may not have had time to develop if read too early. In many cases observations must be made at several dates during the development of the plants in order to note varietal characteristics of a transitory nature. For example, the uprightness or spread of tomato plants, which is a diagnostic character of some varieties, must be noted before the plant becomes heavy with fruit and sprawls on the ground. A thorough knowledge of the characteristics of the variety and good judgment are necessary when identifying plants which are not definitely and obviously of a recognized variety. These plants may be of a degenerate stock, outcrosses, or may have suffered some type of injury. The person making the readings must determine whether such plants are merely poor stock, but within the variety range, or whether they are beyond the limits of the variety. He must keep in mind that they may be true to variety but altered by injury from cultivators, insect damage, or other causes to the extent that they no longer have their natural appearance. Familiarity with the variety under test is essential for the person making the readings.

A variety test may show any of the following results: (1) All plants may be of the variety as labeled; (2) the entire sample may be of a variety other than as labeled; (3) there may be a mixture of plants of one or more varieties in addition to the variety labeled; (4) there may be plants beyond the range of variety, commonly referred to as "off-type" plants; or (5) there may be related weeds such as weedy species of *Brassica* in crops of the genus *Brassica*.

Because of confusion, in some cases resulting from similar names and synonyms, it is essential that the person making the test should be absolutely sure of the characteristics of each variety he is testing, and, furthermore, he should be sure that he has a sample of the correct variety for check planting.

TESTING FOR MOISTURE

The moisture content of seeds is one of the most important factors influencing their retention of viability and general appearance. It is frequently desirable to know the moisture content of seed immediately after harvest, prior to storage or shipment, and at other times, in order that the seeds may be stored or shipped under conditions favorable to retention of viability. For these reasons seed-testing laboratories are sometimes called upon to test seeds for moisture or to offer information regarding methods of testing for moisture. A brief summary of available information on this subject may serve as a guide to those interested in testing seeds for moisture content.

Methods for determining moisture in seeds may be roughly classified into: (1) Basic methods in which the moisture is driven out of the seeds by heat and measured by the loss in weight of the original material, or the weight or volume of the condensed moisture; and (2) practical methods designed for rapid routine work and standardized against one or more of the basic methods. Even the basic methods should be considered rather empirical because all the moisture probably cannot be driven out of seeds without at the same time driving out small amounts of other volatile constituents, or causing chemical changes in the material that would result in weight changes that in turn would introduce errors in the moisture determination. In applying any method, therefore, it is necessary to adhere closely to the prescribed procedure in order that the results of all tests made by that method will be comparable. It also follows that tests made by different methods may, in many instances, not be strictly comparable.

Except for the cereal grains and a few other seeds there is a conspicuous lack of well recognized or "official" methods for determining moisture content. Recognized and suggested basic methods for determining moisture in various seeds are outlined as follows:

BASIC METHODS

AIR-OVEN METHODS

An air-oven method in which a weighed portion of the finely ground material is heated in an air oven for 1 hour at 130° C. and the loss of weight determined, is the official basic method under the official grain standards of the United States for determining moisture in all grains except corn. It is also the official basic method under the official rice standards of the United States for determining moisture in rice. If the initial moisture of the grain or rice is in excess of 13 percent a two-stage procedure is used in which a weighed portion of grain is partially dried to a moisture content of less than 13 percent before grinding, and the loss of weight in this preliminary drying is determined. The partially dried grain or rice is then ground and a weighed portion dried for 1 hour at 130° C. In calculating the moisture content of such grain or rice the moisture losses in both stages of the procedure must be taken into consideration. Complete details

for making moisture tests by this air-oven method are given in Service and Regulatory Announcements No. 147 (*47*).

One of the official methods of the Association of Official Agricultural Chemists for determining moisture in grain is an air-oven method in which a weighed portion of the finely ground grain is heated in an air oven for 2 hours at 135° C. and the loss of weight determined. Complete details for making moisture tests by this air-oven method are given in the Official Methods of Analysis of the Association of Official Agricultural Chemists (*5*).

Leendertz (*33*) has suggested an air-oven method in which the ground seed is heated for 105 minutes at 130° C. as a suitable method for ryegrass, beet, spinach, parsley, carrot, lettuce, chicory, and various *Brassica* seeds. For onion and radish seeds he suggests heating the material for 12 hours at 105° C.

Any of the above-mentioned air-oven methods should prove to be reasonably satisfactory for most seeds except those that contain more than about 25 percent of oil or that contain oil having an iodine number higher than about 150. Seeds with a high oil content usually cannot be satisfactorily ground without loss or gain of moisture; and seeds containing oil of high iodine number should be tested by a method not requiring grinding of the seeds, since the oil in the ground material will oxidize readily on heating which in turn will cause a gain in weight that will interfere with the accuracy of the moisture determination. In all instances care should be taken to avoid any appreciable loss or gain of moisture during the grinding process. It is safer to use a two-stage procedure when the moisture content is in excess of about 13 percent.

WATER-OVEN METHOD

The official basic method for determining the moisture content of corn under the official grain standards of the United States is a water-oven method in which a weighed portion of the unground corn is heated for 96 hours in a water-jacketed oven maintained at the temperature of boiling water (99° to 100° C.) at an atmospheric pressure of 760 mm. The moisture content is determined from the loss of weight during heating (*47*). This method is also the official basic method for determining moisture in dry peas and beans under the official standards of the United States for these commodities.

VACUUM-OVEN METHOD

One of the official methods of the Association of Official Agricultural Chemists for determining moisture in grain is a vacuum-oven method in which a weighed portion of the finely ground grain is heated, until no appreciable further loss of weight occurs (usually about 5 hours), at 98° to 100° C. in an oven in which a partial vacuum is maintained at a pressure equivalent to 25 millimeters of mercury or less. The moisture content is determined from the loss of weight during heating (*5*). This vacuum-oven method should prove to be reasonably satisfactory for most seeds with the exceptions noted above for seeds of high oil content or that contain oil of high iodine number.

Seeds that contain more than about 25 percent of oil or that contain oil having an iodine number higher than about 150 present a special problem in moisture testing. Perhaps the most satisfactory method for such seeds is the vacuum-oven method outlined above except that the seeds should not be ground. The time required to attain constant weight under such circumstances may be considerably longer than 5 hours.

TOLUENE DISTILLATION METHOD

Another of the official methods of the Association of Official Agricultural Chemists for determining moisture in grain is the toluene distillation method in which a weighed portion of the finely ground grain is boiled in toluene in an apparatus that condenses the volatilized materials, collects the condensed water in a tube, and returns the condensed toluene to the boiling flask. The boiling is continued as long as any water continues to accumulate in the tube provided for that purpose, and the moisture content of the grain is calculated from the volume of water condensed (*5*). This method should prove to be reasonably satisfactory for most seeds that can be satisfactorily ground without any appreciable loss or gain in moisture.

PRACTICAL METHODS

In certain types of practical work it is necessary to make moisture tests more quickly than can be done with any of the above-mentioned basic methods. Arbitrary practical methods standardized against one or more of the basic methods have been devised for this purpose. In general, the results obtained by such methods are likely to be less accurate than those obtained by the basic methods, but they may be sufficiently accurate for most practical purposes. The most commonly used of these methods are described briefly as follows:

THE BROWN-DUVEL DISTILLATION METHOD

For many years moisture content was determined in the routine inspection of grain by heating a weighed portion of unground grain in oil to a definite temperature attained in a definite period of time. The moisture volatilized by this heating is condensed, then collected and measured in a graduated cylinder. The method is arbitrary and the exact procedure to be followed for each kind of grain in order to obtain results equivalent to those obtained by the applicable official basic oven method has been determined. This method is described in Bulletin No. 1375, U. S. Department of Agriculture (*13*).

The Brown-Duvel method should be applicable to most seeds but before it can be used it would be necessary to determine the exact procedure necessary for each kind of seed in order to obtain results equivalent to those obtained by an appropriate basic method. The proper procedures have been established for wheat, corn, oats, rye, grain sorghums, barley, buckwheat, flaxseed, soybeans, emmer, rice, beans, peas, mustard seed, cottonseed, and peanuts (shelled).

The Brown-Duvel moisture tester has been largely replaced by electric moisture meters in the routine inspection of grain, but it is still used under various conditions of testing in which electric meters cannot be depended on to give reliable results.

ELECTRIC MOISTURE METERS

Electric moisture meters are now widely used in routine work for the determination of moisture in grain. They have a great advantage in speed over all other methods for determining moisture. Most of these instruments are based on measurements of either the conductivity or the dielectric properties of the grain. Both the conductivity and the dielectric properties of any kind of grain depend primarily on the moisture content and temperature of the grain, but they also are affected to some extent by many other variable factors. For this reason electrical methods cannot be depended on to give reliable results under all circumstances.

It is probable that the moisture content of most kinds of seeds can be determined with a fair degree of accuracy under most circumstances by means of electric moisture testers. In using any electric moisture tester, however, it is first necessary to calibrate the instrument against an accepted basic moisture-testing method. Separate calibrations must be made for each kind of seed, and in the case of some kinds of seed it is also necessary to make separate calibrations for individual classes, varieties, or varietal types. Because of the errors inherent in electric moisture-testing methods, each calibration should be based on the testing of a large number of samples, covering a wide range in moisture content, obtained from as many different points of origin as possible, and preferably representing the crops of at least several years. It is obvious, therefore, that a large amount of work is necessary before a reliable calibration table or chart can be prepared for use in testing any kind of seed with any electric moisture tester. Much work has been done in calibrating certain electric moisture meters for use with the various cereal grains but relatively little has yet been accomplished in this field for most other kinds of seed.

TOLERANCES

DEFINITION AND NECESSITY OF TOLERANCES

If an entire seed lot could be tested, its true value would definitely be ascertained; however, this is neither feasible nor ordinarily possible. Thus, in seed testing the quality of the lot must be determined from a sample that represents the entire lot. Owing to the time and facilities involved small samples must usually be tested. The size of the sample to be tested is an important factor in determining the quality of the lot because the determinations become less accurate as the sample size is reduced.

It is well known that results of tests cannot be exactly duplicated on repeated testing of another portion of the same sample or by testing additional samples from the original seed lot. This is true, because no two subsamples drawn from the master sample or from the seed lot are exactly alike. This expected variation in samples is due to the nonuniform distribution of seeds and other particles in the seed lot and is usually referred to as sampling variation.

Thus, sampling variation is normal, even in seed lots which are relatively uniform, and the laws of probability can be applied to the results of tests to predict the expected variation. When the approximate sample size is known, or when it is a standard quantity as set forth in the rules, the expected variation can be calculated for the different percentages of purity and germination, and for the number of noxious-weed seeds, for any degree of certainty or probability desired.

In many statistical treatments of data several results are averaged to get the mean of all the tests made and the statistical inference is that the mean is the correct value plus or minus a calculated amount. In seed testing we ordinarily deal with only one-half the range of variation—that is, we either add or subtract the calculated amount (tolerance) to the results of a test or to a fixed standard, but not both. For example, the pure seed tolerance for alfalfa having a purity of 97.0 percent is 1.18 percent. If 97.0 percent is a standard or fixed number any test result as low as 95.82 percent would be within tolerance of 97.0. Although not of much importance in seed testing it is nevertheless true that any test result as high as 98.18 percent is also within tolerance of 97.0.

In most seed-testing work the result of a test is not compared with a fixed standard but the result of a single test is compared with that of another single test. In this case neither test can be regarded as more valid than the other. However, the expected variation between two tests, conducted independently, has been calculated for each percentage of pure seed, weed seed, and so forth and for the number of noxious-weed seeds. If the results of two such tests are within the calculated tolerance it can be concluded that each represents a valid test on a representative sample drawn from the seed lot. If, on the other hand, the two results are not within tolerance it cannot be concluded that either represents a correct test (plus or minus the tolerance) of

the seed. However, either party may be able to show, by repeated tests, that his test result represents an accurate statement and that the other test could not possibly represent seed of equal quality.

Thus, in seed testing the tolerances represent (*a*) the expected variation between a fixed standard and the extreme limit of calculated variation, and (*b*) the expected or normal variation between two tests conducted independently of each other. The value of the seed lot may be better or worse than the result of a valid test to the extent of the tolerance.

Statistically calculated tolerances are not expected to cover variation in results caused by experimental error, differences of interpretations, or lack of uniformity in seed lots. However, in some instances, rather arbitrary and empirical factors have been introduced into the tolerances which may cover some variations of this nature.

PROBABILITY OR DEGREE OF CERTAINTY

In the above discussion reference has been made to calculating tolerances to a predetermined degree of certainty, often referred to as probability. In calculating the tolerances for pure seed (or any other component) the tolerances may be so wide that in 100 trials of the same bulk of uniformly blended seed at least 95 would be within tolerance. This degree of certainty is referred to as P=0.05 or 1:20 and means that no more than 1 in 20 trials would be expected to be outside tolerance. As the tolerances are increased there is less chance that any test result will be outside the tolerance range. If the tolerances are calculated to P=0.01 as has been done and published in the Canadian *Methods and Procedures of Seed Testing* (*10*), there is not more than 1 chance in a 100 that the result of a valid test will fall outside the tolerance range. The choice of the probability used in calculating the tolerance is arbitrary and determined by the nature of the data and the use to which these data will be put. In seed testing and seed regulatory activities a probability statement of P=0.05 has been generally accepted. Once the degree of certainty is adopted the limits of tolerance can be read directly from published tables. Probabilities of P=0.05 and P=0.01 are referred to as significant and highly significant, respectively.

PURE-SEED TOLERANCES

Pure-seed tolerances are calculated from the formula $0.6+\left(0.2\times\frac{a\times b}{100}\right)$. In this formula a represents the percentage of the component being considered (pure seed, crop seed, weed seed, inert) and b represents the difference between this percentage and 100.

Because the distribution of the particles in chaffy grasses is not so uniform as in free-flowing seeds an extra tolerance is added to that calculated by the above formula. The additional tolerance is found by multiplying the regular tolerance (calculated by the formula given above) by the lesser of a and b divided by 100. Tolerances for other crop seeds, weed seeds, and inert matter for both free-flowing seeds and chaffy grasses are calculated by the formula and procedure given above, except that 0.2 is substituted for the 0.6 outside the parentheses. These purity tolerances are not based entirely on statistics but might be regarded as arbitrary tolerances. The 0.6 and

0.2 outside the parentheses are arbitrary values selected to cover or compensate for chance errors inherent in seed testing. The remainder of the formula constitutes a sliding or shifting value to cover systematic errors due to sampling variation.

GERMINATION TOLERANCES

The germination tolerances used in the United States are purely arbitrary and are somewhat wider for germination percentages of 60 to 100 than statistical tolerances for 400 seeds at $P=0.05$. They do not take into consideration the number of seeds tested nor any particular degree of certainty. The constant germination tolerance of 10 for all tests falling below 60 percent is entirely out of line with statistical tolerances. Statistical tolerances gradually decrease as the percentages of germination increase above 50 percent and decrease below 50 percent. For example, tolerances calculated to a degree of certainty of 1 to 20, on the basis that 2 independent tests are made on 400 seeds per test, would decrease from 6.9 for 50 percent germination to 1.8 at 1 percent germination. No doubt, differences in interpretation of the germination test leading to wide variations in test results have been an important factor in retaining the arbitrary germination tolerances.

NOXIOUS-WEED SEED TOLERANCES

The rate of occurrence of noxious-weed seeds is stated in numbers per unit weight. It is important to determine the rate of occurrence accurately. The accuracy of such a determination depends on the number of noxious-weed seeds found rather than on the size of the sample examined. When a small number of individual particles are concerned, as is usually the case in testing for noxious-weed seeds, it is not possible to state definitely the amount of seed to be examined for a desirable given degree of certainty. However, in order that results of different tests on the same lot of seed may be compared it is necessary to use samples of standard size. When comparing the results of a test with a fixed standard, it is necessary to base the statement in the standard on the same quantity as tested. For example, a seedsman claims 90 dodder per pound in lespedeza seed but the analyst may find 15 in 50 grams. The 90 dodder in a pound represents 10 in 50 grams and thus 15 should be compared with 10—not 135 (9×15) with 90.

The noxious-weed seed tolerances are based on the Poisson distribution and calculated to a certainty of $P=0.05$ by the formula $Y=X+\sqrt{3.841X}+1$, where Y is the number of noxious-weed seeds for which the tolerance is being calculated and X is the lowest limit of the tolerance range.

The wording of the State seed laws will have to be used as a guide in determining whether tolerances are to be applied to each kind of noxious-weed seed or to the total of all kinds found, or both.

TOLERANCES FOR FLUORESCENCE TESTS AND OTHER 400- TO 1,000-SEED SEPARATIONS

Various kinds of tests are made on 400 to 1,000 seeds, such as the fluorescence test of ryegrass, varietal separations, and separations of similar kinds of seeds. Although the present rules for seed testing

specify that 5 grams of sweetclover seed shall be used in the mottled seed test, it is entirely possible that this amount may be reduced in the future to a specific number of seeds. In all these cases where a specific but relatively small number of seeds is used special tolerances must be recognized. Tolerances for 400- to 1,000-seed separations have been calculated to a certainty of $P=0.05$ and appear in the Appendix.

In all these tests a previous purity test is made in which the sample is separated into seed having similar characters, other crop seed, weed seed, and inert matter. The 400- to 1,000-seed test is used to separate the seeds having similar characteristics. Therefore, the tolerances mentioned above cover only the latter part of the test. It has been learned by experience that tolerances obtained by addition of the regular pure seed tolerances and the 400- to 1,000-seed tolerances are too wide. Consequently, only ½ of the pure-seed tolerances are added to the 400- to 1,000-seed tolerances.

APPLICATION OF TOLERANCES

There are certain allowances permitted in connection with the testing and labeling of seed which should not be confused with tolerances. Such allowances as including 5 percent of straw-colored Sweet Sudan grass seed with pure seed and 5 percent of fluorescent ryegrass seedlings with perennial ryegrass are not tolerances. Likewise, some State laws permit specified numbers of noxious-weed seeds above which none are permitted or above which labeling is required. These are definite allowances and not tolerances. If tolerances are not used with these allowances, the only completely safe way seedsmen can label seed to comply will be to subtract the tolerance from the allowance and refrain from selling any seed showing noxious-weed seeds in excess of this amount. If the seedsman uses test results falling within the tolerance range of a fixed standard, he is running a risk that the true value of the seed lot is below the standard and that a control laboratory may obtain results outside the tolerance range. In making a single test one never knows the position in the tolerance range in which his test result will fall.

Since tolerances are provided to take care of the unavoidable variation in test results they are not to be applied prior to labeling by adding them to the results found by test. Tolerances should never be used for the purpose of permitting labeling to show higher quality than is actually found by the test.

The various tolerances used in connection with the rules for seed testing are listed in the Appendix, pages 356 to 368.

CALCULATIONS, RECORDS, AND REPORTS

CALCULATION OF LABORATORY TEST RESULTS

PURITY

The rules for seed testing provide that the percentage by weight of each component of the pure seed separation shall be determined by totaling the weights of all components and dividing the sum (and not the original weight) into the weight of each. This is illustrated in the following example:

Component	*Weight, Grams*	*Percent*
Pure seed	4.945	94.92
Other crop seed	0.120	2.30
Inert matter	0.050	0.96
Weed seed	0.095	1.82
Total weight	5.210	100.00

The only exception to the above procedure is when the working sample is 500 grams. In this case, the other crop seed, weed seed, and inert matter are weighed. The original weight is divided into each of these to determine the respective percentages. The pure seed percentage is determined by subtracting the sum of the percentages of inert matter, other crop seeds, and weed seeds from 100 as illustrated in the following example:

Original sample weight=502.8 grams

Component	*Weight, Grams*	*Percent*
Pure seed	----	----
Other crop seed	2.56	0.51
Inert matter	3.25	.65
Weed seed	1.74	.35
		1.51

Pure seed=100.00—1.51=98.49 percent

Procedures and examples of recording results and calculating percentages of mixtures based on 400- to 1,000-seed separations are given under the heading "Application of Purity Procedures to Specific Groups of Seeds" for the following kinds: Bluegrasses; bentgrasses; sorghums; oats; Sweet Sudan grass; and millet. Specific procedures and examples of calculating results are also given in the same section for a 5-gram separation of mottled seeds of sweetclover and the fluorescence test of ryegrass.

The above-named special tests are made by first conducting a regular purity analysis and then taking a small subsample from the pure seed and making a critical separation of either a definite number of seeds or a weighed amount. The percentages of the regular purity analysis are determined in the usual way; then determine the percentage of each component in the subsample and multiply each of the latter by the percentage of pure seed in the regular purity analysis.

Example: Bluegrass mixture

a. Regular purity analysis—	*Weight, Grams*	*Percent*
Pure seed	0.9438	85.80
Other crop seed	.0082	.75
Inert matter	.1364	12.40
Weed seeds	.0116	1.05
	1.1000	100.00

b. 1,000-seed separation—	*Number of seeds*	*Percent*
Poa pratensis	835	83.50
Poa compressa	115	11.50
Poa trivialis	50	5.00
	1,000	100.00

$$85.80 \times \begin{cases} 83.50 = 71.64 \\ 11.50 = 9.87 \\ 5.00 = 4.29 \end{cases}$$

85.80

Report the following:

Pure seed—	*Percent*
Kentucky bluegrass	71.64
Canada bluegrass	9.87
Other crop seed (0.75+4.29)	5.04
Inert matter	12.40
Weed seeds	1.05
	100.00

GERMINATION

Four hundred seeds should be used for each germination test. In cases where it is impossible to separate varieties or indistinguishable kinds of pure seed, such as ryegrass and sweetclover, only one germination test is made and the result is interpreted to represent the germination of each kind or variety tested. When the kinds of pure seed can be separated a complete germination test is made on each kind.

The numbers of germinating seeds should be recorded on the test card at the time of each count. At the end of the test period, the hard seeds (if present) are recorded. The numbers of germinated and hard seeds are then totaled and each divided by 400 (the number of seeds tested) to obtain the percentages of germination and hard seed.

Although not regularly reported, the number and types of abnormal seedlings present should be recorded. Retests are sometimes avoided by an explanation of the types of abnormal growths. Notes should also be made on the record card regarding any unusual condition of the sample, such as the presence of excessive mold, live or dead insects, evidences of frost damage, decayed seeds, chemical injury from fungicides, or the presence of disease. For example, in recording the results of germination tests for beans which have been mechanically damaged, the record card should include information under the following headings:

1. Normal (usually the only percent reported besides the hard seed).
2. Abnormal:
   a. Baldheads (all types).
   b. Other abnormals (various types including those with malformed hypocotyls and stubby roots).

c. Splits (those with cotyledons too broken for growth to continue beyond the formation of enlarged leaves within the cotyledons, and vestiges of root and hypocotyl).

3. Decayed seed.

4. Hard seed.

If fungi are present, their presence should be indicated. Any other unusual conditions of the seed should also be noted.

LABORATORY RECORDS

Records of purity and germination tests are preferably written in ink on small cards which should be filed for future reference. The form will vary with the needs of the laboratories. Copies of suggested purity and germination forms are given on pages 369 and 370 in the Appendix.

REPORTING THE RESULTS OF TESTS

The report of results of the purity analysis should give all calculated percentages. Results of germination tests are reported in round numbers, fractions of one-half of 1 percent or more being regarded as the next whole number; and fractions of less than one-half of 1 percent being dropped. For example, an actual germination of 90.50 percent would be reported as 91 percent, and a germination of 90.49 as 90 percent.

The analyst must frequently decide which of two results to report when a sample is tested for germination by more than one method or when a check test of any kind is made. The Standardized Test Committee has recommended that the results of the different tests be averaged, if within tolerance. If not within tolerance, the higher result should be reported. This appears to be a logical procedure and it is followed in the Federal laboratories. In no case should tolerances be added to the percentages reported for either the purity or germination test.

Noxious weeds are reported as the number found in the weights examined. This may be expressed as number per unit weight, in grams, ounces, or pounds.

Incidental weed seeds should be listed and may be reported as the number or percentage found in the weights examined; or the figures may be converted and reported as the number present per pound. In the Federal laboratories the incidental weed seeds are merely listed and not reported by number or percent found, unless they are present to the extent of over one-half of 1 percent by weight.

In all cases the laboratory report should be clear and concise and any pertinent information regarding the seed covered by the report should be given.

The purity and germination report forms may vary, depending on the requirements of each laboratory. Copies of two report forms used by the Federal laboratories are illustrated in the Appendix, pages 371 and 372.

IDENTIFICATION OF SEEDS[4]

The identification of seeds is a specialized field of taxonomic botany that is still comparatively new. Although the character of the seed remains remarkably constant under varying environmental conditions, its use as a classification feature has been overlooked throughout the years and information on the identification of seeds is still very meager. Seeds of plants are rarely described in taxonomic publications and the seeds, when illustrated, usually show little diagnostic detail.

Just before the turn of the century, the need for identification of seeds arose as a result of the desire on the part of growers and dealers for information on the trueness to name of seeds to be planted, and the nature of the extraneous seeds that the crop seeds might carry.

The present study includes: (1) Seeds of all field crops, other than vegetable, except those that offer no problems in seed identification, such as cotton and peanuts; (2) seeds of plants declared primary or secondary noxious weeds under the seed laws of the different States; (3) common field weeds, including relatively harmless weeds that could be confused with closely related noxious weeds; and (4) newly introduced weeds. Included also are some seeds found only in imported seed that may serve to indicate origin, or that may in time become naturalized in this country.

It was impossible to consider such a large number of plants in as great detail as the amount of available material and its usefulness would warrant, and the question of which to include and which to omit presented a real problem. The principal criterion used in determining the selection was the economic importance of the plant, or its suitability as a representative of the family to which it belongs. It was necessary to limit the number of species in the following genera: *Agropyron*, *Agrostis*, *Avena*, *Festuca* (fine-leaved species), *Panicum*, and *Brassica*. These have been published in detail elsewhere, as listed under "Available Publications on Seed Testing," page 318.

Most of the cereal and forage crops belong to the grass or legume families, and seeds of these species are fully described and illustrated on plates I to XII and plates XVIII to XXIII, respectively. Descriptions are also included of the more important groups in the mustard, morning-glory, and pink families. The more important

[4] Pioneer work on seed identification in this country was conducted by F. H. Hillman, formerly on the staff of the Federal Seed Laboratory, who made outstanding contributions in this field. In 1918, with the assistance of Helen H. Henry, he prepared the first comprehensive treatise on crop and weed seeds under the title "The More Important Forage-Plant Seeds and Incidental Seeds Commonly Found With Them." This publication consisted of 15 photographic plates of seed drawings of 370 species of plants. The 15-plate set was reissued by the Department of Agriculture in 1935, and it is still considered a standard reference on seed identification in seed laboratories in this country. Use has been made in this Manual of many of these illustrations, as well as many hitherto unpublished drawings by Mr. Hillman and Miss Henry. The additional illustrations appearing in this Manual were prepared by Regina Olson Hughes.

species in 51 other families are illustrated. The names and plate numbers of these families and species may be found in the Lists of Plant Names, pages 373 to 423.

It frequently happens in describing seeds that there is no term that specifically applies, and the usual botanical terminology must be used in a modified sense. These terms are defined in the Glossary in the sense in which they are used throughout this publication.

GRAMINEAE (GRASS FAMILY)

(Pls. I–XII)

Flowers of the grass family (fig. 63) are arranged in spikelets consisting of a shortened axis (rachilla) and from two to many two-ranked bracts. The lowest bracts, called the glumes, are empty. The bracts above (lemmas) each bear a single flower (pistil and stamens), and between the flower and the rachilla is a second bract, the palea. The spikelets are usually aggregated in spikes or panicles at the ends of the main culm or branches.

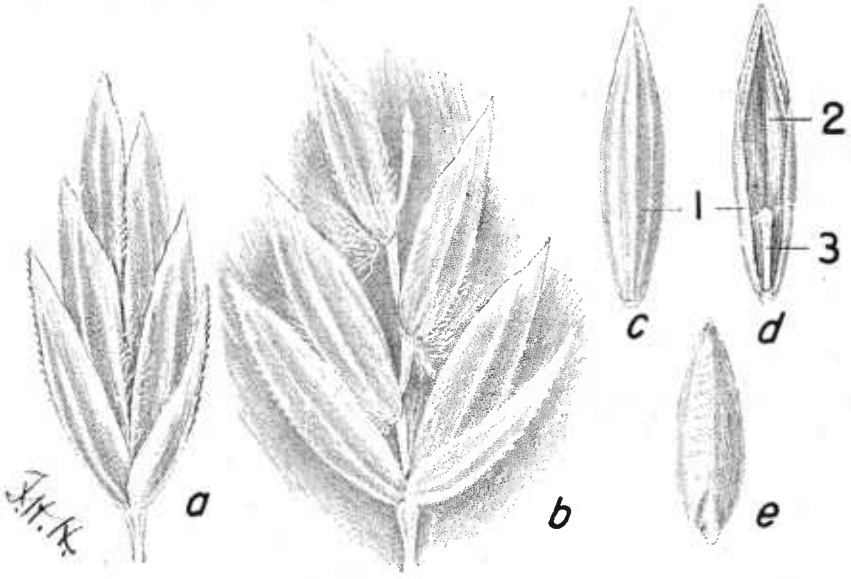

FIGURE 63.—A spikelet and florets of bluegrass: *a*, Spikelet as it appears at maturity; *b*, the spikelet spread apart, showing the jointed rachilla, the two empty glumes at the base, and four mature florets above; *c*, back view of a floret, showing the lemma (1); *d*, front view of a floret, showing the edges of the lemma (1), the palea (2), and the rachilla segment (3); *e*, the caryopsis, showing the embryo area at the base.

The fruit of the grass family is the ripened floret, consisting of a caryopsis or grain enclosed in the two chaffy scales, the lemma and palea. In most of the species considered herein, the spikelets are several-flowered and a joint of the axis (rachilla) persists at the base of the palea and is often an important diagnostic feature. In the species having one-flowered spikelets the rachilla is lacking or merely a rudiment, as in *Agrostis* for example. The palea has two nerves or keels, and the character of the hairs along the keels is a useful

distinguishing feature in certain species. The caryopsis lies in the palea with the hilum (point of attachment) toward it. The small embryo lies in a distinct area at the base of the caryopsis on the side toward the lemma, opposite the hilum. The caryopsis may be hard, as in bluegrass, or soft, as in orchard grass.

The lemma and palea may be more or less adnate to the caryopsis in many species, and the unit popularly considered the seed is the ripened floret—the caryopsis with its lemma, palea, and rachilla segment. In some species the lemma and palea are loose and the caryopsis becomes hulled in the threshing process, and in such cases the hulled grain is referred to as the seed. The term "seed" as used in this publication refers to the unit considered the seed of a particular species as it appears in commercial channels.

The size of seeds in a sample may vary considerably. The sizes stated in the seed keys represent an average seed insofar as is possible, and they are intended to show the relative sizes of the different species in a genus as an aid in their determination. For convenient reference, the genera are arranged alphabetically, and seed keys are provided for the larger groups.

AGROSTIS [5]—BENTGRASS

(Pl. I, 1–8)

The spikelets of *Agrostis* are one-flowered, and the rachilla is usually not prolonged. When present, it may vary from fairly long and hairy to a mere prickle. These rudimentary rachilla segments do not appear to have any diagnostic value.

Seeds of *Agrostis* are too small to be recognized as to kind without magnification. An examination of a small quantity of seed with a good hand lens or a low-power binocular microscope will show certain features that will give a clue to the identity of the seed sample, but for a more critical determination of the individual seeds that make up the bulk a magnification of about 40 is necessary. Commercial seed lots may contain a variable proportion of hulled grains. As a rule, these cannot be identified as to species with certainty.

Forms of *A. tenuis*, colonial bent, are sometimes called browntop, Rhode Island, Prince Edward Island, New Zealand, Astoria, and Highland bent. The last-named two are the principal horticultural varieties in use at present. Astoria bent is distinguished from common colonial bent chiefly by the larger size and more oblong shape of the seeds. This difference is apparent when seeds are viewed in quantity, but no way has been found whereby the smaller seeds of Astoria bent could be distinguished with certainty from common colonial bent.

Highland bent appears to be an aberrant form and may be a distinct species instead of a horticultural variety of *A. tenuis* as it is now classified. The main distinguishing features of the seed are the uniform spindle-shape and deeply notched tip of the palea. The Dryland browntop of New Zealand appears to be identical with Highland bent.

There are numerous strains of *A. palustris*, creeping bent, formerly known as carpet bent. Many of these are reproduced vegetatively because no seed is available. Seed of other forms, such as seaside bent, is available commercially.

[5] A more complete study of *Agrostis*, with photographic plates of seed drawings, may be obtained by purchase from the Grain Branch, Production and Marketing Administration, U. S. Department of Agriculture, Washington 25, D. C.

PRINCIPAL SOURCES OF SEED

A. alba, redtop: Illinois; incidental in bentgrass from other sources.
A. tenuis, colonial bent or browntop: Rhode Island; Canada; New Zealand; western Europe.
A. tenuis, Astoria bent: Washington; Oregon.
A. tenuis, Highland bent: Oregon; New Zealand.
A. palustris, creeping bent: Oregon; Washington; Rhode Island; Connecticut; Canada; New Zealand.
A. canina, velvet bent: Rhode Island; Connecticut; Canada; western Europe.
A. elliottiana, Elliott bentgrass: Incidental in redtop, Illinois grown.
A. hiemalis, winter bentgrass: Incidental in redtop, Illinois grown.
A. scabra, ticklegrass: Incidental in bentgrass from west coast.
A. exarata, spike bent: Incidental in bentgrass from west coast.

BULK DISTINCTIONS OF THE COMMERCIAL SPECIES

Seeds buff color, highly glossy; lemmas predominantly 3-nerved and awnless, not keeled on the back; palea tips truncate or with broad, shallow notch.

A. alba, redtop (pl. I, 1).

Seeds buff color and glossy to silvery and lustrous; lemmas predominantly 5-nerved and awnless, keeled on the back; paleas broad, narrowed to a shoulderlike apex.

A. palustris, creeping bent (not illus.)

Seeds pale buff color, lustrous to somewhat glossy; uniformly spindle-shaped; basal hairs and awns infrequent; paleas with narrow, deep V-notch.

A. tenuis, Highland bent (not illus.).

Seeds dull gray, weathered looking; lemmas 3-nerved; geniculate, twisted awns from near the base common.

A. tenuis, colonial bent (pl. I, 2).
A. tenuis, Astoria bent (not illus.).

Paleas so reduced they appear to be lacking; grain very soft; lemmas long-awned from about the middle or lower.

A. canina, velvet bent (pl. I, 5).

SEED KEY

A. Palea from one-half to slightly exceeding the caryopsis; caryopsis hard.

a. Lemma stiff, glossy and buff-colored, or slightly lustrous and silvery; awns mostly lacking or, if present, short and straight to semigeniculate, sometimes twisted and geniculate in the variety Highland.

aa. Lemmas rounded or slightly flattened on the back, apex 3- to 4-nerved (rarely 5-nerved); paleas mostly loose, tapering from near the base.

Apex of paleas truncate or broadly notched; lemma oblong or narrowly elliptic, length 2 mm. or more, width ½ mm.; basal hairs long and appressed or spreading, short and stubby, or lacking; awns when present arise well above the middle of lemma ..... *A. alba*, redtop (pl. I, 1).

Apex of paleas deeply V-notched; lemma uniformly spindle-shaped, length 1¾ to 2 mm., width ½ mm.; basal hairs mostly lacking, occasionally long and spreading; awns when present arise from near the base to about the middle of lemma ..... *A. tenuis* var. Highland bent (not illus.).

bb. Lemmas keeled above the callus, apex 5-nerved (rarely 3-nerved); paleas mostly loose, narrow abruptly near the top, apex various but not notched as above; lemma ovate-lanceolate or elliptic, length 1¾ to 2 mm., width ½ mm.; basal hairs mostly short and stubby, sometimes longer and spreading, or lacking; awns when present arise from near the top of the lemma.
A. palustris, creeping bent (not illus.).

b. Lemmas light gray, with a dull, weathered texture; awns frequent, twisted and geniculate, sometimes short and straight, arise from near the base to about the middle of lemma.
Lemmas not keeled above the callus or only slightly so, apex 3-nerved; paleas thin, mostly adherent to the grain, apex variously notched; lemmas lanceolate to oblong, length 1¾ to 2 mm., width ½ mm.; basal hairs mostly short and copious, sometimes longer, or lacking.
A. tenuis var. colonial bent (pl. I, 2).
A. tenuis var. Astoria bent (not illus.).

B. Palea reduced to a minute scale; caryopsis soft or semifluid.

a. Lemmas coarsely granular, especially along the 5 prominent nerves, thin and transparent, usually obscuring the deeply grooved grain; length 1½ to 2 mm., width less than ½ mm.; awns long, threadlike or much reduced, arise about three-quarters from the base of lemma; basal hairs long, copious, appressed.
A. elliottiana, Elliott bentgrass (pl. I, 6).

b. Lemmas finely granular, thin and transparent, obscuring the grain or partially so.

aa. Awns long, twisted and geniculate, sometimes straight, arising about the middle of lemma or lower, sometimes lacking in certain strains; lemma 1½ mm. long or more, width less than ½ mm.; basal hairs short and stubby, sometimes lacking ..... *A. canina*, velvet bent (pl. I, 5).

bb. Awns lacking, or occasional in *A. scabra.*
Lemmas equal to grain or shorter, dull; length 1 to 1¼ mm., width less than ½ mm.; basal hairs lacking, or infrequent ..... *A. hiemalis*, winter bentgrass (pl. I, 7).
Lemmas exceeding the grain, semipolished and smoother than *A. hiemalis;* length 1½ to 1¾ mm., width less than ½ mm.; awn when present straight and delicate, arising about two-thirds from base of lemma; basal hairs long and copious ..... *A. scabra*, ticklegrass (pl. I, 8).

c. Lemmas smooth, whitish, opaque, obscuring the grain, the margins overlapping on ventral side in upper half; awnless seeds 1½ mm. long, ½ mm. wide; basal hairs short and sparse or lacking; awned seeds 2 mm. long, ½ to ⅔ mm. wide, basal hairs long, appressed ..... *A. exarata*, spike bent (pl. I, 3 and 4).

AGROPYRON [6]—WHEATGRASS

(Pl. I, 9–16)

Seeds of 12 species of *Agropyron* that are of economic interest are described. These include the kinds now in production, certain native and introduced species in experimental plantings, and species that may occur as field weeds. The taxonomic status of three of the species—the so-called standard crested wheatgrass (formerly known as *A. cristatum*), fairway (formerly considered a variety of *A. crista-*

[6] A more complete study of *Agropyron*, with photographic plates of seed drawings, may be obtained by purchase from the Grain Branch, Production and Marketing Administration, U. S. Department of Agriculture, Washington 25, D. C.

tum), and intermediate wheatgrass (*A. intermedium*)—is still somewhat uncertain.

It has been observed that seeds of commercial crested wheatgrass are not uniform in character, and variation in plant types has been observed in the field. In studying field plantings of crested wheatgrass Swallen and Rogler (*44*) report that about 95 percent of the plants are of the *A. desertorum* type, and they consider the complex as one species, *A. desertorum*, retaining the already well-established common name of crested wheatgrass.

Regarding the fairway variety, Swallen and Rogler (*44*) state that this may be a species distinct from *A. cristatum*, but for the present it is being classified as *A. cristatum*, fairway crested wheatgrass. Compared with the standard crested wheatgrass, seeds of fairway are smaller with all lemmas glabrous and uniformly long-awned.

Commercial seed of *A. intermedium*, intermediate wheatgrass, including the variety Ree wheatgrass, consists of seeds which may be considered typical of *A. intermedium*, with a variable proportion of seeds that appear to be intermediate between *A. intermedium* and *A. trichophorum*, hairy intermediate wheatgrass. Space permits showing only the more typical types of seeds in this complex. The field plantings, as reported, yield a variable population. It has not been determined whether these off-type forms are simple varieties of a species or a natural segregation as a result of hybridization. There appears to be some intergrading between *A. intermedium* and *A. trichophorum*, and some authors consider the latter to be a variety of *A. intermedium* rather than a distinct species.

Samples of *A. smithii*, western wheatgrass, sometimes contain a trace of seed with lightly pubescent lemmas. This pubescent form is now recognized as *A. smithii* var. *molle* and is reported to have about the same distribution as the species. It is not known whether the pubescence is a constant feature or whether the plant produces both glabrous and pubescent lemmas. A separation of the two kinds in a seed sample would be of doubtful value at the present time.

Seeds of *A. riparium*, streambank wheatgrass, and *A. dasystachyum*, thickspike wheatgrass, may occur incidentally with crop seeds. Seeds of both species have pubescent lemmas and are somewhat similar to *A. smithii* var. *molle* in this respect. As pointed out in the seed key, seeds of *A. riparium* are smaller and markedly flatter than *A. smithii*. The more widely distributed *A. dasystachyum* is distinguished from *A. riparium* chiefly by the long spreading hairs on the rachilla, the acuminate or short-awned lemma, and somewhat larger size of the seed.

Seeds of *A. subsecundum*, bearded wheatgrass, another widely distributed species, may occur incidentally with certain crop seeds. The seeds resemble slender wheatgrass somewhat but may be distinguished by the bifid lemma and long awn.

For purposes of classification the seeds may be grouped on the basis of pubescence into two groups: (1) Lemma pubescent; and (2) lemma grabrous. Each group may be further divided on the shape of the lemma, as keeled or rounded on the back. All measurements in the seed keys that follow are approximate values representing the majority of seeds of the kind. Some deviation from these measurements may be expected in any seed sample.

SEED KEY

Group I

Lemma Pubescent

A. Lemma keeled, at least on upper half; sinus U-shaped or broadly V-shaped.

a. Elliptic, length 8 to 10 mm., width 2 mm., apex narrowly truncate, midnerve projecting into a short, stout awn-point.
A. trichophorum, hairy intermediate wheatgrass (pl. I, 16).

b. Narrowly lance-shaped.
Length (excl. of awn) 6 to 7 mm., width 1 mm.; acute-pointed or with awn ¼ to ⅓ the length of the lemma.
A. desertorum (in part), standard crested wheatgrass (formerly *A. cristatum*) (pl. I, 14).
Length (excl. of awn) 8 to 10 mm., width 2 mm.; acuminate or terminating in a short awn.
A. intermedium (in part), intermediate wheatgrass (pl. I, 15).

B. Lemma rounded on the back, narrowly elliptic.

a. Sinus V-shaped.
Length (excl. of awn) 8 to 10 mm., width 1½ mm.; awn from 1 or 2 mm. to ½ the length of the lemma, occasionally acute-pointed and awnless; lemma does not extend to keels of palea in lower half; rachilla hairs short, appressed; seed flatter than the variety *molle*, below___ *A. riparium*, streambank wheatgrass (not illus.).
Length (excl. of awn) 9 to 11 mm., width 1¾ to 2 mm.; awn ¼ the length of lemma or shorter; rachilla hairs longer than in *riparium;* edges of lemma extend to keels of palea throughout, or nearly so; seed markedly thicker than *riparium.*
A. smithii var. *molle*, no common name (not illus.).

b. Sinus U-shaped.
Length (excl. of awn) 9 to 11 mm., width 2 mm.; acuminate or with short awn point; lemma does not extend to keels of palea in lower half; rachilla hairs long and spreading.
A. dasystachyum, thickspike wheatgrass (not illus.).

Group II

Lemma Glabrous or Sparingly Scabrous on Nerves Toward the Top

A. Lemma keeled, lance-shaped; hairs on keels of palea short, stout, wide-spaced.

a. Length (excl. of awn) 6 to 7 mm., width 1 mm., acute-pointed or with awn ¼ to ⅓ the length of the lemma_____ *A. desertorum*, standard crested wheatgrass (formerly *A. cristatum*) (pl. I, 14).

b. Length (excl. of awn) 5 to 6 mm., width 1 mm.; awn ⅓ to ½ the length of the lemma____ *A. cristatum*, fairway crested wheatgrass (pl. I, 13).

B. Lemma rounded or slightly flattened on the back, if keeled only slightly so; hairs on keels of palea not as above.

a. Rachilla hairs long and spreading; sinus mostly U-shaped.
Lemma oblanceolate, awnless or with very short awn; length 8 to 10 mm.; width 1½ mm.; callus hairs continuous across the back.
A. trachycaulum (*A. pauciflorum*), slender wheatgrass (pl. I, 11).
Lemma narrowly lanceolate, bifid; awn about twice the length of the lemma; length (excl. of awn) 8 to 10 mm.; width 1½ mm.; callus hairs mostly continuous across the back; palea markedly shorter than lemma.
A. subsecundum, bearded wheatgrass (not illus.).

b. Rachilla hairs short and appressed, minute and sparse, or lacking; awn ¼ to ⅓ the length of lemma (shorter or lacking in *intermedium* and *elongatum*).

aa. Narrowly lance-shaped or elliptic.
Sinus V-shaped, occasionally narrowly U-shaped.
Rachilla flares out at the top, lies against keels of palea; palea often grooved down the center, apex deeply V-notched; lemma (excl. of awn) 9 to 10 mm. long, 1½ to 1⅓ mm. wide; callus hairs not continuous across the back; margins of lemma extend to keels of palea throughout, or nearly so.
A. smithii, western wheatgrass (pl. I, 10).
Sinus U-shaped.
Rachilla straplike, lies flat against the palea, usually between the keels; palea smoothly concave or with a longitudinal fold down the center, apex truncate, rounded, or with shallow notch; lemma (excl. of awn) 8 to 9 mm. long, 1½ mm. wide; callus hairs mostly lacking, or short and few at outer ends; margins of lemma usually do not extend to keels of palea in lower portion.
A. repens, quackgrass (pl. I, 9).
Rachilla not straplike, lies against keels of palea or between them; apex of palea truncate, rounded, or slightly indented; lemma (excl. of awn) 9 to 10 mm. long, 2 mm. wide; callus hairs short and sparse or lacking; margins of lemma extend to keels of palea or nearly so.
A. intermedium, intermediate wheatgrass (pl. I, 15).
A. intermedium, Ree wheatgrass (in part) (not illus.).

bb. Narrowly oblong; sinus V-shaped or narrowly U-shaped.
Lemma 3-nerved at the top, apex truncate or minutely lobed, length 10 to 12 mm., width 2 to 2½ mm.; apex of palea truncate or obtuse, hairs on keels long, fine, close-spaced; grain thick---- *A. elongatum*, tall wheatgrass (pl. I, 12).
Lemma 5-nerved at the top, awned; length (excl. of awn) 9 to 10 mm. or longer, width 1 to 1½ mm.; apex of palea finely notched or obtuse, hairs on keels not long and dense; margins of lemma do not extend to keels of palea in lower half; grain flat.
A. inerme, beardless wheatgrass (not illus.).

AIRA—HAIRGRASS

(Pl. I, 17–18)

Two species of hairgrass are commonly found with crop seeds, neither of which is of any economic importance. The spikelets are two-flowered, disarticulating above the glumes. Both florets of a spikelet are shown in the illustrations.

Aira elegans (*A. capillaris*), fine hairgrass (pl. I, 17). The seeds are 1½ to 1¾ mm. long, ¼ to ⅓ mm. wide; dark brown shading to silvery white at the top; lemma rounded on the back, the inrolled margins partially obscuring the palea; apex prolonged into two very slender teeth.

The basal florets (shown in the two views at left in the illustration) are awnless or with only short hairlike awns; hairs at base silvery, short and sparse, confined mostly to the outer ends of the callus; rachilla short. Upper florets (shown in two views at right in illustration) have no rachilla; awns about 2½ mm. long, geniculate and twisted; basal hairs longer, mostly appressed, extend clear across callus.

Aira caryophyllea, silver hairgrass (pl. I, 18). The seeds are 2½ to 3 mm. long, ½ mm. wide, awn 3 to 3½ mm. long; in general appear-

ance resemble *A. elegans* but may be distinguished by the larger size. In this species both upper and lower florets in the spikelet bear long geniculate twisted awns, but only the lower floret carries a rachilla segment (shown in middle seed in the illustration); basal hairs long and copious.

ALOPECURUS—FOXTAIL

(Pl. I, 19–23)

Five species of *Alopecurus* are described, four of which are field weeds. One species, *A. pratensis*, meadow foxtail, is in limited cultivation.

The one-flowered, strongly compressed spikelets disarticulate below the glumes so that the unit commonly considered the seed consists of the ripened floret with its attached glumes. The glumes are equal or nearly so, united at the base; ciliate on the keels and, in certain species, on the lateral nerves. The species may be distinguished by the size and character of the glumes and the relative length of the protruding awn.

In commercial seed samples the ripened florets without the attached glumes may sometimes be found. The smooth translucent lemma, bearing an awn from near the base, completely enfolds the flattened grain, the margins united in the lower half; the palea appears to be wanting. The caryopsis is golden yellow or dull brown, soft or semifluid, minutely wrinkled and striate lengthwise. The free grains may occur with such crops as crimson clover, timothy, and the smaller grass seeds.

SEED KEY

A. Spikelets 2 to 3 mm. long.
  Awn of lemma geniculate; glumes usually exceeding the lemma.
    Awn approximately 3 mm. longer than the glumes.
      A. geniculatus, water foxtail (pl. I, 21).
    Awn approximately 2 mm. longer than the glumes.
      A. carolinianus, Carolina foxtail (pl. I, 20).
    Awn of lemma straight, frail; glumes usually shorter than lemma.
      Awn scarcely exserted beyond glumes.
        A. aequalis, short-awn foxtail (pl. I, 19).

B. Spikelets 4 to 5½ mm. long.
  Awn of lemma geniculate, approximately 5 to 7 mm. longer than the glumes.
    Glumes thin, long-ciliate on keels and lateral nerves; scar small, inconspicuous———— *A. pratensis*, meadow foxtail (pl. I, 22).
    Glumes thick, granular, short-ciliate on keels and at base of nerves, scabrous above; scar large, prominent.
      A. myosuroides, slender foxtail (pl. I, 23).

ANDROPOGON—BEARDGRASS

(Pl. II, 25–32)

Eight species of *Andropogon* are described. Three of the species are well-known range grasses: *A. scoparius*, little bluestem; *A. gerardi* (*A. furcatus*), big bluestem; and *A. hallii*, sand bluestem. There is some intergrading between *A. gerardi* and *A. hallii*. Seeds of the two species are about equal in size and general structural features; but the callus, rachis, and pedicel of *A. hallii* are usually more densely pubescent than *A. gerardi*.

Four species now in experimental plantings are promising pasture plants: *A. ischaemum*, Turkestan or yellow bluestem; *A. sericeus*, Queensland beardgrass; *A. nodosus*, angleton grass; and *A. intermedius*, Australian bluestem.

A. virginicus, broomsedge, is a common weed of old fields in the eastern half of the United States.

STRUCTURAL FEATURES

The spikelets are borne in pairs at each node of a jointed rachis. A single joint of the inflorescence is the unit commonly considered the seed. It consists of one fertile, sessile spikelet, and one pedicellate spikelet, which may be either sterile or staminate, together with the attached rachis segment. The rachis and pedicel of the sterile spikelets are often densely pubescent. In some species the sterile spikelet is suppressed, only the pedicel being developed, as in *A. scoparius* (pl. II, 27).

Glumes of the fertile floret are hardened and awnless, completely enclosing a thin and transparent lemma and palea. The transparent lemma usually bears a bent or twisted awn from the apex or from between the lobes at the apex. The awn is rather weak and easily detached and would be mostly lacking in processed seed.

Sometimes a seed sample consists of seeds that have been hulled by processing. The characteristic shapes and sizes of the free grains in the different species are shown in the illustrations.

SEED KEY

A. Length (excl. of awn) 5 to 9 mm. or more.

a. Back of lemma with broad longitudinal groove; rachis joint and pedicel expanded and cupped at the apex; pedicels and callus densely villous, especially in *hallii*.

A. gerardi (*A. furcatus*), big bluestem (pl. II, 25).
A. hallii, sand bluestem (pl. II, 26).

b. Back of lemma not grooved; rachis joint cupped at the apex, pedicel bearing a reduced sterile floret; pedicels and callus villous.

Lemma with fringe of hairs across the back near the top, hairs as long as lemma or nearly so.
A. sericeus, silky bluestem (pl. II, 31).

Lemma without fringe of hairs across the back near the top.
A. scoparius, little bluestem (pl. II, 27).

B. Length (excl. of awn) less than 5 mm.

a. Rachis joint and pedicel cupped at the apex, villous.

aa. Rachis joint and pedicel with a wide dark-colored groove down the middle; lemma with a minute pit on the back.
A. intermedius, Australian bluestem (pl. II, 29).

bb. Rachis joint and pedicel not grooved; lemma not pitted.

Lemma with a few long hairs arising from cushionlike bases near the top; shape obovate or oblanceolate.
A. nodosus, angleton grass (pl. II, 30).

Lemma sparingly pubescent below the middle, smooth above; shape narrowly lanceolate.
A. ischaemum, yellow beardgrass (pl. II, 28).

b. Rachis joint and pedicel not cupped at the apex, long and flexuous, villous ---------- *A. virginicus*, broomsedge (pl. II, 32).

ANTHOXANTHUM—VERNALGRASS

(Pl. II, 33)

The spikelets of vernalgrass consist of one fertile floret enclosed by two awned, sterile lemmas. The rachilla disarticulates above the glumes, the sterile lemmas falling attached to the fertile floret. The

fertile floret with the two attached sterile lemmas, as shown at the left in the illustration, is the unit commonly considered the seed. When found as an incidental seed with other crop seeds, the sterile lemmas may be lacking as a result of processing, as shown at the right in the illustration.

Two species are described: *A. odoratum*, a perennial, is sometimes included in meadowgrass mixtures; and *A. aristatum* (*A. puellii*), an annual. Both species may occur as incidental seeds with crop seeds.

A. odoratum, sweet vernalgrass (pl. II, 33): The sterile lemmas are about 3 mm. long, subequal, reddish brown, often yellowish at the tip; pubescent, the hairs long and appressed, arising to well above the middle of the lemma; the first sterile lemma is short-awned from near the apex, the second is awned from near the base, the awn twisted and geniculate. The fertile lemma, enclosing the plump grain, is 2 mm. long or less, dark reddish brown, smooth and glossy.

A. aristatum, annual vernalgrass (not illustrated): The seed differs from sweet vernalgrass chiefly in the position of the pubescence on the sterile lemmas. In sweet vernalgrass the hairs extend to near the top of the lemma; in annual vernalgrass the point of attachment of the hairs usually does not extend higher than the middle of the lemma. Both fertile and sterile lemmas of annual vernalgrass are usually lighter in color than sweet vernalgrass.

APERA

Spikelets of *Apera* are one-flowered, disarticulating above the glumes, the rachilla prolonged into a short bristle less than ½ mm. in length. The lemma bears a long slender awn from near the apex; the lemma and palea equal or nearly so.

Apera spica-venti, windgrass (pl. II, 34): Lemmas are light yellowish brown, sparingly hirsute above the middle; length 2 to 2½ mm.; awn 2 to 3 times the length of the lemma; the grain is soft, yellowish. The seeds may occur incidentally with sweet vernalgrass and similar crops.

ARISTIDA—THREE-AWN

(Pl. I, 24)

The genus *Aristida* is characterized by one-flowered spikelets that disarticulate above the glumes. The lemma is hard, convolute, with a sharp-pointed callus at the base, and usually terminating in three awns.

Aristida dichotoma, poverty grass. The seeds are dull grayish brown, flecked with dark brown or black; length (excl. of awn) 5 to 6 mm.; sparingly pubescent on the midnerve; central awn 3 to 6 mm. long, spirally coiled and horizontally bent, lateral awns shorter; callus with a long tuft of whitish hairs at each end.

The seeds of poverty grass may occur with certain crop seeds from the eastern half of the United States.

ARRHENATHERUM—OATGRASS

(Pl. II, 35)

The spikelets of oatgrass are two-flowered, the lower floret staminate, the upper floret perfect, the spikelets disarticulating above the glumes. The staminate floret, bearing a twisted geniculate awn,

remains attached to the fertile floret at maturity, the whole appearing as a single fruit, as shown in the illustration.

Arrhenatherum elatius, tall oatgrass (pl. II, 35): Lemmas are 9 to 10 mm. long, light straw color, seven-nerved, minutely scabrous on upper half, often with scattered long, whitish hairs on the lower half. The staminate floret bears a long twisted, geniculate awn from near the base, the fertile floret usually bears a short straight awn from near the tip. This short awn is usually broken away in the seed-cleaning process. The hairs at the callus are light-colored, long and spreading.

The seed of oatgrass is sometimes hulled by processing. The hulled grains are light yellowish, 4 to 5 mm. long; in side view the dorsal, or embryo, edge is nearly straight, the ventral edge is convex.

Tall oatgrass is grown as a meadow grass in the North and East. An improved variety, *A. elatius* var. Tualatin, is going into production. The seed of this variety does not appear to be distinguishable from the species.

AVENA [7]—OATS

(Pl. II, 36–41)

Spikelets of *Avena* are 2 to 3 flowered, disarticulating above the glumes and between the florets. The character of the abscission is an important feature in distinguishing the species. The caryopsis or grain is firmly enclosed by the hardened lemma and palea and hulled grains are usually found only in seed that has been severely milled. The hulled grain, however, may provide valuable diagnostic features.

Five species and a fatuoid form are illustrated and described: The common cultivated oats, *A sativa* and *A. byzantina;* wild oat, *A. fatua;* slender oat, *A. barbata;* sand oat, *A. strigosa;* and a homozygous fatuoid form that occurs with cultivated oats. The heterozygous fatuoid is not included in this study.

CULTIVATED OATS

As reported, there are approximately 125 recognized agronomic varieties of cultivated oats in this country, with many hundreds of synonymous strains. The identification of these varieties and strains is not a part of this study. In the illustrations the red oats group (*A. byzantina*) is represented by the varieties Fulghum and Red Rustproof, the common or northern oats (*A. sativa*) by the variety Victory (pl. II, 36, 37). The two groups may be roughly divided on color and texture of lemma, but neither feature is entirely dependable. Distinction in color becomes evident when seeds are viewed in quantity but in the individual seed it may not be so apparent. Generally speaking, the lemma of the *sativa* group is smooth, that of *byzantina* coarsely granular so that it grates on the forceps. The two types are well represented by the varieties Victory and Fulghum. Between the two extremes are finely granular, intergrading forms that cannot be distinguished by this character alone.

[7] A more complete study of *Avena*, with photographic plates of seed drawings, may be obtained by purchase from the Grain Branch, Production and Marketing Administration, U. S. Department of Agriculture, Washington 25, D. C.

FATUOIDS AND WILD OATS

Fatuoids tend to resemble in size, color, and texture the variety of oats with which they occur. In morphological features the homozygous fatuoid (pl. II, 38) bears a superficial resemblance to *A. fatua* but the two kinds are readily distinguishable by size and shape, and color may be helpful to some extent in making a determination. *A. fatua* is usually gray or black, occasionally yellow, but apparently there are no white and no real red. On the other hand, there are not many kinds of black cultivated oats in the United States, and only a very few gray. Consequently, unless the oat sample in question is gray or black, the fatuoid would not be likely to exhibit that color. There is perhaps one exception, an occasional black fatuoid may appear in red oats, particularly in the variety Fulghum.

As reported, gray oats are rarely grown outside the South, New York (the var. Cornellian), and adjacent States. The var. Columbia, more reddish gray than the gray of *A. fatua* is grown rather widely from spring seeding. Three varieties of black oats are grown but not to any great extent: Tech, grown from fall seeding in Virginia; Coast Black, in certain small areas of California, mostly for hay purposes; Victor, in limited production in western Oregon and possibly in other small areas where it is said to be favored for feeding race horses.

TYPES OF ABSCISSION

There are three general types of articulation of the spikelet from its pedicel and of the florets from each other. (1) Complete abscission: An absciss layer is developed between the floret and its pedicel or rachilla segment so that the matured floret breaks off readily, showing a smooth, well-developed callus around a prominent basal cavity (pl. II, 39). (2) Partial abscission: An absciss layer is not developed around the entire base of the floret, usually only on the sides, whereas a small portion on the front and at the back remains lightly solidified with the pedicel and the floret does not break off smoothly at these points. (3) Fracture: The points of articulation have become lightly to completely solidified. The floret may break off more or less regularly along the line where the absciss layer would normally develop, but there is no callus as in type (1) and the basal cavity is greatly reduced or, as is common in the upper florets, the rachilla itself breaks and a portion of the segment remains attached to the base of the floret (pl. II, 36, 37, 41).

PUBESCENCE

The character of the basal hairs, rachilla hairs, and awns appears to be fairly constant in the wild species and homozygous fatuoids, but hairs on the lemma may vary considerably in individual plants of a species. The awns are stout, geniculate, the bend usually well above the tip of the lemma, twisted below. The cultivated forms are characterized by a reduction in awns and pubescence. The awns, generally few in number, may be straight or semigeniculate and twisted, the bend usually below the tip of the lemma. In the variety Winter Turf the awns may be heavier than in most of the cultivated varieties.

CARYOPSIS

The shape of the caryopsis is very characteristic in the two groups, the wild and the cultivated species. In edge view, the dorsal line is nearly straight in cultivated oats; in the wild species and the fatuoids the dorsal line is longitudinally arched and, *A. barbata* and *A. strigosa* excepted, the caryopsis is markedly thicker through the lower half.

In ventral view, all species except *A. fatua* are transversely arched by two thick longitudinal folds with a deep groove between them. The ventral side of *A. fatua* is flat, with a fine longitudinal groove.

Wild species and fatuoids that are awned show the imprint of the awn as a distinct groove on the dorsal side of the caryopsis. This groove appears to be lacking in cultivated oats. Just above the embryo is a whitish area, the scutellum. It is interesting to note that the scutellum is more or less distinct in all but *A. fatua* where it is completely lacking or only a faint whitish line.

The character of the caryopsis is particularly helpful in distinguishing *A. fatua* and the fatuoids when other diagnostic features of the floret are in doubt. The shape of the caryopsis is not entirely dependable as some degree of overlapping may occur, especially in terminal florets. The ventral face and the scutellum appear to be fairly constant and may serve as reliable features in distinguishing the two forms. In *A. fatua* the ventral side is flat, scutellum lacking or very faint; in fatuoids the ventral side is transversely arched, scutellum large, triangular, distinct.

SEED KEY

A. All florets of spikelet disarticulate by complete abscission; all florets awned, awn geniculate, the bend well above tip of lemma or equal to it, twisted below.

a. Lemma terminates in two minute teeth; rachilla and base copiously hairy, hairs long and stiff, basal hairs long and spreading or short and bushy; lemma with scattered long stiff hairs or completely devoid of hairs.

aa. Seed broadly elliptic; in edge view about twice as thick at base of awn as at the base; caryopsis much thickened in lower half, scutellum distinct---- *Fatuoid*, homozygous (pl. II, 38).

bb. Seed narrowly elliptic; in edge view only slightly thicker at base of awn; caryopsis slightly thickened about midway, scutellum lacking or only a faint whitish line.
A. fatua, wild oat (pl. II, 39).

b. Lemma terminates in two long bristles; lemma, rachilla, and base copiously hairy, hairs long, stiff, spreading; in edge view not evidently thickened at the middle; caryopsis slender, scutellum distinct.
A. barbata, slender oat (pl. II, 40).

B. All florets in spikelet disarticulate by fracture.

a. Lemma acute, terminates in two minute teeth, awns when present are straight or semigeniculate and twisted below, the bend usually below the tip of lemma; caryopsis not prominently thickened in lower half; scutellum large, distinct.

aa. Lemma finely to coarsely granular, devoid of hairs or sparsely hairy-------- *A. byzantina*, red or southern oat (pl. II, 37).

bb. Lemma smooth to finely granular, devoid of hairs or only an occasional hair.
A. sativa, common or northern oat (pl. II, 36).

b. Lemma acuminate, terminates in two long bristles, with distinct light-colored nerves; both florets awned, awns geniculate and twisted below; caryopsis shape as in *A. fatua* but smaller, scutellum large, distinct. *A. strigosa*, sand oat (pl. II, 41).

AXONOPUS—CARPET GRASS

(Pl. II, 42–43)

The single-flowered spikelets of the carpet grasses disarticulate below the glume, and the fertile floret with its persisting glume and sterile lemma is the unit popularly considered the seed. The first glume is lacking and the sterile lemma does not bear a sterile palea. Fertile florets without the attached glumes and sterile lemmas are not commonly found in cleaned seed.

Axonopus affinis and *A. compressus* are very similar and intergrading forms may be expected. *A. affinis* is the more widely distributed of the two species and it is being utilized for lawn and pasture purposes in the South and Southeast. Seed in commercial channels at the present time is likely to be of this species.

SEED KEY

Spikelet 2 to 3 mm. long; sparsely long hairy along margins; midnerve of glume and sterile lemma wanting or faint.
Glume and sterile lemma obtuse or short-pointed, equaling or slightly exceeding the grain--- *A. affinis*, narrow-leaved carpet grass (pl. II, 42).
Glume and sterile lemma acute, exceeding the grain.
A. compressus, broad-leaved carpet grass (pl. II, 43).

BECKMANNIA—SLOUGHGRASS

Beckmannia syzigachne, American sloughgrass (pl. II, 44): The spikelets are one-flowered, disarticulating below the glumes, the spikelet falling entire. The glumes are about 3 mm. long, laterally compressed, light straw color, deeply keeled and faintly wrinkled transversely, the acuminate apex of the lemma protruding between them at the top. The grain is soft, and light yellow in color.

The seed may occur incidentally with crop seeds. The soft, hulled grain is sometimes found in samples of timothy or similar meadow grasses.

BUCHLOË—BUFFALO GRASS

Buchloë dactyloides, buffalo grass (pl. II, 45): The staminate and pistillate flowers are usually borne on separate plants, the two inflorescences being strikingly different. The pistillate spikelets are borne in curiously modified hard, whitish burlike heads. These burs are the units commonly considered the seed.

Each bur consists of two to five or six spikelets held together by a thickened base and surrounded by thick, hard, overlapping second glumes, each of which terminates in three rigid, usually green-tipped, acuminate lobes. As a rule, not all of the spikelets in a bur contain caryopses. A good grade of seed will average 50 to 75 percent filled burs.

Seed samples sometimes consist of caryopses that have been hulled by processing. The hulled seeds are light brown, 2½ to 3 mm. long, ovate or broadly elliptic, and markedly thicker at one end.

BOUTELOUA—GRAMA GRASS

(Pl. II, 46–48)

The spikelets of grama grass consist of one fertile floret with rudiments of one or more florets above it, the entire spikelet falling from the glumes which remain on the rachis.

The gramas are native range grasses of the Great Plains that are being utilized for regrassing purposes. Three of the more important species are illustrated and described in the seed key that follows.

SEED KEY

A. Lemma of fertile floret keeled on the back.

a. Lemma glabrous or sparingly long-pubescent at the callus and along the sharply keeled back, lustrous; lateral nerves exserted as short awns; length (excl. of awn) approximately 4 mm., width ½ mm.; free grains thick, 3-angled---- *B. gracilis*, blue grama (pl. II, 47).

b. Lemma copiously short-pubescent at the callus and sparingly long-pubescent above, dull and porous in texture; lateral nerves exserted as long awns; length (excl. of awn) 4 to 5 mm., width 1 mm.; free grains obovate in dorsal view, in edge view the embryo side straight, the hilum side convex-------- *B. hirsuta*, hairy grama (pl. II, 48).

B. Lemma of fertile floret not keeled on the back; length (excl. of awn) 5 mm., width 1 to 1½ mm.; midnerve a fine line, usually evident to the base.

a. Lemma flattened on the back, dull, minutely hispid at the top, glabrous below; lateral nerves exserted as short awns; free grains oblong in dorsal view, in edge view flat and straight.
B. curtipendula, side-oats grama (pl. II, 46).

BROMUS—BROMEGRASS

(Pl. III, 49–57)

The spikelets of bromegrass are several-flowered, the rachilla disarticulating above the glumes and between the florets. The seeds of commerce consist of the caryopsis within a lemma and palea and the attached rachilla segment.

Four perennial species are in cultivation or being increased for production: *B. inermis*, smooth brome; *B. catharticus*, rescue grass; *B. marginatus*, mountain brome; and *B. carinatus*, California brome. Eight annual species are included. Some of these have limited forage value but for the most part they are considered field weeds. The distinguishing features of these 12 species are set forth in the seed key.

The species *B. secalinus*, *B. commutatus*, *B. japonicus*, and *B. mollis* are closely related. Although they are recognized as distinct species, the forms are separated only by arbitrary characters and some intergrading can be expected. The fully developed mature florets of the three species are readily recognized. However, when the seeds occur incidentally with crop seeds they may be immature, or the distinguishing features of lemma and palea may be damaged in the cleaning process, and such seeds cannot be identified with certainty in all cases. The distinguishing features of terminal florets of a spikelet are often less well defined than in the lower florets. These terminal florets, partly because of their smaller size, sometimes remain with the cleaned crop seed and their positive identification is not always possible.

B. secalinus and *B. commutatus* each has a recognized variety having pubescent lemmas; *B. secalinus* var. *velutinus* and *B. commutatus* var. *apricorum*. In this country the two varieties are confined to the Pacific coast and are comparatively rare.

Seeds of *B. carinatus* and *B. marginatus* are somewhat similar. Seed of Bromar, an improved variety of *B. marginatus*, is shown in the illustration (pl. III, 57).

SEED KEY

A. Lemma flattened dorso-ventrally, 3-nerved or obscurely 5-nerved; length 9 to 12 mm., width 2 mm., awn lacking or, if present, 1 to 2 mm. long.
Lemma narrowly oblanceolate, not overlapping keels of palea, thin and papery, short-pubescent near the base, glabrous above; palea narrower than the grain, with a longitudinal fold down the middle, minutely pubescent, hairs on keels very short, fine, close-spaced; rachilla bristly pubescent; grains thin and flat---- *Bromus inermis*, smooth brome (pl. III, 55).

B. Lemma sharply compressed or folded laterally, obscuring the palea, thick and stiff, 7 to 9 nerved; length 10 to 15 mm.; awned or awnless.

a. Long-awned; width as folded 1½ to 2 mm.; in side view, slightly broader above the middle.
Lemma appressed-pubescent, rarely glabrous; awn 7 to 15 mm.; palea nearly equal to lemma; rachilla sparingly appressed-pubescent---------- *B. carinatus*, California brome (not illus.).
Lemma minutely hispid on midnerve at the top and sparingly below; awn 4 to 6 mm.; palea mostly shorter than lemma; rachilla granular or minutely hispid.
B. marginatus, mountain brome (pl. III, 57).

b. Awnless, or with awn 1 to 3 mm. long; width as folded 2½ to 3 mm.; in side view, broader below the middle, flatter than *marginatus*.
Lemma minutely hispid, especially along the nerves, sometimes almost glabrous; palea about ⅔ the length of lemma; rachilla sparingly short-pubescent to glabrous, usually shorter than *carinatus* and *marginatus*.
B. catharticus, rescue grass (pl. III, 56).

C. Lemma involute or compressed laterally in part, never flattened throughout, 5 to 7 nerved; palea usually partially obscured by margins of lemma.

a. Lemma linear, long-awned, light to dark brown or purplish, terminates in two hyaline teeth 1 to 2 mm. long, or 3 to 5 mm. long in *rubens* and *rigidus;* palea markedly shorter than lemma, narrow, tapering from the base.

aa. Lemma thin and papery, keeled and glabrous at the base, flattened and pubescent above; hairs on keels long (1½ to 2 mm.), fine, and pointed, close-spaced, usually with shorter hairs between; callus smooth and polished or with a few hairs on each end.

aaa. Lemma pilose, in some forms glabrous or nearly so, length 8 to 12 mm., width 1½ mm., awn 12 to 15 mm.; apex of palea obtuse or minutely notched.
B. tectorum, downy chess (pl. III, 49).

bbb. Lemma hispid and sparingly long-pubescent near the margins, length 12 to 15 mm., width 1 to 1½ mm., awn 18 to 20 mm.; palea terminates in deep V-notch.
B. rubens, foxtail chess (not illus.).

bb. Lemma stiff, more or less involute throughout most of its length; hispid, especially along midrib and along margins; hairs on keels of palea widespaced, shorter and broader at the base than in *rubens* and *tectorum;* apex of palea obtuse or truncate.

aaa. Callus smooth and polished, or with a few hairs at each end; length of lemma 15 mm. or longer, width 1¾ to 2 mm., awn 15 to 20 or 30 mm.
B. sterilis, barren chess (pl. III, 50).

bbb. Callus white-pubescent over entire surface and on lemma just above it; length of lemma 25 to 30 mm. or longer, width 2 mm., awn 25 to 35 mm. or more.
B. rigidus, ripgut grass (not illus.).

b. Lemma elliptic or narrowly obovate with attenuate base, more or less involute or keeled in lower portion; awns 8 to 9 or 10 mm., or 2 to 5 in *secalinus*.

aa. Palea markedly shorter than lemma, spatulate, with a minute longitudinal fold down the middle, thin and partially adherent to grain, flat in upper portion with shallow concavity below; lemma thin and papery.

aaa. Lemma finely pubescent, mostly with transverse wrinkles between the nerves, apex distinctly notched; the fine nerves usually distinct to the base.
B. mollis, soft chess (pl. III, 54).

bbb. Lemma glabrous or minutely pubescent at the top and along margins, smooth or with transverse wrinkles between the nerves; apex minutely notched or obtuse; midnerve evident to the base, lateral nerves often obscure--- *B. japonicus*, Japanese chess (pl. III, 51).

bb. Palea equal to lemma or nearly so; lemma thick and stiff, minutely pubescent toward the top and along margins.

aaa. Palea equal to grain, usually with a deep V-shaped cavity, smooth or variously folded or wrinkled, scarcely narrowed at the notched or obtuse apex, usually narrower than the grain; lemma scarcely broader than the grain, margins usually not overlapping keels of palea, midnerve evident to about the middle, lateral nerves obscure; grain compressed laterally, obtuse, seed appears thick and blocky.
B. secalinus, chess (pl. III, 53).

bbb. Palea longer than the grain, often a little shorter than the lemma, broader at the top and narrowed abruptly to a notched or obtuse apex, concavity shallow, smooth or sometimes creased or wrinkled; lemma much broader than the grain above the middle, apex obtuse or with shallow notch, midnerve evident to base, lateral nerves often obscure in lower half, the margins involute in lower portion; grain flatter than in *B. secalinus*.
B. commutatus, hairy chess (pl. III, 52).

CENCHRUS—SANDBUR

Cenchrus pauciflorus, field sandbur (pl. III, 63): The spikelets, usually two in number, are enclosed in a spiny bur. The burs are not commonly found in crop seeds, but the hulled grains may occur in alfalfa and similar crops.

The hulled grains are light brown, broadly oval or oblong, with a relatively large embryo area; length 3 to 3½ mm.

CHLORIS—FINGERGRASS

(Pl. III, 58–60)

Spikelets of *Chloris* are several-flowered, disarticulating above the glumes. The lower floret is sessile and perfect, the upper florets

sterile. The sterile florets consist of empty lemmas, and if more than one is developed the smaller ones are often enclosed in the lower, producing an inflated, wedge-shaped rudiment. The entire spikelet, mature fertile floret and attached sterile florets, is the unit usually considered the seed. The pubescence on the fertile lemma and the character of the sterile lemmas are important diagnostic features.

Seeds of four species are described. *C. gayana*, Rhodes grass, is a pasture plant of the Southern States. Three species may occur incidentally with crop seeds: *C. virgata*, feather fingergrass, a native species; *C. divaricata*, slender chloris; and *C. acicularis*, windmill grass, occur in importations of Rhodes grass from Australia and may in time become established here.

SEED KEY

A. Fertile lemma keeled, margins ciliate; a small groove between margin and keel; rachilla bearing one to three obtusely pointed or wedge-shaped sterile lemmas.

a. Keel of lemma without pubescence; cilia on margins appressed below, longer and spreading at the top; basal hairs sparse, appressed; color yellowish straw; length (excl. of awn) 3 to 3½ mm., width approx. 1 mm.; awn 2 to 5 mm.....*Chloris gayana*, Rhodes grass (pl. III, 60).

b. Keel of lemma densely pubescent, humped; cilia on margins appressed below, much longer and spreading at the top; basal hairs dense, spreading; color dark brown; length (excl. of awn) 3 to 3½ mm., width 1 mm. or more; awn 6 to 10 mm. or longer.
C. virgata, feather fingergrass (not illus.).

B. Fertile lemma keeled, margins not ciliate; not grooved between margin and keel; rachilla about ½ the length of lemma, bearing a whitish, deeply 2-cleft sterile floret.
Keel of lemma without pubescence; minutely hispid in upper portion, apex deeply 2-cleft; color light to dark brown, whitish toward the top; basal hairs whitish, appressed or spreading; length (excl. of awn) 3 mm., width ½ mm., awn 8 to 10 mm..... *C. divaricata*, slender chloris (pl. III, 58).

C. Fertile lemma flattened dorso-ventrally, with prominent cordlike midnerve throughout entire length, terminating in long awn; rachilla about ½ the length of lemma, bearing a very narrow long-awned sterile floret.
Lemma glabrous or sparingly and minutely hispid at the top, apex minutely cleft, the long narrow base with tuft of white spreading hairs at the callus; color light brown; length (excl. of awn) 6 mm., width ½ to ⅔ mm., awn 10 to 12 mm. or longer..... *C. acicularis*, windmill grass (pl. III, 59).

CORYNEPHORUS

Corynephorus canescens, club-awn grass (pl. III, 61): The spikelets are two-flowered, disarticulating above the glumes. The mature floret or seed is about 1½ mm. long or more; the lemma and palea are silvery, thin and transparent, the callus and rachilla densely villous. The awn, arising from near the base, is jointed about the middle, the joint with a ring of short stiff hairs; below the joint the awn is dark reddish brown and finely striate, pale gray above the joint.

The seed occurs with imported crops, such as bentgrass.

CYNOSURUS—DOGTAIL

(Pl. III, 64–65)

The panicle of *Cynosurus* consists of two kinds of spikelets, sterile and fertile. The fertile spikelets are two to three flowered, disarticu-

lating above the glumes. The processed seed consists of the caryopsis with its lemma, palea, and rachilla segment.

Two species of *Cynosurus* are of interest: *C. cristatus*, crested dogtail, a perennial, sometimes used in grass mixtures for meadows or found incidentally with crop seeds; and *C. echinatus*, an annual, sometimes occurring as a weed seed with crop seeds from the west coast. The chief distinguishing features of seeds of the two species are color, size, and length of awn.

SEED KEY

A. Seed sulphur yellow; length (excl. of awn) 3½ to 4 mm., width 1 mm. or less; awn approximately 1 mm.; lance-shaped, with fine midnerve above the middle; lemma coarsely granular and finely hispid toward the top and along margins; rachilla with wide disc at the apex.
Cynosurus cristatus, crested dogtail (pl. III, 64).

B. Seed pale gray; length (excl. of awn) 5 to 7 mm., width 1¼ to 1½ mm.; awn 10 to 15 mm.; elliptic; lemma finely hispid on upper half and along margins, obscurely 5-nerved above the middle; rachilla threadlike, with distinct disc at the apex_____ *C. echinatus*, bristly dogtail (pl. III, 65).

DACTYLIS

Dactylis glomerata, orchard grass (pl. III, 66): The lemma is compressed laterally and curved to one side toward the top, ciliate on the keel, lightly five-nerved, short-awned; length, including the short awn, 7 to 8 mm.; grain soft.

DANTHONIA—OATGRASS

(Pl. III, 67–68)

Danthonia spicata, poverty oatgrass (pl. III, 67): The lemma is 3½ to 5 mm. long, sparsely villous except on the two-toothed summit; palea is broad, flat, obtuse, reaching to the base of the awn.

Seeds produced from cleistogenes sometimes occur with crop seeds. These seeds (pl. III, 68) are long and slender, the lemma tip not cleft, the rachilla prolonged into a long bristle.

DESCHAMPSIA—HAIRGRASS

(Pl. III, 69–70)

The spikelets of *Deschampsia* are two-flowered, disarticulating above the glumes and between the florets. Two species are described, *D. caespitosa* and *D. flexuosa*. Both species may occur with crop seeds.

Deschampsia caespitosa, tufted hairgrass (pl. III, 69): The lemmas are silvery, smooth, and semiglossy, length about 2½ mm.; awn attached at the base, straight or semigeniculate; basal hairs long and spreading at the ends, shorter across the middle; palea about equal to lemma, arched longitudinally, finely pubescent on the keels; rachilla about half the length of the lemma, pubescent with long, spreading hairs.

Deschampsia flexuosa, crinkled hairgrass (pl. III, 70): The lemmas are light brown, becoming lighter toward the tip, sparingly hirsute on upper half, length about 4 mm.; awn attached near the base, twisted and geniculate; basal hairs copious, long and spreading; palea about equal to lemma, flat, pubescent on the keels; rachilla with a tuft of long spreading hairs on either side, near the top.

DISTICHLIS—SALTGRASS

(Pl. III, 71–72)

The hulled grains of two species of saltgrass may occur with crop seeds: *D. stricta* is widely distributed throughout the western half of the United States; *D. spicata* is confined to coastal areas of the Atlantic, Pacific, and Gulf coasts. The grains are a dull light brown, roughly ovate in shape, with minute longitudinal wrinkles. Remnants of style branches appear as two minute beaks or prongs at the top of the grain. The character of these beaks is an important distinguishing feature.

D. stricta, desert saltgrass (pl. III, 71): The grains are 3 to 4 mm. long and terminate in a long two-pronged beak. Occasional seeds are longer and narrower than those shown in the illustration, and the beak is correspondingly longer. When found in processed seed the beak is often partially broken away, but even in this condition the size of the seed and the remnant of the beak will usually distinguish it from *D. spicata*.

D. spicata, seashore saltgrass (pl. III, 72): The grains are about 2 mm. long and terminate in two minute prongs at the apex, the apex not prolonged into a definite beak.

ECHINOCHLOA

(Pl. IV, 76–78)

The spikelet of *Echinochloa* is essentially as in *Panicum*, but the thin and papery second glume and sterile lemma are awned or awn-tipped, and bear scattered spinelike hairs. The size of the spikelets, length of awn, and relative length of the second glume and sterile lemma serve to distinguish the species.

Seed samples may contain a variable proportion of hulled seeds (the caryopsis within its lemma and palea). The lemma and palea are hard, smooth, and shining; plano-convex, the lemma so sharply arched it is difficult to grasp with forceps. Size and shape are the chief distinguishing features of the hulled seeds.

SEED KEY

A. Hulled seed 2 mm. long.
Broadly elliptic. Spikelet; sterile lemma and second glume equal, short-pointed——— *Echinochloa colonum*, jungle rice (pl. IV, 76).

B. Hulled seed 2¾ to 3 mm. long.
Broadly elliptic. Spikelet; sterile lemma long-awned, second glume acute-pointed——— *E. crusgalli*, barnyard grass (pl. IV, 77).
Broadly lance-shaped. Spikelet; sterile lemma short-awned, second glume short-pointed.
E. crusgalli var. *frumentacea*, Japanese millet (pl. IV. 78).

ELYMUS—WILD-RYE

(Pl. IV, 81–84)

The spikelets of *Elymus* are two to six flowered, disarticulating above the glumes and between the florets. In certain species the mature florets are somewhat similar to *Agropyron*.

Six species are described. One species, *Elymus canadensis*, including the improved variety Mandan wild-rye, is in commercial production. Three species are in limited production or experimental plant-

ings: *E. glaucus; E. junceus;* and *E. triticoides.* Seeds of *E. virginicus* and *E. riparius*, as well as the above-named species, may occur incidentally with crop seeds.

Elymus canadensis, Canada wild-rye, is a widely distributed, variable species, with several more or less intergrading botanical varieties. The lemmas are mostly copiously hirsute, in some varieties sparingly so or nearly glabrous. Completely glabrous lemmas appear to be rather rare.

Elymus riparius, riverbank wild-rye, is confined to the eastern half of the United States, north of Arkansas, Kentucky, and North Carolina. The seeds of *E. canadensis* may be distinguished from this species by the hirsute lemmas and longer paleas.

Elymus virginicus, Virginia wild-rye, is also a widely distributed and variable species, with several recognized varieties. The seeds may be distinguished from *E. canadensis* and *E. riparius* by the short awn and coarsely granular lemma.

SEED KEY

A. Awn 20 to 30 mm. long or longer.

a. Awn straight; palea markedly shorter than the lemma.
Lemma coarsely granular, sparingly hispid on the nerves above, bifid, callus pubescent; length (excl. of awn) 11 to 12 mm., width 1¼ mm_____ *Elymus glaucus*, blue wild-rye (pl. IV, 82).
Lemma scurfy and minutely hispid, lateral nerves often exserted at the tip, callus short-pubescent; length (excl. of awn) 10 to 12 mm., width 1½ mm.
E. riparius, riverbank wild-rye (not illus.).

b. Awn divergent and curved; palea equal to lemma or nearly so.
Lemma hirsute, not bifid or with exserted nerves, callus glabrous or with short hairs at each end; length (excl. of awn) 10 to 12 mm., width 1½ mm.
E. canadensis, Canada wild-rye (pl. IV, 81).

B. Awn less than 5 mm.

a. Lemma stiff, glossy, smooth, or sparingly scabrous on midnerve at the tip; callus smooth; length (excl. of awn) 8 to 9 mm., width 1½ mm. or more.
E. triticoides, beardless wild-rye (not illus.).

b. Lemma coarsely granular, sparingly scabrous, callus smooth; length (excl. of awn) 8 to 9 mm., width 1½ mm. or more.
E. virginicus, Virginia wild-rye (pl. IV, 84).

c. Lemma scurfy, pubescent, callus smooth or sparingly pubescent; length (excl. of awn) 8 to 10 mm., width 1½ mm. or more.
E. junceus, Russian wild-rye (pl. IV, 83).

ERAGROSTIS—LOVEGRASS

(Pl. IV, 85–90)

The spikelets of lovegrass are several-flowered, disarticulating above the glumes. Processed seed consists almost entirely of hulled caryopses.

Seven species are described, only two of which are of recognized agricultural value in this country, *Eragrostis curvula*, weeping lovegrass, and *E. trichodes*, sand lovegrass. The other species under consideration are either of experimental interest or as incidentals with crop seeds.

SEED KEY

A. Surface light brownish yellow, embryo area black; smooth or faintly striate.

a. Length 1¾ to 2 mm., width 1 mm. or less; embryo area oblong, with a distinct rim_____ *Eragrostis curvula*, weeping lovegrass (pl. IV, 88).

b. Length 1 mm. or less, width ½ mm.; embryo area obtusely triangular or broadly oval, not distinctly rimmed.
E. lehmanniana, Lehman lovegrass (pl. IV, 89).

B. Surface and scar area light brown or dark reddish brown.

a. Ventral side with deep longitudinal cavity; surface reticulated; broadly oblong.

aa. Length 1 to 1½ mm., width 1 mm. or more; reticulations faint.
E. trichodes, sand lovegrass (pl. IV, 90).

bb. Length ½ to ¾ mm., width ½ mm.; reticulations prominent.
E. capillaris, lacegrass (pl. IV, 85).

b. Ventral side without longitudinal cavity.

aa. Surface finely striate; narrowly oblong, length 1 mm. or more, width ½ mm_____ *E. chloromelas*, Boer lovegrass (pl. IV, 87).

bb. Surface faintly reticulated; rotund, with a pointed base; length and width about equal, ¾ to 1 mm.
E. cilianensis, stinkgrass (pl. IV, 86).

cc. Surface neither striate nor reticulate; ventral side strongly arched; length 1 to 1½ mm., width ½ mm.
E. tef, teff (not illus.).
(*E. abyssinica*).

FESTUCA [8]—FINE-LEAVED FESCUES

(Pl. IV, 95–96)

Seeds of the fine-leaved fescues are very similar, and because of the large number of strains involved they present a serious problem in identification.

Two species represent the cultivated forms: *Festuca ovina*, sheep fescue; and *F. rubra*, red fescue, with its variety Chewings fescue (*F. rubra* var. *commutata*). *F. rubra* has, in addition, several recognized strains such as Illahee, Rainier, and Prince Georges. *F. capillata*, hair fescue, is not a cultivated crop in this country but occurs incidentally with other crop seeds.

The principal weedy species found incidentally with crop seeds are *F. myuros*, rattail fescue; *F. octoflora*, sixweeks fescue; and *F. megalura*, foxtail fescue. Space does not permit showing all of these species in the illustrations.

Seeds of the *ovina-rubra* group are too variable to permit accurate identification of the individual seeds in all cases. However, when a small sample is viewed it should, in most cases, be possible to identify it as to kind by a combination of characters such as relative size, length of awn, and character of lemma. With practice, it is often possible to recognize bulk samples of the various strains of the *rubra* group. Two seed keys are presented, one key showing the distinguish-

[8] A more complete study of the species of fine-leaved fescues, with photographs of seed drawings, may be obtained by purchase from the Grain Branch, Production and Marketing Administration, U. S. Department of Agriculture, Washington 25, D. C.

ing features of the different species, the other key showing bulk distinctions to be found in the *ovina-rubra* group.

SEED KEY TO THE SPECIES

A. Length (excl. of awn) 9 to 10 times the width; awn twice the length of the lemma or longer; rachilla flat against the palea, apex in oblique position, not expanded into a disc.

a. Edges of lemma with long ciliate hairs toward the top (except on primary florets)_____ *Festuca megalura*, foxtail fescue (not illus.).

b. Edges of lemma devoid of cilia; width approx. ½ mm.
F. myuros, rattail fescue (pl. IV, 96).

B. Length (excl. of awn) less than 9 times the width; awn ½ length of lemma or less; rachilla stands away from palea, apex in nearly horizontal position, expanded into a disc.

a. Broadly elliptic; awnless or nearly so, occasionally with short awn. Length (excl. of awn) approx. 3 mm., width 1 mm.
F. capillata, hair fescue (not illus.).

b. Narrowly elliptic, oblong or lanceolate; awn ⅕ to ½ length of lemma (exceptions in *F. octoflora*).
Length (excl. of awn) 4 to 4½ mm., width ½ mm. or more; lemma sparingly scabrous toward the top and along margins, to almost smooth; awn sometimes shorter or longer than above.
F. octoflora, sixweeks fescue (not illus.)
Length (excl. of awn) 4 to 7 mm., width 1 to 1½ mm.; pubescence on lemma variable_____ *F. ovina*, sheep fescue (not illus.).
F. rubra vars. and strains, red fescue (pl. IV, 95).

KEY TO THE BULK DISTINCTIONS OF SEEDS OF THE *OVINA-RUBRA* GROUP

A. Length (excl. of awn) 4 to 5 mm., width 1 mm.

a. Lemmas mostly sparingly short-pubescent at the top, hairs appressed or longer and spreading, occasionally short-pubescent along margins at the base; rachillas sparingly pubescent, hairs long and spreading, or short-pubescent to almost smooth; awns mostly ⅕ the length of the lemma, occasionally ½ or longer; in some lots keels of palea inrolled, almost touching in upper ⅓ so seed appears long-pointed on ventral side, other lots more open and flaring.
F. ovina, sheep fescue (not illus.).

b. Lemmas smooth, sparingly short-pubescent at top and on margins at the base, or long-pubescent over entire surface; rachillas smooth or sparingly to copiously long-pubescent; awns ⅕ to ½ the length of lemma or longer_____ *F. rubra*, commercial red fescue (pl. IV, 95).

c. Lemmas smooth or minutely scabrous at top and on margins at the base; rachillas sparingly pubescent to almost smooth; awns ⅕ or less to ½ the length of the lemma.
F. rubra var. *commutata*, commercial Chewings fescue (not illus.).

d. Lemmas minutely and sparingly scabrous at top and along sides or almost smooth, occasionally with longer soft pubescence along the sides, texture tends to be delicate and papery; rachillas sparingly pubescent to smooth; awns ½ the length of lemmas or less.
F. rubra, Illahee strain (not illus.).

B. Length (excl. of awn) 6 to 7 mm., width 1 to 1½ mm.

a. Hairs on keels of paleas long, close-spaced; lemmas sparingly long-pubescent along margins or almost smooth; rachilla hairs few or lacking; awns ⅓ to ½ the length of the lemma.
F. rubra, Rainier strain (not illus.).

FESTUCA [9]—TALL FESCUE; MEADOW FESCUE

(Pl. IV, 93–94)

Two species of tall fescue are important agricultural crops: *Festuca elatior*, meadow fescue; and *F. arundinacea*, tall fescue, with two horticultural varieties, Alta fescue and Ky–31.

As pointed out in the seed key, seeds of meadow fescue and tall fescue are readily distinguished by their shape, together with the texture and pubescence of the lemmas. Distinguishing the seeds of tall fescue and its varieties Alta fescue and Ky–31 fescue is more difficult. The distinctions between them are fine, and it is possible that these may not be apparent in all seed lots.

SEED KEY

A. Lemma short-pointed, awnless, glabrous and smooth, or minutely and sparingly scabrous at the tip_____ *F. elatior*, meadow fescue (pl. IV, 93).

B. Lemma long-pointed, awned, or rarely awnless, coarsely granular, scabrous on nerves, especially toward top, and sparingly between nerves and along the margins_____ *F. arundinacea*, tall fescue (pl. IV, 94).
var. Alta (not illus.).
var. Ky–31 (not illus.).

HORDEUM—BARLEY

(Pl. V, 104–108)

The spikelets of *Hordeum* are one-flowered, usually with three spikelets at each joint of the rachis. The unit of three spikelets consists of a middle fertile floret, which is usually sessile, and two pedicellate lateral, infertile florets (except in *H. vulgare*). The character of the infertile florets and the attached glumes are important diagnostic features. In processed seed the clusters may be broken apart, only the matured fertile florets remaining. Without the attached glumes and sterile florets it is not always possible to identify the seed with certainty.

Five species are illustrated and described. One species, *Hordeum vulgare*, is an important cultivated crop. Four species may occur as weeds with such crops as alfalfa and orchard grass: *H. brachyantherum* (*H. nodosum*); *H. jubatum*; *H. pusillum*; and *H. leporinum* (*H. murinum*).

There are many varieties of cultivated barley. In some varieties the grain is naked, but these are in rather limited cultivation. Most varieties have persisting hulls (lemma and palea), the chief distinguishing features being length and pubescence of awn and rachilla, and the presence or absence of transverse wrinkles in the hull. The identification of varieties by seed character is not a part of this study. Seeds of some varieties are described by Åberg and Wiebe (*1*).

SEED KEY

A. Fertile floret broadly elliptic, thick; length to tip of palea 10 to 12 mm., width 4 mm., awn about 15 mm.; lemma and palea thick and stiff, smooth or with fine transverse wrinkles; rachilla threadlike; in edge view, ventral side convex, dorsal side nearly straight__ *Hordeum vulgare*, barley (pl. V, 104).

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[9] A more complete study of the species of tall fescues and ryegrass, with photographic plates of seed drawings, may be obtained by purchase from the Grain Branch, Production and Marketing Administration, U. S. Department of Agriculture, Washington 25, D. C.

B. Fertile floret narrowly elliptic or lanceolate, flattened; length to tip of palea 6 to 8 or 9 mm., width 1½ to 2 mm., awned; lemma stiff, granular, minutely and sparingly hispid at the top; midnerve faint or obscure; rachilla thread-like, ½ to ¾ the length of the lemma.

a. Fertile floret sessile, sterile florets pedicellate; fertile floret disarticulates by partial abscission.

aa. Glumes all bristlelike; keels of palea inturned, flattened, close together and nearly parallel.

aaa. Palea with a fine longitudinal fold down the middle; awn 18 to 20 mm. long.
H. jubatum, foxtail barley (pl. V, 107).

bbb. Palea without longitudinal fold down the middle; awn 5 to 6 mm. long.
H. brachyantherum, meadow barley (pl. V, 106).

bb. Inner glumes expanded below and tapering into long awns, the two outer glumes bristlelike; keels of palea not inturned and flattened, spread apart about midway; grain thicker than *jubatum* and *brachyantherum* (*nodosum*); awn 5 to 6 mm. long——— *H. pusillum*, little barley (pl. V. 105).

b. Fertile and sterile florets pedicellate; inner glumes slender and ciliate on the margins, the two outer glumes bristlelike; awn of fertile floret about 35 mm. long; fertile floret disarticulates by fracture; keels of palea inturned, forming two thick longitudinal rolls, the margins almost touching. *H. leporinum* (*H. murinum*), wall barley (pl. V, 108).

LEPTOLOMA

Leptoloma cognatum, fall witchgrass (pl. V, 109): The first glume is minute, the second glume and sterile lemma as long as the fertile lemma; pale straw color, thin and papery, with fine appressed hairs between the prominent nerves, and longer hairs at the margins. When found incidentally with crop seed the hairs may be almost entirely rubbed off, as shown in upper right of the illustration. The unit considered the seed is usually the caryopsis within the lemma and palea, with or without the glumes or only portions of them persisting.

The lemma is approximately 2¼ to 2½ mm. long, ¾ mm. wide; hardened, minutely tubercled and finely striate lengthwise; dark brown, the margins lighter and thinner, overlapping the palea at the top. The palea is similar to the lemma in surface and texture.

The seed may occur with alfalfa and similar crops from the Great Plains.

LOLIUM—RYEGRASS

(Pl. V, 110–113)

Seeds of ryegrass and the tall fescues (pl. IV, 93–94) are very similar but they are readily distinguished by the character of the rachilla, shape of the seed, and to some extent, the position of the hairs on the keels of the palea.

The rachilla of ryegrass is flattened, sometimes with an angle down the middle, the apex, scarcely or not at all expanded, lies flat against the palea. In the tall fescues the rachilla is cylindrical, the apex, expanded into a disk, tends to stand away from the palea.

Three species of *Lolium* are in cultivation: *L. perenne*, perennial ryegrass; *L. multiflorum*, Italian ryegrass; and *L. rigidum*, Wimmera ryegrass. Westernwolth, a variety of *L. multiflorum*, and Wimmera ryegrasses are in experimental plantings. Two species occur as weeds

in cultivated fields, *L. temulentum*, darnel, and the more recently introduced *L. persicum*, Persian ryegrass.

Seeds of the two weedy species are readily recognized. In the cultivated species it is usually possible to distinguish the seed in bulk but individual seeds are more difficult to identify, especially if the seed has been severely milled.

SEED KEY

A. Seed narrowly oblong; not markedly thickened through the middle; palea not transversely wrinkled.

a. Lemma awnless, or when present awn short and frail.
Length approximately 6 mm.
Lolium perenne, perennial ryegrass (pl. V, 110).
Length 7 to 9 mm. ---- *L. rigidum*, Wimmera ryegrass (not illus.).

b. Lemma awned, occasional seed awnless.
Length, exclusive of awn, approximately 6½ to 7 mm.
L. multiflorum, Italian ryegrass (pl. V, 111).
L. multiflorum var. Westernwolth (not illus.).
Length, exclusive of awn, approximately 8 to 10 mm.
L. persicum, Persian ryegrass (pl. V, 112).

B. Seed broadly elliptic; markedly thickened through the middle; palea transversely wrinkled.
Length, exclusive of awn, approximately 7 mm.
L. temulentum, darnel (pl. V, 113).

NASSELLA

Nassella trichotoma, no common name (pl. V, 116): The laterally compressed, roughly triangular caryopsis is completely enclosed in a hardened, tuberculate lemma, the overlapping edges of which completely obscure the membranous palea (see view at right in illustration); yellowish or brownish straw color.

The lemma, exclusive of awn, is 2 to 2¼ mm. long and approximately 1 mm. wide at widest point; awn about 30 mm. long, straight or flexuous, twisted; basal hairs silvery white, copious, appressed, ⅓ to ½ the length of the lemma. The palea is membranous, about ½ the length of the caryopsis. View at lower left in the illustration shows the long, acuminate, awn-tipped glumes.

This seed is a characteristic impurity in importations of oats from Argentina.

PANICUM [10]—PANICUM

(Pl. VI, 121–138)

The spikelet of *Panicum* consists of two thin papery glumes, a sterile floret, and a fertile floret. The first glume is usually much reduced; the second glume and sterile lemma are similar in texture but longer. The lemma and palea of the fertile floret are hard and, in many species, smooth and shiny; in other species roughened by vertical rows of minute tubercles. In some species the tubercles may be fused to form transverse ridges on the lemma. The character of the lemma and seed scar are important diagnostic features.

[10] A more complete study of *Panicum*, with photographic plates of seed drawings, may be obtained by purchase from the Grain Branch, Production and Marketing Administration, U. S. Department of Agriculture, Washington 25, D. C.

SEED KEY

A. Lemma roughened, dull.

a. Seeds 1½ to 2 mm. long; narrowly elliptic, with coarse transverse ridges---------- *P. maximum*, Guinea grass (pl. VI, 132).

b. Seeds 2½ to 4 mm. long.

aa. Broadly obovate.

2½ mm. long, obscurely roughened, both faces strongly convex; olive green to dark yellowish green.
P. brachyanthum, no common name (pl. VI, 124).

bb. Broadly elliptic.

2½ mm. long; both faces strongly convex, with coarse transverse ridges; dark straw color to light brown.
P. fasciculatum, browntop panicum (pl. VI, 128).

3 mm. long; one face convex, with coarse transverse ridges; ivory to pale golden yellow
P. ramosum, browntop millet (pl. VI, 136).

cc. Narrowly elliptic.

2¾ to 3 mm. long, minutely roughened and striate lengthwise ---------- *P. purpurascens*, Para grass (pl. VI, 135).

dd. Lance-shaped.

3½ to 4 mm. long, with coarse transverse ridges and fine vertical lines------ *P. texanum*, Texas millet (pl. VI, 137).

B. Lemma smooth, glossy.

a. Seeds 1 to 1¾ mm. long.

aa. Narrowly elliptic.

1½ mm. long; scar oval, inconspicuous; dark yellow streaked with olive green----*P. capillare*, witchgrass (pl. VI, 125).

bb. Narrowly oblong or lance-shaped.

1¾ mm. long; scar broadly crescent-shaped; dark yellow streaked with olive.
P. capillare var. *occidentale*, barbed witchgrass (pl. VI, 126).

1¾ mm. long; scar broadly triangular; flat; olive green or dark yellowish green.
P. dichotomiflorum, fall panicum (pl. VI, 127).

cc. Broadly elliptic.

aaa. 1½ mm. long; scar oval, callus narrow (vertically); light straw color with greenish tinge.
P. anceps, beaked panicgrass (pl. VI, 121).

bbb. 1¼ to 1½ mm. long; scar broadly triangular; callus wide (vertically), pointed; yellowish straw color.
P. huachucae, hairy panicgrass (pl. VI, 131).

ccc. 1¾ to 2 mm. long; scar crescent-shaped, large, prominent; olive green or dark yellowish green.
Winglike points of scar approximately ½ mm. long.
P. hillmani, Hillman panicgrass (pl. VI, 130).
Winglike points of scar approximately ¼ mm. long.
P. bergii, Berg's panicgrass (pl. VI, 123).

ddd. 1½ mm. long; scar lens-shaped with a minute knoblike projection at base; dull yellow streaked with olive green.
P. gattingeri, Gattinger's witchgrass (pl. VI, 129).

b. Seeds 2 to 3 mm. long.

aa. Narrowly elliptic.

2 mm. long; straw color splashed with brown; palea longer than lemma.
P. antidotale, blue panicgrass (pl. VI, 122).

bb. Angularly elliptic.
2½ to 3 mm. long; pale straw color, sometimes streaked with dark gray_____*P. virgatum*, switchgrass (pl. VI, 138).

cc. Obovate or broadly elliptic.
3 mm. long; callus wide (vertically), pointed.
P. obtusum, vine-mesquite (pl. VI, 134).

dd. Rounded and turgid or broadly elliptic and flatter.
3 mm. long; scar crescent-shaped; colors, various.
P. miliaceum, proso; broomcorn millet (pl. VI, 133).

PASPALUM—PASPALUM

(Pl. VII, 139–148)

The one-flowered spikelets of *Paspalum* are planoconvex, the first glume usually wanting, second glume and sterile lemma about equal, thin and papery; the fertile lemma stiff and hard (except in *P. malacophyllum*).

Ten species are described. Two of the species, *P. dilatatum*, Dallis grass, and *P. notatum*, Bahia grass, are in cultivation as pasture grasses in the Southern States. Two species are in more limited use for pasture: *P. urvillei*, Vasey grass, and *P. malacophyllum*, ribbed paspalum. *P. distichum*, knotgrass, has some value as a soil binder. Seeds of these and other species may occur incidentally with Southern crop seeds.

SEED KEY

A. Papery glumes (second glume and sterile lemma) persisting (partially in *boscianum*); fertile lemma stiff and hard, yellowish, finely roughened.

a. Glumes long-pubescent, especially along the margins; broadly lance-shaped, only slightly convex on the back.
Light yellowish-brown, 5-nerved; length 3 to 3½ mm., width 2 to 2½ mm_____ *Paspalum dilatatum*, Dallis grass (pl. VII, 140).
Reddish-brown, 3-nerved; length 2¼ to 2¾ mm., width 1½ mm.
P. urvillei, Vasey grass (pl. VII, 148).

b. Glumes sparingly short-pubescent over entire surface; length 2½ to 3½ mm., width 1¼ to 1½ mm.; elliptic to lance-shaped.
P. distichum, knotgrass (pl. VII, 141).

c. Glumes without pubescence or nearly so; strongly convex on the back.

aa. Length 4 mm. or more; oval; width 3 mm.; glumes grayish, dull, 5-nerved; fertile lemma light brown, roughened.
P. floridanum, Florida paspalum (pl. VII, 142).

bb. Length less than 3 mm.; fertile lemma finely roughened.

aaa. Glumes dull reddish brown, 5-nerved; fertile lemma dark reddish brown.
Elliptic; sterile lemma (plane surface) with 4 distinct, transverse ridges just inside the raised margins; length 2½ to 2¾ mm., width 1¾ mm.
P. plicatulum, brownseed paspalum (pl. VII, 146).
Oval or obovate; sterile lemma not ridged; length 2 to 2¼ mm., width 2 mm. or more.
P. boscianum, bull paspalum (pl. VII, 139).

bbb. Glumes dull grayish brown, oval to orbicular; fertile lemma yellowish.
Length 2½ to 2¾ mm., width 2½ mm.; 3 nerves distinct on the back.
P. laeve, field paspalum (pl. VII, 143).
Length 1½ to 2 mm., width 1½ mm.; midnerve on the back faint, lateral nerves obscure or lacking.
P. setaceum, slender paspalum (pl. VII, 147).

B. Papery glumes not persisting; fertile lemma strongly convex on the back.

a. Fertile lemma oval, stiff, smooth and glossy, often slightly wrinkled transversely, 3-nerved; length 3 to 3½ mm., width 2¾ to 3 mm.
P. notatum, Bahia grass (pl. VII, 145).

b. Fertile lemma not stiff and glossy; narrowly elliptic, distinctly 5-nerved, dull, granular; length 2 mm., width 1 mm.
P. malacophyllum, ribbed paspalum (pl. VII, 144).

PENNISETUM

(Pl. VII, 149–150)

The panicle of *Pennisetum* is cylindric, dense, and spikelike. The large caryopses burst through the lemma and palea, falling free from the panicle. Processed seed consists almost entirely of hulled caryopses.

Two species are of interest in this country: *P. glaucum*, pearl millet; and *P. purpureum*, Napier grass. These are in limited use for forage in the extreme South. Shape and thickness are the only features distinguishing the caryopses of the two species.

SEED KEY

A. Obovate or top-shaped; in edge view, dorsal edge is straight, ventral edge convex; length 3 to 3½ mm., width 2 to 2½ mm.
P. glaucum, pearl millet (pl. VII, 149).

B. Shape roughly oblong, flattened dorsoventrally; in edge view, both dorsal and ventral edges straight and nearly parallel; length 4 mm., width 2 mm.
P. purpureum, Napier grass (pl. VII, 150).

PHALARIS—CANARY GRASS

(Pl. VII, 151–156)

The spikelet of canary grass consists of one terminal perfect floret and two sterile lemmas below it (rarely only one or none). The sterile lemmas are reduced and closely appressed to the fertile floret, the entire spikelet disarticulating above the glumes. The seed of commerce consists of the one fertile floret with its sterile lemmas attached just above the callus. The lemma of the fertile floret is stiff, laterally compressed and more or less enclosing the palea.

Seven species are described. Three of these are cultivated crops: *P. canariensis*, canary grass; *P. arundinacea*, reed canary grass; and *P. tuberosa* var. *stenoptera*, Harding grass. Seeds of the other species occur incidentally with crop seeds.

SEED KEY

A. Sterile lemmas 2, equal or subequal.

a. Fertile lemma, 5 to 6 mm. long, 2½ mm. wide.
Elliptic; buff-colored, glossy, glabrous or nearly so, ciliate on margins near the top; sterile lemmas glabrous, spreading, usually lacking in threshed seed.
Phalaris canariensis, canary grass (pl. VII, 155).

b. Fertile lemma, length 4 mm. or less, width 1 to 1½ mm.; light to dark grayish brown, glossy.

aa. Linear-lanceolate; length 3 to 3½ mm., width 1 mm.; fertile lemma very sparingly pubescent and ciliate on the margins toward the top; nerves distinct on the dark gray-brown surface; sterile lemmas long-pubescent along their margins.
P. arundinacea, reed canary grass (pl. VII, 152).

bb. Ovate or ovate-lanceolate; length 2½ to 3 mm., width 1¼ mm.; fertile lemma sparingly pubescent toward the top, nerves obscure; sterile lemmas glabrous.
P. angusta, timothy canary grass, (pl. VII, 151).

cc. Ovate, tapering abruptly to an awl-shaped apex; length 2½ to 3 mm., width 1½ mm.; fertile lemma copiously long-pubescent over entire surface, nerves obscure; sterile lemmas sparingly pubescent along the sides.
P. caroliniana, Carolina canary grass (not illus.).

B. Sterile lemma 1; second lemma, if present, so reduced it appears to be lacking; fertile lemma glossy, yellowish to grayish brown; nerves distinct whitish lines.

a. Fertile lemma ovate-lanceolate; pubescent on upper half; length 4 mm., width 1½ to 1¾ mm.; sterile lemma glabrous, second sterile lemma much reduced or lacking.
P. tuberosa var. *stenoptera*, Harding grass (pl. VII, 154).

b. Fertile lemma ovate; copiously pubescent on upper half; length 3 to 3½ mm., width 1½ to 1¾ mm.; sterile lemma glabrous.
P. minor, little canary grass (pl. VII, 153).

C. Sterile lemmas lacking.
Fertile lemma elliptic to lance-shaped; glabrous, glossy, pale gray, often tipped with yellow at top and base; length 3½ to 4 mm., width 1½ to 1¾ mm_____ *P. paradoxa*, hood canary grass (pl. VII, 156).

POA [11]—BLUEGRASS

(Pl. VIII, 159–164; pl. IX, 165–170; pl. X, 171)

Seeds of *Poa* are characterized by their small size and five-nerved lemmas, keeled along the heavy midnerve and often finely pubescent, with long weblike hairs at the base in most of the species. The hard, dark brown caryopsis is strongly compressed laterally, with a blunt keel on the back above the embryo and a more or less pronounced groove on the opposite side. The grain is usually thickest through the middle, or slightly below, and pointed at both ends. There is a tendency for it to adhere to the palea so that free grains do not commonly occur except in severely milled samples.

The back of the lemma is keeled along its entire length in most species. The keel may be strongly arched longitudinally as in *P. trivialis*, or nearly straight as in *P. pratensis*, for example. The texture of the lemma and the presence or absence of pubescence are important diagnostic features. Because of the fragile nature of the pubescence and of the lemma itself, seeds that have been processed may be badly rubbed or torn. Commercial lots of *P. pratensis* and *P. arachnifera* are familiar examples of this condition. In such cases a careful examination under a magnification of 40× to 60× is necessary to see the evidence of these structures. The apex of the lemma is characteristic in many species, but this in itself is not always conclusive. Florets in the upper part of a spikelet tend to be more slender and pointed than the basal florets. Thus, in a species that predominantly has a broad, rounded apex some seeds with pointed lemmas may be present.

The palea, usually slightly shorter than the lemma, is smooth in some species and pubescent in others. As in other grasses, the margins

[11] A more complete study of *Poa*, with photographic plates of seed drawings, may be obtained by purchase from the Grain Branch, Production and Marketing Administration, U. S. Department of Agriculture, Washington 25, D. C.

of the palea fold over the grain along the two longitudinal nerves. These nerves, known as keels, are fringed with minute hairs. The character of these hairs, and in some cases the type of notch at the apex of the palea, furnish reliable distinguishing features. (See pl. X, 171.)

The rachilla is slender with parallel sides, the apex expanded into a disc. In some species the rachilla is typically elongated. The presence or absence of pubescence on the rachilla is an important diagnostic feature in certain species.

In a spikelet the basil web is neatly folded against the base of the lemma of each floret. The hairs may be characteristically long and copious or few, or entirely lacking in certain species. After the floret has been removed from the spikelet the web usually appears as a long matted tuft of fine hairs. These delicate hairs are sometimes completely rubbed off in the process of cleaning and threshing. In the illustrations the first view in all figures shows an unrubbed seed as removed from a plant specimen. Other views for the most part show the seed as it appears when rubbed from the panicle or as it would appear in commercial seed lots.

In some cases there is not a wide divergence between species in size, shape, or character of rachilla so that the lemma and palea must be relied on to furnish the principal clues for identification. Where fine distinctions such as these are involved, it is difficult to find descriptive terms that will convey the desired picture to the reader. With practice, however, these distinctions become readily apparent. Attention is directed to three species having seed that is sometimes difficult to distinguish: *P. juncifolia* (not illustrated); *P. ampla;* and *P. nevadensis.* The chief distinctions may be found in the character of the pubescence and in the texture of the lemma. These differences may be so slight that some seeds are not always distinct. In occasional plant specimens of these three species the distinguishing features are not clearly evident and the question can be raised as to the possibility of intergrading between the species.

SEED KEY

A. Lemma without pubescence, or only very sparingly pubescent on nerves toward the base (exceptions in *P. pratensis.*)

a. Lemma smooth or very finely granular; unrubbed seed webbed at the base.

aa. Apex folded; intermediate nerves distinct to the base.

aaa. Hairs on keels of palea coarse, short, wide-spaced, do not extend to tip of palea (pl. X, 171); lemma 2½ to 3 mm. long.

P. pratensis, Kentucky bluegrass (pl. IX, 169).

bbb. Hairs on keels of palea short, fine, close-spaced, extend to tip of palea (pl. X, 171); lemma 2½ to 3 mm. long; basal web scant.

P. trivialis, rough bluegrass (pl. IX, 170).

bb. Apex flares out; intermediate nerves obscure or lacking on lower half.

Hairs on keels of palea short, fine, close-spaced, extend to the tip (pl. X, 171); lemma 2½ mm. long; basal web short, scant, may appear to be lacking.

P. compressa, Canada bluegrass (pl. VIII, 164).

b. Lemma coarsely granular (grates on forceps), or scaberulous, no basal web.

aa. Apex obtuse and flaring, sometimes acuminate; intermediate nerves obscure.

aaa. Rachilla finely pubescent or granular; lemma mostly obtuse, finely pubescent all over, 4 to 5 mm. long.
P. juncifolia, alkali bluegrass (pl. X, 171*i*).

bbb. Rachilla smooth or finely granular; lemma mostly acute-pointed, sparingly pubescent on upper portion and on nerves, 4 to 5 mm. long.
P. ampla, big bluegrass (pl. VIII, 160).

bb. Apex acute to acuminate; intermediate nerves obscure or lacking.

aaa. Rachilla pubescent; lemma 5 to 6 mm. long.
P. cusickii, Cusick bluegrass (pl. X, 171*n*).

bbb. Rachilla smooth; lemma 4 to 5 mm. long.
P. nevadensis, Nevada bluegrass (pl. IX, 167).

B. Lemma pubescent.

a. Pubescence confined to nerves; webbed at base except in *annua*, *longiligula*, and *fendleriana*.

aa. Pubescence on lower half, dense, long and matted, longer toward base.
Hairs on keels of palea fine, wide-spaced, becoming long on lower half (pl. X, 171); apex of palea deep V-notched, web very long; lemma 5 to 6½ mm. long.
P. arachnifera, Texas bluegrass (pl. VIII, 161).
Hairs on keel of palea coarse, short, wide-spaced, do not extend to tip of palea as in pl. X, 171*a*; basal web shorter; lemma 2½ to 3 mm. long.
Poa pratensis, Merion bluegrass (not illus.).

bb. Pubescence on lower half, long, silky (well above middle of keel in *annua* and *glaucifolia*).

aaa. Hairs on keels of palea fine, close-spaced, extend to tip (pl. X, 171); basal web long, scant.
Rachilla pubescent; lemma 3 to 3½ mm. long, acuminate.
P. nemoralis, wood bluegrass (pl. IX, 166).
Rachilla smooth or finely granular; lemma 2½ to 3½ mm. long, obtuse.
P. glaucifolia, no common name (pl. X, 171*o*).

bbb. Hairs on keels of palea long and dense, do not extend to tip (pl. X, 171); no basal web.
Rachilla smooth; lemma 2½ to 3 mm. long.
P. annua, annual bluegrass (pl. VIII, 159).

ccc. Hairs on keels of palea short, blunt, close-spaced, extend to tip (pl. X, 171); basal web long, scant.
Rachilla coarsely granular to sparingly scabrous; lemma 3 to 3½ mm. long, finely granular.
P. interior, inland bluegrass (pl. IX, 165).

ddd. Hairs on keels of palea dense, uneven, long below, becoming shorter and wide-spaced toward the top, do not extend to tip (pl. X, 171); no basal web.
Rachilla pubescent, hairs long and bristly; lemma 4½ to 5 mm. long, acute to acuminate, scaberulous.
P. longiligula, long-tongue mutton grass (pl. X, 171*q*).
Rachilla sparingly pubescent, hairs stiff and spreading but shorter than above; lemma 4 mm. long, obtuse, finely to coarsely granular.
P. fendleriana, mutton grass (pl. X, 171*r*).

eee. Hairs on keels of palea short, coarse, wide-spaced, do not extend to tip (pl. X, 171); basal web long, copious. Rachilla smooth; lemma 2½ to 3 mm. long.
P. pratensis, Kentucky bluegrass (pl. IX, 169).

cc. Pubescence on lower half, sparse and shorter; basal web long, scant.
Hairs on keels of palea short, fine, close-spaced, extend to tip (pl. X, 171).
Rachilla smooth; lemma 2 to 2½ mm. long.
P. palustris, fowl bluegrass (pl. IX, 168).

b. Pubescence not confined to nerves; no distinct basal web (*bulbosa* excepted).

aa. Pubescence on lower half of nerves dense, long and lax, sparingly hairy between nerves and on margins.
Lemma 3 to 3½ mm. long, obtuse; hairs on keels of palea long on lower half, short above, extend to tip; apex finely notched (pl. X, 171); hairs at callus.
P. arida, plains bluegrass (pl. VIII, 162).

bb. Sparingly pubescent on lower half, hairs long and lax, mostly confined to keel and marginal nerves; no basal web; hairs at callus.

aaa. Lemma acute-pointed, broad at base; narrow hyaline margins above middle.
Hairs on keels of palea short, close-spaced, extend to tip of finely notched apex (pl. X, 171); rachilla pubescent, sometimes only granular; lemma 4 to 5 mm. long.
P. secunda, Sandberg bluegrass (X, 171*j*).

C. Florets mostly converted into flask-shaped, purple-colored bulblets.
P. bulbosa, bulbous bluegrass (pl. VIII, 163).

SETARIA—MILLET; BRISTLEGRASS

(Pl. X, 172–179; pl. XI, 180–183)

The spikelet of *Setaria*, as in *Panicum*, consists of a thin and papery much reduced first glume, a longer second glume and sterile lemma of like texture, and a fertile floret with hardened lemma and palea. It is subtended by an involucre of one to several bristles. The spikelet falls free from the bristles so that these seldom appear in the harvested seed. The caryopsis enclosed in the hardened lemma and palea is popularly considered the seed. Hulled caryopses are found occasionally in processed seed.

Seeds of certain species of *Setaria* are quite similar in appearance. These may be segregated into three type groups:

1. *Setaria viridis; S. verticillata.*
2. *S. geniculata; S. faberi; S. lutescens.*
3. *S. italica*, the foxtail millets.

Special attention should be directed to the distinguishing features of the species within each of these groups. It will be observed that seed shape is the chief point of distinction in group (1). The species in group (2) may be distinguished by size, shape, and the position of the margins of the lemma in relation to the keels of the palea. The cultivated millets in group (3) are distinguished primarily on the character of the surface of the lemma which is either minutely tuberculate or finely undulate.

Setaria italica, foxtail millet (pl. XI, 180–183): The horticultural varieties of foxtail millet in cultivation in this country fall into two

general groups: (1) German millet; and (2) Common millet. The term "golden millet" has been used for both of these forms, and since it has no specific meaning its use is confusing and should be discontinued. Commercial seed lots are often mixtures of the two forms, the mixture probably due in large measure to hybridization. No means were found whereby seeds of hybrids could be distinguished.

Seeds of the millets are characterized by a waxy or oleaginous surface that is finely roughened by minute tubercles or faint undulations. From an examination of herbarium material it appears that the character of the seed surface (lemma and palea) is constant and, as will be pointed out, may be considered the principal feature distinguishing the German and Common millet groups. The surface details may be recognized under a hand lens, but a binocular microscope with a magnification of about 20 or higher is desirable for an accurate determination.

Seed shape is useful in making bulk determinations, but certain elliptic forms are common to both groups so that shape cannot be considered a constant character for the identification of an individual seed. Seed color varies to a certain extent as pointed out in the seed key. The glumes when present are helpful in making a diagnosis. As shown in the illustrations, the internode between the first and second glumes is noticeably longer in German millet than in Common millet. In this respect also, some intergrading may be found. Hulled grains may be present in commercial seed samples. The grains (not illus.) are broadly elliptic or rounded, thick, creamy white or yellowish. The larger size and yellowish color distinguish them from the flatter, grayish-green caryopses of *S. viridis* and *S. lutescens*, which are common impurities in millet samples.

The illustrations show the usual types of seed that may be found in any one panicle of the kind under consideration. In some cases, in order to show the detail of seed surface, it was necessary to sacrifice the degree of convexity of the more turgid seeds. This detail is shown more clearly in the edge views of the seeds.

SEED KEY

A. Seeds 2 to 2¼ mm. long.

a. Lemma smooth, glossy.

Broadly elliptic or rounded.

Setaria magna, giant bristlegrass (pl. X, 177).

b. Lemma finely roughened with vertical lines of minute tubercles and irregular transverse ridges.

Narrowly elliptic.

Apex obtuse; greenish yellow or light brown mottled with darker brown_____ *S. viridis*, green foxtail (pl. X, 179).

Apex short-pointed; greenish yellow to dark brown.

S. verticillata, bur bristlegrass (pl. X, 178).

Broadly elliptic.

Apex pointed, terminating in a stout awl-point.

S. macrostachya, plains bristlegrass (pl. X, 176).

c. Lemma roughened with coarse transverse ridges.

Narrowly elliptic.

Apex short-pointed, 3-pronged; ridges close-spaced; greenish yellow to dull brown.

S. geniculata, knotroot bristlegrass (pl. X, 173).

Lance-shaped.

Apex long-pointed; fine vertical lines, ridges less coarse than in *geniculata*; color light cream or yellow.

S. grisebachii, Grisebach bristlegrass (pl. X, 174).

B. Seeds 2½ to 2¾ mm. long.

a. Lemma finely roughened---- *S. italica*, foxtail millet (pl. XI, 180–183).

aa. Vertical lines of minute tubercles forming irregular transverse ridges.

Rounded and turgid or broadly elliptic and flatter.

Pale straw color to golden yellow.

Var. German millet (pl. XI, 182).

Grayish white or yellowish.

Var. White Wonder millet (pl. XI, 183).

bb. Minute transverse undulations, not evidently tuberculate.

aaa. Narrowly to broadly elliptic.

Pale golden yellow. Var. Common millet (pl. XI, 180).

Orange to golden yellow.

Var. Siberian millet (not illus).

Uniform orange color-- Var. Kursk millet (not illus).

Yellowish straw color, light brown mottled with dark brown, or dark brown.

Var. Hungarian millet (pl. XI, 181).

bbb. Lance-shape to narrowly elliptic.

Golden yellow------ Var. Goldmine millet (not illus.).

b. Lemma roughened with coarse transverse ridges.

aa. Broadly elliptic.

Ridges sharply defined, wide-spaced, with distinct smooth areas between; greenish, golden yellow, or dark brown.

S. lutescens, yellow foxtail (pl. X, 175).

bb. Broadly to narrowly elliptic.

Ridges close-spaced, irregular; greenish yellow to dark brown---------- *S. faberi*, giant foxtail (pl. X, 172).

SORGHUM

(Pl. XI, 185–194)

The spikelets are borne in pairs on a jointed rachis, one perfect and sessile, the other sterile or staminate and pedicellate, the fertile spikelet falling with the joint of the rachis and attached sterile pedicellate spikelet.

The mature, fertile floret consists of a pair of hardened glumes enclosing a thin and translucent lemma and palea. The color of the two glumes and the presence or absence of pubescence may vary with the variety. The glumes may be persistent and fit smoothly on the grain, as in Sudan grass and Johnson grass, or the glumes may be loose, tending to spread apart from the grain as in many of the sorghums. In certain varieties of sorghum the globose grain is much longer than the loose glumes and the grains become almost completely hulled in processing. Depending somewhat on the variety, the seed in commerce may be in the hulls, or completely hulled.

Sudan grass and Johnson grass (pl. XI, 185–186): Three varieties of Sudan grass are in cultivation at the present time: Common Sudan (shown in the illustration); Tift Sudan; and Sweet Sudan. The glumes of Sweet Sudan are sienna or reddish brown in color; those of Common and Tift Sudan are mostly light straw color and do not appear to be distinguishable.

Seeds of Sudan grass and the closely related Johnson grass may be distinguished by the size, shape, and color of the glumes, and the character of the attached rachis segment and pedicel.

Sorghum-Sudan hybrids (pl. XI, 187): Certain seeds of sorghum-Sudan hybrids may be recognized by their shape and larger size, as

shown in the illustration. Because of the larger size, the seeds in the illustration are not drawn to the same scale as the Sudan seed. However, not all hybrid seeds are distinguishable by seed character.

Sorghum (pl. XI, 188–194): The sorghums are commonly classified as grain or sweet sorghums (sorgo). There are many horticultural varieties in each group. The sweet sorghums are represented in the illustrations by the variety Sumac, which is completely hulled in the threshing process, and Black Amber, the grain of which remains in the glumes. The grain sorghums are represented by the varieties Kafir, Hegari, Feterita, and Milo.

SEED KEY

A. Glumes and pedicels[12] persisting; spikelet narrowly to broadly elliptic.

a. Base with smooth callus; pedicels expanded and cuplike at apex.

Glumes 4½ mm. long, 1½ to 2 mm. wide; hulled grain broadest above the middle, pointed toward the base, flattened dorso-ventrally_____ *Sorghum halepense*, Johnson grass (pl. XI, 185).

Glumes 6 to 7 mm. long, 3 to 3½ mm. wide; hulled grain oval or broadly elliptic, not markedly flattened dorso-ventrally. *Sorghum-Sudan* hybrids (pl. XI, 187).

b. Base without smooth callus; pedicels not expanded and cuplike at the apex.

Glumes 5½ to 6 mm. long, 2 to 2¼ mm. wide; hulled grain broadest below the middle with obtusely pointed base; flattened dorso-ventrally_____ *S. sudanense*, Sudan grass (pl. XI, 186).

Glumes 6 to 7 mm. long, 3 to 3½ mm. wide; hulled grain oval or broadly elliptic, not markedly flattened dorso-ventrally. *Sorghum-Sudan* hybrids (pl. XI, 187).

B. Glumes, if present, not close fitting on the grain, pedicels usually lacking; grain broadly elliptic, orbicular, or obovate, not flattened dorso-ventrally, or only slightly so.

a. Embryo area plane, slightly elevated, with margined rim; grain commonly ivory with reddish brown spots; in edge view, both sides curved, base short-pointed_____ *S. vulgare* var. Kafir (pl. XI, 191).

b. Embryo area depressed, margin not rimmed, a very short ridge at the base.

aa. Grain orbicular, bluish or chalky white, sometimes with reddish brown spots, subcoat red-brown.

Surface distinctly crackled; length 5 mm., width 5 mm.; in edge view, one side straight, the other side curved, the long-pointed base off-center. *S. vulgare* var. Feterita (pl. XI, 193).

Surface smooth or only slightly crackled; length 4½ to 5 mm., width 4 mm.; in edge view, both sides curved, the base scarcely pointed____ *S. vulgare* var. Hegari (pl. XI, 192).

bb. Grain obovate, the base long-pointed; color salmon or brownish; glumes, if present, with a transverse wrinkle below the middle_____ *S. vulgare* var. Milo (pl. XI, 190).

c. Embryo area neither distinctly elevated nor depressed, a coarse ridge extending to top of embryo area or nearly so; grain buff or brown.

Grain in edge view top-shaped or elliptic; glumes shorter, equal to, or longer than the grain. *S. vulgare*, Sweet sorghum (pl. XI, 188–189).

Grain in edge view thickened below the middle, tapering toward the top; glumes about equal to grain, tan, red, or dark brown. *S. vulgare* var. *technicum*, broomcorn (pl. XI, 194).

[12] The rachis segment and pedicel of sterile spikelet.

SPOROBOLUS—DROPSEED

(Pl. XII, 196–198)

The spikelets of dropseed are one-flowered, disarticulating above the glumes. The caryopsis is free from the lemma and palea and falls readily from the spikelet at maturity.

Two native species are utilized for range reseeding: *Sporobolus airoides*, alkali sacaton; and *S. cryptandrus*, sand dropseed. Seeds of these two species, as well as *S. neglectus*, puff dropseed, and *S. clandestinus*, scratch dropseed, may occur incidentally with crop seeds.

SEED KEY

A. Lemma silvery and transparent, or opaque in *neglectus;* free grains oval, flattened, semitranslucent.

a. Free grains yellowish brown, smooth or nearly so; embryo area less than ½ the length of the grain; length 1¼ mm., width ¾ mm.
Sporobolus cryptandrus, sand dropseed (pl. XII, 197).

b. Free grains yellowish brown with dark brown spots; striate lengthwise and sometimes pitted; embryo area prominent, about ¾ the length of the grain; length 1¾ mm., width 1 mm.
S. neglectus, puff dropseed (pl. XII, 198).

B. Lemma yellowish or grayish, not silvery; free grains oval, flattened, dull dark brown, strongly striate lengthwise; length 1½ mm., width 1 mm.
S. airoides, alkali sacaton (not illus.).

C. Lemma dull grayish brown flecked with purple, sparingly long-pubescent, length (including awn) 10 to 15 mm.; free grains oblong, flattened, yellowish brown, semitranslucent, minutely striate or nearly smooth; embryo area about ½ the length of the grain; length 3½ mm., width 1¼ mm.
S. clandestinus, scratch dropseed (pl. XII, 196).

ZOYSIA

(Pl. XII, 202–203)

Seeds of two species of *Zoysia* are available commercially: *Z. japonica*, Japanese lawn grass; and *Z. matrella*, Manila grass. The latter is reported to be the more widely used of the two species. Another species, *Z. tenuifolia*, Mascarene grass, is in experimental plantings. The plant is a poor seeder under conditions in this country and the seed is not in the trade at the present time.

The spikelets are 1-flowered, laterally compressed, disarticulating below the glumes. The first glume is wanting; the second glume is hard and stiff, smooth, short-awned, and completely enfolding a thin lemma and palea. The thin palea is sometimes lacking. The usual commercial seed consists of the caryopsis firmly locked in the hardened second glume. Hulled grains are usually found only in severely milled samples.

SEED KEY

A. Seeds broadly ovate, short-pointed or short-awned; length (excl. of awn) 3½ to 4 mm., width 1½ mm.; color dull brownish, commonly with a purplish tinge---------- *Z. japonica*, Japanese lawn grass (pl. XII, 202).

B. Seeds narrowly lance-shaped, short-awned; length (excl. of awn) 3 to 3½ mm., width 1 mm.; color bright yellowish straw color.
Z. matrella, Manila grass (pl. XII, 203).

CARYOPHYLLACEAE (PINK FAMILY)

(Pls. XV–XVI, 273–293)

The seed pods of plants in the pink family are usually 1-celled and many seeded. The seeds, attached to the base or to a central column in the pod, have a hilum or scar that is characteristic of the family. The slender embryo is coiled or curved around the outside of a mealy endosperm, except in *Dianthus* where it is nearly straight.

The species under consideration are of interest chiefly as field weeds. They include such well-known weeds as chickweed, spurry, cow cockle, campion, catchfly, and corncockle.

LYCHNIS—CAMPION; AND *SILENE*—CATCHFLY

(Pl. XV, 279–280, 283–291)

Plants of these two genera differ only in minor features, and the same is true of their seeds. The two groups are included in one seed key.

The seeds are hemispheric or kidney-shaped, often asymmetrical and angular, slightly flattened laterally; color black, reddish brown, or gray, with black-tipped protuberances or tubercles arising from minute interlocking grayish plates. The plates may be roughly oblong or circular, with variously indented margins. The color of these plates gives the seeds a light gray or a darker steel gray aspect. The shape of the plates may be a useful diagnostic feature in some cases.

The hilum or scar may be a tranverse slit or an oval cavity. In certain species the cells around the scar become elongated, forming a collar wholly or partially surrounding the scar, or they may form two padlike structures overlapping the ends of the oval scar cavity.

The character and arrangement of the protuberances or tubercles, and the shape and position of the elongated cells at the scar are important diagnostic features.

With the possible exception of *L. dioica*, red cockle, the species described in the key are found commonly with crop seeds. *Silene cretica*, no common name, occurs in imported seed, such as crimson clover.

SEED KEY

A. Elongated cells at the scar collarlike; scar a circular or oval cavity; 1½ to 2 mm. across or larger.

a. Collar high, completely surrounds scar cavity, or nearly so; tubercles fine, pointed, so close-spaced the seed may appear minutely spiny, not arranged in a pattern; grayish plates very small, roundish. *Lychnis dioica*, red campion (pl. XV, 280).

b. Collar shorter, surrounds ½ to ¾ of scar cavity; tubercles short, blunt, not close-spaced like above, not arranged in a pattern; grayish plates very small, roundish_____ *Lychnis alba*, white cockle (pl. XV, 279).

B. Elongated cells at the scar in two padlike structures, one on each side of the oval scar cavity.

a. Cells of pad long, narrow, so that pads appear finely striate. Seeds 1½ to 2 mm. across, flattened, angular; tubercles pointed, in 4 or 5, often interrupted, concentric rows on the sides of seed; rows indefinite in edge view of seed; grayish plates oblong. *Silene cucubalus*, bladder campion (pl. XV, 289).

b. Cells of pad narrow, uneven in length.
Seeds 1½ mm. across; thick, with rounded margins; tubercles short, blunt, crowded, not arranged in a pattern; in edge view tubercles usually in rows both above and below the scar; grayish plates roundish or linear oblong.
S. noctiflora, night-flowering catchfly (pl. XV, 291).

c. Cells of pad broader, uneven in length.

aa. Seeds 1½ to 2 mm. across; tend to be asymmetrical and obtusely angled; tubercles short, blunt, in 3 or 4 concentric rows on the sides; in edge view tubercles appear crowded, not in distinct rows above the scar; grayish plates oblong, prominent.
S. dichotoma, forked catchfly (pl. XV, 290).

bb. Seeds 1¼ mm. across; more uniform and symmetrical in shape than *dichotoma;* tubercles as in *dichotoma* but in edge view appear in 3 or 4 distinct rows above the scar; grayish plates oblong---------- *S. cserei*, no common name (pl. XV, 288).

cc. Seeds ½ to ¾ mm. across; thick, with rounded margins, scarcely flattened laterally; tubercles pointed or blunt, large for the size of the seed, not arranged in a pattern; grayish plates roundish-- *S. antirrhina*, sleepy catchfly (pl. XV, 283).

C. Elongated cells at the scar lacking or much reduced.

a. In side view scar lies within a narrowly or broadly U-shaped cleft or sinus; seed flattened laterally, margins angular.

aa. Scar a narrow transverse slit.

aaa. Seeds 1½ mm. across; tubercles short, fine, inconspicuous, in 2 or 3 concentric rows along the margins, no pattern above; in edge view tubercles in about 4 poorly defined rows above the scar, the linear grayish plates lying in a transverse position.
S. conoidea, no common name (pl. XV, 286).

bbb. Seeds 1¾ to 2 mm. across; tubercles linear with sharp edge at the top or rounded and knoblike, arranged in somewhat indistinct concentric rows on the sides; in edge view, knobs above scar very large, the bases touching, not in rows, below the scar much smaller.
S. cretica, no common name (pl. XV, 287).

bb. Scar an oval cavity: Seeds 1 mm. across; a depressed, crescent-shaped area of elongated cells below the scar; tubercles short, fine, inconspicuous, not in rows; grayish plates linear-oblong---------- *S. gallica*, English catchfly (pl. XV, 284).

b. In side view scar lies within a shallow indentation: Seeds 1¼ mm. across, thick, with obtusely angled margins; tubercles long, fine, pointed, in about 3 concentric rows near the margins, no pattern above; in edge view, tubercles stand out in 3 or 4 sharp, wide-spaced rows above the scar, crowded and much smaller below the scar; grayish plates oblong or diamond-shaped.
S. conica, conical catchfly (pl. XV, 285).

CRUCIFERAE (MUSTARD FAMILY)

(Pls. XVI–XVIII, 310–344)

The pods of plants in the mustard family are usually two-celled, the two valves separating at maturity. The pod may be much longer than broad, or shorter, sometimes indehiscent and nutlike, or separating across into one-seeded joints.

The seeds, without endosperm, are filled by the large embryo which is folded or curved in various ways. As shown in the illustrations, the position of the cotyledons and radicle as seen in cross-section is

often helpful in making an identification when considered with other features of the seeds.

The mustard family includes a great variety of plants. Many of them are economically important, particularly in the genus *Brassica*. Some species are noxious weeds while others are objectionable field weeds when they occur in quantity.

BRASSICA [13]

(Pls. XVI–XVII, 315–319)

As pointed out in the seed key that follows, seeds of *Brassica* (including rape, cabbage, mustard, and related kinds) are distinguished chiefly by the configuration of the seed surface. The main distinguishing features include the following: (1) The nature of the reticulation or network of lines or ridges; (2) the size of the spaces between the lines of the network; and (3) the size of the microscopic pits or stipples. The interspaces vary somewhat in size and shape on different parts of the seed, and the seed key refers to those most frequently seen along the median part of the seed. The distinguishing features are all microscopic in size and can be recognized only under a magnification of about 20 to 40 diameters.

Seeds of some of the species are very similar, and individual seeds cannot be identified with certainty in all cases. Likewise, seeds of closely related groups, such as certain turnips and turnip-rapes, cannot always be distinguished.

SEED KEY

A. Seeds pale straw color or yellow.

a. Seeds small (less than 2 mm.); stipples distinct.

aa. Reticulations fine distinct lines.
B. juncea, brown or India mustard (not illus.).

bb. Reticulations lacking or only faint lines.
B. campestris var. *sarson*, Sarson (not illus.).

b. Seeds large (2 mm. or more); stipples not evident; reticulations thick and indefinite or obscured; interspaces very small.
B. hirta, white mustard (not illus.).

B. Seeds grayish black, dull brown, or reddish.

a. Seeds large (2 to 3 mm.).

aa. Stipples small, dull or shiny; interspaces small, shallow, poorly defined (except in *oleracea*).

aaa. Reticulations thin, flat.
B. napus var. *biennis*, winter rape (pl. XVI, 318).

bbb. Reticulations thicker than the var. *biennis*, not sharply defined; stipples on ridges plainly evident.
B. napus var. *annua*, summer rape (not illus.).
B. napus var. *pabularia*, Siberian kale (not illus.).

ccc. Reticulations narrow, well-defined lines; stipples minute.
B. oleracea, cabbage (not illus.).

bb. Stipples large, shiny; interspaces large, shallow, poorly defined; reticulations broad and thick.
B. napus var. *napobrassica*, rutabaga (not illus.).

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[13] For a more complete treatment of the genus *Brassica*, see Distinguishing the Species of *Brassica* by Their Seed. By A. F. Musil, U. S. Department of Agriculture. Misc. Pub. 643. 1948. pp. 35. illus.

b. Seeds small (less than 2 mm.). Some exceptions in *campestris, juncea, pekinensis.*

aa. Stipples minute, partially obscured.

aaa. Reticulations fine, poorly defined, or obscure; interspaces very small.
B. kaber, charlock (pl. XVII, 317).

bbb. Reticulations prominent silvery lines; interspaces small.
B. tournefortii, Mediterranean wild turnip (not illus.).

ccc. Reticulations distinct, thick raised lines; interspaces large, concave, glossy.
B. nigra, black mustard (pl. XVII, 319).

bb. Stipples larger, distinct, dull or shiny.

aaa. Reticulations distinct fine lines devoid of stipples; interspaces large, shallow, not concave.
B. juncea, brown or India mustard (pl. XVII, 316).

bbb. Reticulations fine ridges with stipples evident; interspaces very small but well defined; stipples shiny, prominent.
B. campestris, turnip-rape and turnip (pl. XVI, 315).

ccc. Reticulations reduced or lacking; interspaces very small (larger in *pekinensis*), poorly defined, in occasional seeds larger and distinct.
B. perviridis, spinach mustard (not illus.).
B. pekinensis, Pe-tsai (Chinese cabbage) (not illus.).
B. chinensis, Pakchoi (celery-mustard) (not illus.).

CARDARIA

(Pl. XVII, 322-323)

Cardaria draba and its var. *repens,* which were formerly included with the genera *Lepidium* and *C. pubescens,* are noxious weeds. Several common names of these plants are in local usage. These names may be found in the List of Plant Names near the end of this Manual.

Well-developed, mature seeds of the two species appear to be distinguishable. However, because there are intergrading and off-type forms, individual seeds cannot be identified as to species in all cases. The more typical seeds are described below.

Cardaria draba, hoary cress (pl. XVII, 322): The seeds are reddish brown; length 2½ mm. or more, width about 2 mm.; oval, slightly flattened laterally and markedly thicker on the cotyledon edge than on the radicle edge, the surface roughened by minute reticulations; the tip of the radicle is usually even with the tip of the cotyledons.

Seeds of *Cardaria draba* var. *repens,* lens peppercress (not illus.), are usually not distinguishable from the species. The tip of the folded cotyledons tends to overtop the tip of the radicle as in *C. pubescens,* but other features are similar to those of *C. draba.*

Cardaria pubescens, ballcress (pl. XVII, 323): The seeds are reddish brown; length 2½ mm. or more, width about 2¼ mm.; broadly oval, slightly flattened laterally, the thickness of the seed about equal throughout. The surface reticulations are extremely minute and the seed appears smoother than *C. draba.*

CHORISPORA

Chorispora tenella, no common name (pl. XVII, 324): The elongated pod breaks up into hard, indehiscent joints which are commonly considered the seed. They may be found in crops such as alfalfa from States west of the Mississippi River. The soft and mealy grain would not be likely to occur in processed seed.

The joints or seeds are brownish and rectangular in shape; length 2 to 2½ mm., width 1¾ to 2 mm., thickness about 1¼ mm.; one side is straight or convex longitudinally, obscurely veined; the other side convex, with a rough, corky tissue between wide smooth margins.

CONRINGIA

Conringia orientalis, hares-ear-mustard (pl. XVII, 325): The seeds are narrowly oblong, often asymmetrical, length approximately 3 mm., width 1½ mm. or more; color light reddish brown, with a bublelike surface when viewed under magnification. The folded cotyledons are slightly flattened on the back so that the seed stands on a plane surface with the radicle side uppermost. The radicle is large and thick, with a slight groove on either side throughout its entire length, the tip usually bent to one side. Compare with the smaller and rougher seed of *Lepidium campestre*. The seed may be found with such crop seeds as clover and alfalfa, both domestic and imported seed.

CORONOPUS

Coronopus didymus, wart-cress (not illus.): The pod consists of two flattened, indehiscent segments. The segments break apart readily and they may occur in both domestic and foreign crop seeds. The free grains are found occasionally in processed seed.

The segments are ivory to brownish in color; shape roughly hemispheric, about 2 mm. across, strongly reticulate or wrinkled. The long axis of the seed has an open slit or cavity about 1 mm. long, surrounded by a wide callus.

The grains are sickle-shaped, flattened, minutely reticulate, the interspaces shiny; length about 1½ mm. The cotyledons are folded back, their margins evident as two ridges on the sides of the seeds; the tip of the radicle markedly longer than the tip of the cotyledons.

ERUCA

Eruca sativa, salad-rocket (pl. XVII, 326): The seeds are oval or oblong, length approximately 3 mm., width 2¼ mm. or more, slightly flattened laterally; color yellowish to light brown or greenish, usually with two green lines on each side of the radicle, outlining the margins of the two cotyledons. The position of the radicle and folded cotyledons is plainly evident on the surface of the seed. The seeds may occur incidentally with such crops as alfalfa and flax, especially in imported seeds.

LEPIDIUM

Lepidium campestre, field mustard (pl. XVII, 331): The seeds are oval to obovate, length approximately 2 mm., width 1½ mm. or more; color dull, dark brown, the surface roughened by minute tubercles. (Compare with the smoother surface of *Conringia orientalis*.) The folded cotyledons are distinctly flattened on the back so that the seed stands firmly on a plane surface, with the radicle side

uppermost. The radicle flattens out toward the tip and is not bent to one side as in *Conringia*. This seed is a common impurity in various crop seeds.

Lepidium latifolium, perennial mustard (pl. XVII, 333): The seeds are oval or broadly oblong, flattened laterally, the cotyledon edge markedly thicker than the opposite or radicle edge; length approximately 1¼ mm., width 1 mm.; color light reddish brown, the surface very minutely reticulate. The seed is very similar to that of shepherds-purse (*Capsella bursa-pastoris*), but the latter is narrowly oblong and the thickness is uniform throughout the length of the seed. The weed is established locally in the Pacific Northwest.

RORIPPA

Rorippa austriaca, yellow fieldcress (pl. XVII, 339): The seeds are broadly oval and variously warped; length and width about equal, ¾ to 1 mm.; color light reddish brown; the surface coarsely reticulated, the interspaces shiny.

The weed is established locally on the Pacific coast and in the Northeastern States. Because of its small size, the seeds would be likely to occur only with the finer grass seeds.

Rorippa sylvestris, creeping yellowcress (pl. XVIII, 340): The seeds are broadly oval; length and width about equal, ½ to ¾ mm.; color light reddish brown; the surface very minutely reticulated, the interspaces shiny. The seeds are rarely found in crop seeds.

SISYMBRIUM

Sisymbrium irio, tansy mustard (not illus.). The seeds are narrowly oblong, scarcely flattened, length approximately 1¼ mm., width ½ mm., color yellow to light buff, glossy; the tip of the radicle exceeds the tip of the folded cotyledons. The weed is locally established in the Southwest.

LEGUMINOSAE (LEGUME OR PEA FAMILY)

(Pls. XVIII–XXIII, 353-468)

Seeds of species in the legume family vary greatly in size, shape, and surface character but, as shown in the illustrations, all the species under consideration possess a hilum or scar that may be recognized as characteristic of the family.

The hilum is usually an oval or oblong area, with a groove or slit down the middle. The area may be minute, as in some of the clovers, or it may be large enough to be seen without magnification, as in vetch. In some species the hilum is obscured by a persisting layer of corky tissue, as in the cowpea. The size, shape, and position of the hilum are important diagnostic features.

For convenient reference, the genera of the family are arranged alphabetically, and seed keys have been prepared for the larger groups.

ADESMIA

Adesmia muricata, no common name (pl. XVIII, 353): The seeds are somewhat heart-shaped, flattened, length 2 mm. or more, width 1½ to 2½ mm., gray or brownish and mottled with black, somewhat glossy; scar less than ½ mm. long, usually in a wide shallow notch.

The pods are several-jointed, flattened, the segments with short spines and sparingly white-hairy.

The presence of this seed in a sample is indicative of Argentine origin.

AESCHYNOMENE

Aeschynomene virginica, Northern jointvetch (pl. XVIII, 354): Seeds are roughly sickle-shaped, length 2½ mm., width 4 mm., dark or light reddish brown, smooth and semipolished; scar about 1 mm. long, concave, below a hooklike projection near one end of the long axis of the seed, the chalaza a prominent elevation at the other end of the scar.

The pods consist of 5 to 10 nearly square, flattened joints, the joints wrinkled or tubercled in the middle portion.

The species occurs along the eastern and southern Coastal Plain and may be found as an incidental seed in rice.

ALHAGI

Alhagi pseudalhagi, camelthorn (pl. XVIII, 355): The seeds are roughly oblong or oval, length 2 mm. or more, width 3 to 3½ mm., greenish or reddish brown and obscurely streaked or flecked with black; scar usually nearer one end on the long axis of the seed, may be in a shallow indentation or in a distinct notch.

The pods are jointed, light reddish brown in color, length of segment about 4½ mm., width 3 mm.

Seeds of camelthorn have been found in imported Turkestan alfalfa. The plant has become locally established in southern California but, insofar as known, it has not been found in domestic crop seed.

ALYSICARPUS

Alysicarpus vaginalis, Alyce clover (pl. XVIII, 356): The seeds are approximately 1¼ mm. long, 2 mm. wide; oblong, flattened, in edge view seed is broader at the ends than at the middle; smooth, glossy, mostly yellowish brown and finely stippled with dark purple; occasional seeds greenish or reddish without stippling; scar in shallow indentation near the middle on the longer axis of the seed.

The species is adapted to the Southern States and is in limited production in Florida.

ANTHYLLIS

Anthyllis vulneraria, kidneyvetch (pl. XVIII, 357): The seed is oval, length 2½ to 3 mm., width 1½ mm., semipolished, green below the scar, yellowish above; scar in a broad, shallow indentation on the side, near the middle of the seed; the chalaza a brownish spot at one end of the seed.

Kidneyvetch is not cultivated as a crop in this country. The seed may occur incidentally in such crops as crimson clover or alfalfa.

ASTRAGALUS—LOCO; MILKVETCH

(Pl. XVIII, 358–363)

The genus *Astragalus* comprises hundreds of species of world-wide distribution. These include the poisonous locoweeds and some species which appear to have forage value. At the present time certain species are in experimental plantings in various parts of the country. Six species are illustrated and described. The species are readily distinguished by surface character, shape, size, and color.

SEED KEY

A. Surface pitted.
Light olive green with black mottling, slightly glossy; variously shaped, slightly flattened; scar in a deep notch; length about 1½ mm., width 2 to 2½ mm.—*Astragalus flexuosus*, flexuous milkvetch (pl. XVIII, 361).

B. Surface mottled.
Dull brownish with minute black mottling; square or rectangular, flattened, the margins angled; scar in a deep notch about the middle of one edge; length 1¾ to 2 mm., width 2 to 2½ mm.
Astragalus nuttallianus, nuttall milkvetch (pl. XVIII, 362).

C. Surface not pitted or mottled.

a. Length approximately 2 mm., width 1½ mm.
Light greenish brown, rarely with a few purplish flecks; rectangular, flattened, margins often angled; scar off-center on one edge; usually a depression below the scar between the radicle and cotyledons.
Astragalus rubyi, ruby milkvetch (pl. XVIII, 363).

b. Length more than 2 mm.
Dull olive green; roughly oval, slightly flattened; scar on one side just above the middle.
Astragalus chinensis, Chinese milkvetch (pl. XVIII, 358).
Buff color to brown; heart-shaped, flattened, with rounded margins; scar between the two lobes near the top.
Astragalus cicer, chickpea milkvetch (pl. XVIII, 359).
Rectangular, flattened, margins often angled; scar near the middle of one of the longer edges.
Astragalus falcatus, sicklepod milkvetch (pl. XVIII, 360).

CASSIA

Cassia nictitans, sensitive pea (pl. XIX, 364) : The seeds are rectangular, flat, length 4 to 5 mm., width 3½ mm., dull black, with rows of minute pits; scar very minute, at the base of a pointlike projection near one end of the shorter axis of the seed.

Cassia tora, sicklepod (pl. XIX, 365) : The seeds are thick, the long axes obtusely angled, the sides transversely arched, length 4 to 5 mm., width 3 mm.; glossy, light brown, with a light-colored band lying diagonally across the arched sides; scar minute, at one end of the long axis of the seed.

The two species are of interest as field weeds.

CICER

Cicer arietinum, chickpea or garbanzo (pl. XIX, 366) : The seeds are roughly globular, 8 to 9 mm. in diameter, slightly flattened and lobed on one side with the scar at the pointed end and the chalaza about midway, the other side of seed globose; surface slightly roughened by minute raised lines; the color is commonly dull creamy white or brownish, or black in some varieties; scar is oval, about 1½ mm. long, depressed.

Chickpeas are in limited cultivation in California.

CORONILLA

Coronilla varia, crownvetch (pl. XIX, 368) : The seeds are narrowly oblong, slightly flattened, length 1 to 1½ mm., width 4 to 5 mm., dull reddish brown; scar less than one-half mm. long, lies in a broad indentation about the middle of the long axis of the seed; chalaza inconspicuous, not adjacent to the scar.

Creeping crownvetch is in experimental plantings for ground cover purposes; the seeds may occur incidentally in imported alfalfa and clovers.

Coronilla scorpioides, scorpion crownvetch (pl. XIX, 367): The seeds are narrowly oblong, slightly flattened and usually curved, often with a faint longitudinal line on each side; length 1 to 1½ mm., width 4 to 5 mm.; dull reddish brown; scar less than one-half mm. long, lies in a shallow indentation on the convex side; chalaza inconspicuous, not adjacent to the scar.

The seed occurs incidentally in importations of alfalfa and clover.

CROTALARIA

(Pl. XIX, 369–372)

Four species of crotalaria are utilized to some extent for forage and soil improvement in the Southern States: *Crotalaria intermedia*, slenderleaf crotalaria; *C. mucronata* (*C. striata*), striate crotalaria; *C. lanceolata*, lance crotalaria; and *C. spectabilis*, showy crotalaria. Another species, *C. juncea*, sunn crotalaria, does not seed well under most conditions in the South and is not in general use because of insufficient seed. The species are readily distinguished by color, size, and shape.

SEED KEY

A. Seeds salmon-colored, glossy.

a. Length approximately 3 mm., width 2¼ to 2½ mm.; oval; scar within a deep notch on one side just above the middle.
Crotalaria intermedia, slenderleaf crotalaria (pl. XIX, 369).

b. Length 2 to 2½ mm., width 2 mm. or less; oval; scar within a shallow notch on one side just above the middle.
C. lanceolata, lance crotalaria (pl. XIX, 370).

B. Seeds dark olive green, oval; scar below a hooklike projection near the middle of one side.

a. Length 4 to 4½ mm., width 3 to 3½ mm.; a whitish waxy area around the scar———— *C. spectabilis*, showy crotalaria (pl. XIX, 372).

b. Length 6 to 7 mm., width 4½ to 5 mm.; whitish area around scar lacking————*C. juncea*, sunn crotalaria (not illus.).

C. Seeds greenish or brownish, variously streaked and spotted with dark olive green, occasional seed not spotted or streaked. Length 3 mm., width 3 mm.; broadly heart-shaped, scar between the two lobes at the top.
C. mucronata (*C. striata*), striate crotalaria (pl. XIX, 371).

CYAMOPSIS

Cyamopsis tetragonolobus, guar (pl. XIX, 373): The seed of guar is obtusely angled or almost circular, flattened, the surface roughened by minute tubercles; length and width about equal, 4 to 5 mm.; color mostly pearl gray or yellowish, with a few seeds purplish or brown; the scar is in a shallow indentation, usually off-center.

The crop is in limited production in the Southwest.

DAUBENTONIA

Daubentonia texana, rattlebox (pl. XIX, 374): The seeds are broadly oval to semicircular, scarcely flattened, length 5 mm. or more, width 6 to 7 mm., light to reddish brown or yellowish; scar oval, 1½ mm. long, near the middle of the long axis of the seed, the chalaza at the end of the axis.

Seeds of this species may occur incidentally with rice.

DESMODIUM

Desmodium tortuosum, Florida beggarweed or tall tickclover (pl. XIX, 375): Seeds are oval or ovate, flattened and usually slightly warped, length 1½ to 2 mm., width 3 mm., glossy, reddish brown; scar less than ½ mm. long, depressed, with a fine lighter colored collar around the margin; the chalaza is distinct at one end of the scar.

The pods are flat, several-jointed, the segments oval or ovate and more or less warped when dry, brown, short pubescent, and with a distinct network of fine nerves on the sides.

The species is in limited cultivation as a hay and green manure crop in the Southeastern States.

GALEGA

Galega officinalis, galega (pl. XIX, 376): Seeds of galega are oblong, somewhat flattened, length 1½ to 2 mm., width 4 mm., dull olive green or brownish; scar, less than ½ mm. long, in a broad notch about the middle of one of the longer sides of the seed; usually a wide depression below the scar between the radicle and cotyledon; the chalaza not adjacent to the scar.

Seeds of galega may occur incidentally in Italian red clover and alfalfa.

GLYCINE

Glycine max, soybean (pl. XIX, 377): There are more than 100 named varieties of soybeans handled by domestic growers according to Morse (*38*). These are grouped according to utilization into industrial, forage, and vegetable classes.

Seeds of the varieties vary considerably in size, shape, and color. The shape may be oval to almost spherical, or distinctly flattened. The scar is flush with the surface of the seed, narrowly oblong, the slit down the center usually curved in the lower half of its length. The surface is smooth, the color varying with the variety from yellowish to greenish yellow, bright green, reddish brown, or black. The species is represented in the illustrations by the variety Hawkeye.

HEDYSARUM

Hedysarum coronarium, sulla (pl. XIX, 378): The seeds are broadly ovate to orbicular, becoming narrower above the scar, in edge view lens-shaped, length 2 to 3 mm., width 2½ to 3 mm. at widest point; glossy, reddish brown with a variable proportion of yellowish seeds; scar about ½ mm. long, in a deep V-notch near the narrower end of the seed.

The pod consists of several flat, light brown, spiny segments, length of segment about 5 to 6 mm., width 4½ mm., the smooth callus at each end about 1½ mm. long.

Sulla has been grown experimentally in the United States but is not in cultivation at the present time. The seed may occur incidentally with imported crop seeds from southern Europe.

HOFFMANNSEGGIA

Hoffmannseggia sp., rushpea (pl. XIX, 379): Seeds are obovate, flat, length 3 mm., width 2 mm., color light to dark olive green, semiglossy; scar minute, in an indentation at the pointed end of the seed.

The seed may occur incidentally in alfalfa and is indicative of Argentine origin.

INDIGOFERA

Indigofera hirsuta, hairy indigo (pl. XIX, 380): The seeds are 4-sided, somewhat rhomboidal in shape, length and width about equal, 1½ to 2 mm.; surface pitted, yellowish to reddish brown in color; scar less than ½ mm. in length, depressed, lies in about the middle of one of the angles.

Hairy indigo is in limited use as a pasture plant in the Coastal Plain area from Florida to Texas.

LATHYRUS—VETCHLING

(Pl. XIX, 381–385)

Ten species of *Lathyrus* are described which are of interest as crop plants or as contaminants of crop seeds.

GENERAL DISTINGUISHING FEATURES

Three species are in limited cultivation: *Lathyrus hirsutus*, rough pea, also known as Caley pea, Singletary pea, and wild winter pea; *L. tingitanus*, Tangier pea; and *L. sylvestris*, flat pea. As described in the seed key and shown in the illustrations, seeds of these three species are readily distinguished. *L. hirsutus* also occurs as a contaminant in vetch and grain seed. Seeds of this species from Southern sources usually have somewhat coarser and more prominent tubercles than those from the Pacific Northwest.

Seeds of *L. annuus* (not illustrated) are very similar to *L. hirsutus*. This species may occur in imported vetches. It differs from *L. hirsutus* chiefly in being more spherical in shape, larger and rougher; the protuberances are clear-cut, mostly cone-shaped, their bases touching; the scar is depressed, with a distinct rim around the edge.

Seeds of six species may occur as weeds in vetch and similar crops: *L. aphaca*, yellow vetchling; *L. stipularis*, slender vetchling; *L. tuberosus*, groundnut pea; *L. pusillus*, low vetchling; *L. angulatus*, no common name; and *L. sphaericus*, no common name. Insofar as known, *L. stipularis* (not illustrated) occurs only in importations of oats from Argentina. As pointed out in the seed key, the seeds are easily recognized by their small size, shape, and color.

Seeds of *L. tuberosus* and *L. hirsutus* are very similar. Well-developed seeds, as described in the key and shown in the illustrations, are identified chiefly by shape and surface configuration, but some individual seeds may be difficult to distinguish with certainty.

Plants of *L. pusillus* and *L. angulatus* are sometimes confused, but the seeds (not illus.) are readily recognized by shape and surface character, as described in the seed key. *L. pusillus* occurs chiefly in eastern and southern United States; and *L. angulatus*, a European species, is established locally in the Pacific Northwest where it may occur with vetch or similar crops.

SEED KEY

A. Seed surface smooth.

a. Seed glossy.

Length 4 mm. or more, width 3 mm., broadly oblong or narrower at scar end, flattened; commonly reddish brown flecked with black, sometimes pale greenish brown or almost black; scar elliptic, length ½ mm., or less, width ¾ mm.

Lathyrus aphaca, yellow vetching (pl. XIX, 381).

b. Seeds dull.

aa. Length 2½ mm., width 2 mm., narrower at scar end and variously compressed so that seed appears somewhat angular; dull buff color flecked with black, occasional seed almost entirely black; scar elliptic, length 1 mm., width ½ mm.
L. stipularis, slender vetchling (not illus.).

bb. Diameter about 4 mm., spherical to broadly oblong; reddish brown, occasional seeds greenish and minutely spotted with black, the black spots so obscure on the brown seeds they appear to be lacking; scar oval, length 1 mm. or more, width ½ mm. or more; chalaza a large dark spot near the scar.
L. sphaericus, no common name (not illus.).

cc. Length 5½ to 6 mm., width 7 to 8 mm.; broadly oblong, flattened; dark brown, obscurely streaked or flecked with black; scar near one end of the longer axis of the seed, narrowly oblong, length 3½ to 4 mm., width 1 mm. or less, with a roll or ridge around the margin; chalaza a large dark spot near the scar.
L. tingitanus, Tangier pea (pl. XIX, 384).

B. Seed surface not smooth.

a. Scar about ⅓ the length of the circumference of seed, linear, width ½ to ¾ mm., slightly depressed at edges. Seed spherical or slightly flattened, 4½ to 5 mm. long; dull reddish brown; faintly roughened by flattened wavy ridges----------*L. sylvestris*, flat pea (pl. XIX, 383).

b. Scar length 2 mm. or less, broadly elliptic or ovate, 1 to 1½ mm. wide.

aa. Seeds oval or oblong, length 3 mm., width 4½ to 5 mm.; scar near one end of the longer axis; surface very minutely stippled and roughened by rather wide-spaced, flattened ridges or tubercle-like protuberances; chalaza near one end of scar, not prominent.
L. tuberosus, groundnut pea (pl. XIX, 385).

bb. Seeds spherical or compressed at the ends, length 3 to 3½ mm.; surface roughened by close-spaced, knoblike tubercles or ridges; chalaza a large smooth spot near one end of scar, prominent.
L. hirsutus, rough pea (pl. XIX, 382).

cc. Seeds spherical, 1½ to 2 mm. long; light reddish brown with numerous small black flecks; surface minutely stippled, with an irregular network of high thin elevations; scar wedge-shaped, with a high thin rim around the margin.
L. pusillus, low vetchling (not illus.).

dd. Seeds 4-sided, the end plane somewhat triangular with a small oval scar in the wider angle; reddish or grayish brown, finely tubercled; length 2 to 2½ mm., width 2 mm.
L. angulatus, no common name (not illus.).

LESPEDEZA—LESPEDEZA

(Pl. XIX, 386–387; pl. XX, 388–389)

Three species of lespedeza are commercially important in the United States. Two of the species are annual plants: Striate lespedeza (*Lespedeza striata*) and its varieties Common, Kobe, and Tennessee 76; and Korean lespedeza (*L. stipulacea*) with its varieties early Korean and Climax. Sericea lespedeza, also known as Chinese lespedeza (*L. cuneata*, formerly *L. sericea*), is perennial. Two other perennial species, Siberian or rush lespedeza (*L. hedysaroides*) and bicolor lespedeza (*L. bicolor*), are of experimental interest but are not in production at present. Commercial seed of lespedeza may consist chiefly of seed in the pods, with a variable proportion of free seeds which have become hulled in the threshing process, or the seed may be completely hulled by processing.

GENERAL DISTINGUISHING FEATURES

The single-seeded pods are oval in shape, somewhat flattened, more or less pubescent, with a network of slender lines or nerves. When intact, the pod is surrounded by a persistent outer circle of floral leaves (the calyx) at the base of which are attached three scalelike bracts.

The chief distinguishing features of seeds of lespedeza are the length and pubescence of the calyx and shape of the five calyx lobes, and the shape, color, and position of scar of the hulled seeds. The hulled seeds are smooth and lustrous, narrowly oval or ovate in outline, with the scar near the narrower end, usually with a distinct collarlike tissue around it. A plant usually produces two types of pods, one pointed, the other obtuse. Space does not permit showing all types in the illustrations.

The identification of seeds of closely related horticultural varieties is always difficult. When small bulk portions of seed are viewed, common lespedeza and its variety Kobe may be distinguished by the larger size of the latter, but because of natural variation individual seeds of the two kinds cannot be distinguished with certainty. Likewise, the varieties of Korean lespedeza, Climax and Early Korean, appear to be indistinguishable. In the perennial group, the pods of sericea lespedeza (*L. cuneata*) and Siberian lespedeza (*L. hedysaroides*) are readily recognized, but the hulled seeds of the two species appear to be indistinguishable.

SEED KEY

A. Calyx approximately ¾ the length of pod.

a. Calyx slit nearly to base, lobes linear-lanceolate, appressed-pubescent, midrib distinct; hulled seeds greenish or light greenish brown, occasionally flecked with purple.

Hulled seeds 2 to 2½ mm. long, 1½ mm. wide; pods 3½ to 4 mm. long, 2 to 2½ mm. wide, reddish brown.

Lespedeza cuneata, sericea lespedeza (pl. XX, 389).

b. Calyx not slit to near the base, lobes broad, obtusely pointed, 3-nerved, with anastomosing lateral nerves, sparingly pubescent, especially along margins of lobes; hulled seeds purple with light-colored flecks or occasionally purplish brown.

Hulled seeds 2 mm. long, 1½ mm. wide; pods 3 mm. long, 2 mm. wide, reddish_____ *L. striata*, striate lespedeza (pl. XIX, 386).

Hulled seeds 2½ mm. long, 2 mm. wide; pods 4 to 5 mm. long, 2½ mm. wide, grayish_____ *L. striata* var. Kobe (pl. XIX, 387).

B. Calyx approximately ½ the length of pod.

a. Calyx lobes broad, obtusely pointed, distinctly 3-nerved, not pubescent; hulled seed dark purple, not flecked or mottled, scar within a light-colored area.

Hulled seeds 2½ mm. long, 2 mm. wide, uniformly oval in outline; pods 3 to 3½ mm. long, 2½ mm. wide.

L. stipulacea, Korean lespedeza (pl. XX, 388).

b. Calyx lobes acuminate, sparingly pubescent, midrib distinct; hulled seed dark purple; collar around scar prominent.

Hulled seeds 2½ to 3 mm. long, 2 to 2½ mm. wide; pods 6 to 7 mm. long, 4 to 5 mm. wide____*L. bicolor*, bicolor lespedeza (not illus.).

C. Calyx equal to pod or nearly so, slit nearly to base, lobes acuminate, appressed-pubescent, distinctly 3-nerved; hulled seeds greenish or light greenish brown, occasionally flecked with purple.

Hulled seeds 2 to 2½ mm. long, 1½ mm. wide; pods 3½ to 4 mm. long, 2½ mm. wide, grayish brown.

L. hedysaroides, Siberian lespedeza (not illus.).

LOTUS—TREFOIL

(Pl. XX, 390–395)

Two species of trefoil are in limited cultivation for forage in the United States: Birdsfoot trefoil (*L. corniculatus*) and big trefoil (*L. uliginosus*).

There are two botanical varieties of birdsfoot trefoil. One variety, *L. corniculatus* var. *arvensis*, has broad leaflets; the other variety, *L. corniculatus* var. *tenuifolius* has narrow leaflets. The two varieties are considered by some authors as distinct species: *L. corniculatus*, the broadleaf form; and *L. tenuis*, the narrow-leaved form. Seeds of the two varieties appear to be indistinguishable.

Big trefoil also has two botanical varieties. The more widely used, *L. uliginosus* var. *villosus*, is a pubescent form. *L. uliginosus* var. *glabriusculus* is glabrous or nearly so. Importations of *L. uliginosus* are sometimes a mixture of the two varieties. As pointed out in the seed key, seeds of the two varieties are distinguished by the presence or absence of mottling, which appears to be a fairly reliable distinguishing feature.

Three species are of experimental interest and may occur as incidental seeds in crop seeds: *L. purshianus* (*L. americanus*), prairie-trefoil; *L. angustissimus*, slenderpod deervetch; and *L. hispidus*, hispid deervetch.

SEED KEY

A. Scar with a distinct collar, usually of whitish tissue; seeds broadly oval, or occasionally oblong in *corniculatus*.

a. Dull brown, often obscurely flecked with purple; length about 1½ mm., width 1¼ to 1½ mm——*Lotus corniculatus* (pl. XX, 391).

b. Light olive green, brownish or reddish brown, not flecked or mottled; length about 1¼ mm., width 1 mm——*L. angustissimus* (pl. XX, 390).

B. Scar without distinct collar.

a. Seeds broadly oval.

Bright yellow-green or brownish, not mottled, semipolished; length about 1 mm., width 1 mm.
L. uliginosus var. *glabriusculus* (pl. XX, 395).

Dull greenish or brownish, copiously mottled with purple; length about 1 mm., width 1 mm.
L. uliginosus var. *villosus* (pl. XX, 394).

Dull brown or purplish, flecked with dark purple; length about 1¼ mm., width 1 mm——*L. hispidus* (pl. XX, 392).

b. Seeds oblong, greenish to reddish brown, mottled with darker green and flecked with black; semipolished or dull; length 2 mm., width 3 mm. or more; scar in shallow indentation on the longer axis of the seed——*L. purshianus* (pl. XX, 393).

LUPINUS—LUPINE

(Pl. XX, 396–397)

Three species of lupine are of commercial importance in the United States: Blue lupine (*Lupinus angustifolius*); yellow lupine (*L. luteus*); and white lupine (*L. albus*). In recent years nonalkaloid strains have been developed in all three species.

GENERAL DISTINGUISHING FEATURES

There are several selected strains of *Lupinus angustifolius*, three of which are in use at the present time: Bitter blue, which is the common commercial form (pl. XX, 396); alta blue, an alkaloid form; and

common sweet blue. When viewed in bulk, seeds of the alkaloid strains appear pale gray, those of the nonalkaloid strains grayish brown. The darker, brownish color of the latter distinguishes it from the alkaloid forms but individual seeds in a mixture would be difficult to identify with certainty.

Two nonalkaloid strains of *L. luteus* are in production: Florida speckled (pl. XX, 397) and white-seeded yellow (not illus.). The Crescent strain (not illus.), originally selected as a sweet strain, is mixed sweet and bitter and is not in production. Its seeds differ from the Florida speckled in having a prominent white crescent-shaped stripe on each side below the scar. There are also black-seeded strains in this species.

Two strains of *L. albus*, Alabama White and Hastings, have been in experimental plantings. The Hastings strain is now in commercial production. Seeds of these two strains appear to be indistinguishable.

SEED KEY

A. Broadly oval; scar about 1 mm. long, at one end of the shorter axis.
Seed flattened, dull, creamy white streaked and flecked with black, or entirely creamy white in some varieties, length 9 mm., width 7 mm., scar not within a distinct notch------*Lupinus luteus*, yellow lupine (pl. XX, 397).
Seed only slightly flattened, dull, gray or brownish with tiny white spots and obscure brown flecks, length 8 to 9 mm., width 6 mm.; scar with a short black line above it and a triangular black area below it.
L. angustifolius, blue lupine (pl. XX, 396).

B. Obtusely 4-angled or semiorbicular, flattened, creamy white with pinkish cast, semipolished; size variable, length approximately 10 to 15 mm., width 10 to 12 mm.; scar 2 mm. long, lies across one of the angles.
L. albus, white lupine (not illus.).

MEDICAGO—BLACK MEDIC; BUR-CLOVER; ALFALFA OR LUCERNE

(Pl. XX, 398–403)

Six species in the genus *Medicago* are of economic interest. Alfalfa (*Medicago sativa*), with several horticultural varieties, is the most widely grown. California or toothed bur-clover (*M. hispida*) and spotted or southern bur-clover (*M. arabica*) are in cultivation chiefly in the West and Southeast, respectively. Black medic or yellow trefoil (*M. lupulina*) is not an important crop in the United States, although the seed is available commercially. The seed occurs commonly with other crop seeds. Buttonclover (*M. orbicularis*) and cogwheel-clover (*M. tuberculata*) represent the group having spineless burs and are only of experimental interest at the present time. Buttonclover, as well as the bur-clovers, may occur incidentally with red clover and alfalfa, chiefly from such sources as Italy and France.

SEED KEY

A. Symmetrically kidney-shaped, flattened, not warped or only slightly so; scar less than ½ mm. long.

a. Scar at base of prominent projection near one end of the long axis of seed; seed relatively thin, color light yellow or occasionally brownish, length 1½ mm. or more, width 3 mm.
Medicago arabica, spotted bur-clover (pl. XX, 398).

b. Scar in shallow indentation near the middle of the seed, chalaza a prominent brown spot near the scar; seed thicker than *arabica*, yellowish or light brown, length 1½ mm. or more, width 3 mm.
M. hispida, California bur-clover (pl. XX, 399).

c. Scar in deep indentation about the middle of the long axis of seed; the rounded margin of the seed usually scalloped; seed yellowish or light brown, length 2 mm., width 4½ to 5 mm.
M. tuberculata, cogwheel-clover (pl. XX, 403).

B. Roughly oval to kidney-shaped and variously warped; scar in a broad indentation near one end in the more oval seeds or in a distinct notch near the middle in the kidney-shaped seeds; color greenish yellow or light brown, length 1½ mm. or more, width 2½ to 3 mm.
M. sativa, alfalfa (pl. XX, 402).

C. Neither kidney-shaped nor warped.

a. Uniformly ovate, slightly flattened; scar at base of a projection near the narrower end; color yellowish to light brown; length 1 to 1½ mm., width 2 mm. or more_____*M. lupulina*, black medic (pl. XX, 400).

b. Roughly hemispheric, surface roughened by blisterlike protuberances; scar in deep notch at one end, near the straight edge; color tawny to reddish brown; length 2½ to 3 mm., width 3 mm.
M. orbicularis, button-clover (pl. XX, 401).

MELILOTUS—SWEETCLOVER; SOURCLOVER

(Pl. XX, 404–406)

Three species of *Melilotus* are in cultivation in the United States. White sweetclover (*M. alba*) and yellow sweetclover (*M. officinalis*) are crops of major importance throughout the Corn Belt and northward into Canada. Sourclover or yellow melilot (*M. indica*) is grown chiefly in the South and Southwest. Seeds of any of the three species may occur incidentally with other crop seeds from these general areas.

GENERAL DISTINGUISHING FEATURES

Melilotus alba, white sweetclover (pl. XX, 404): The seeds are yellow, with a semitranslucent appearance, uniformly oval in shape and slightly flattened, permitting the seeds to lie flat on a plane surface. In most seeds the hypocotyl forms a distinct angle so that the base of the seed appears squared off or somewhat pointed, whereas some seeds are rounded at the base as shown in the illustration. The scar lies in a broad, shallow indentation near the top, with a wide white line below it between the radicle and cotyledons. The length is usually about 2½ mm., width 1½ mm., or more, but the size may vary somewhat with the variety. The pods have a prominent network of coarse nerves, and the papery, five-toothed calyx and curved stem often persist.

Melilotus officinalis, yellow sweetclover (pl. XX, 405): The color is commonly dull greenish, with a variable proportion of purple mottled seeds, the seeds lacking the semitranslucent appearance common in white sweetclover. The shape is similar to white sweetclover, but the hypocotyl does not form a distinct angle so that the base of seed is quite uniformly rounded. The size tends to average somewhat smaller than white sweetclover. The pods have a network of coarse nerves, the elongated reticulations lying crosswise of the pod; the five-tooth calyx inflated below.

When in the pods, seeds of white sweetclover and yellow sweetclover are usually distinguishable; but, with the exception of the purple-mottled seeds, individual hulled seeds of the two species usually cannot be distinguished with any degree of accuracy. There are several horticultural varieties of both white and yellow sweetclover in use. Madrid, a variety of biennial yellow, and Willamette and

Evergreen, varieties of biennial white, are some of the well-known varieties. No attempt has been made to distinguish the seeds of the various horticultural varieties.

Melilotus indica, sourclover or yellow melilot (pl. XX, 406) : Seeds oval, dull olive green, the surface roughened by minute tubercles so that seeds grate when rubbed together. The size averages smaller than white and yellow sweetclover, usually about 2 mm. long and 1½ mm. wide, often smaller.

ONOBRYCHIS

Onobrychis viciaefolia, sainfoin (pl. XX, 407) : Seed of sainfoin is usually in the pod or hull. The pods are almost semicircular, light straw color, 6 to 7 mm. long; the sides of pod strongly reticulate and often toothed, the back edge margined and toothed.

The hulled seeds are about 3 mm., long, 4½ to 5 mm. wide, dark reddish brown, smooth, semicircular, with the scar in a broad shallow notch slightly off-center on the straight edge of the seed.

Although adaptable throughout the alfalfa regions of the United States, it is only in very limited production. The seeds may occur incidentally in imported crop seeds.

ONONIS

Ononis repens, ononis (pl. XX, 408) : The seeds are roughly orbicular, flattened, length 2¾ mm., width 2½ mm., dull greenish or reddish brown; the scar less than ½ mm. long, concave, depressed below the seed surface, usually lies in a broad, shallow notch. Compare with the somewhat similar seeds of *Medicago orbicularis* (pl. XX, 401).

The seed may occur in imported clover and alfalfa.

ORNITHOPUS

Ornithopus sativus, serradella (pl. XX, 409) : The pods consist of several indehiscent, jointed segments, the segments 3 to 4 mm. long, 2 to 3 mm. wide, a smooth callus across each end; color light grayish brown; prominently nerved.

Hulled seeds are oval in shape, reddish brown, flattened, the scar in a slight indentation on one side.

The species is not a cultivated crop in the United States. The indehiscent segments of the pod may occur incidentally in imported crop seeds. Hulled seeds are not likely to be found in seed samples.

PHASEOLUS—BEAN

Phaseolus aureus, mung bean, also known as green or golden gram (pl. XX, 411) : The seeds are oblong and slightly flattened or almost spherical, length 3½ mm., width 4 to 4½ mm., color light olive green with usually a darker band around the scar, occasional seed brownish, semipolished; scar 1½ mm. long, about ½ mm. wide, ovate or oblong, obscured by a layer of white corky tissue, the layer slightly elevated above the surface of the seed.

Mung beans are grown in the Southwest for human food and as a soil-improvement crop.

Phaseolus angularis, adzuki bean (pl. XX, 410) : The seeds are oblong, slightly flattened, length 5 mm., width 7 to 8 mm., glossy, maroon-colored; scar 3½ to 4 mm. long, ½ to ¾ mm. wide, lies near

one end of the longer axis of the seed, obscured by a layer of white corky tissue flush with the surface of the seed or nearly so.

Adzuki beans are grown to some extent for home use.

PISUM

Pisum sativum var. *arvense*, Austrian winter pea (pl. XXI, 412): Seeds of Austrian winter pea are spherical, about 6 mm. in diameter, grayish to reddish brown and minutely spotted with black, frequently mottled with darker brown; scar ovate, 1½ to 2 mm. long, usually scurfy, flush with the surface of the seed; chalaza about 2½ mm. from the scar.

There are many horticultural varieties of field peas, but the variety Austrian winter is planted most extensively in the United States.

PUERARIA

Pueraria thunbergiana, kudzu (pl. XXI, 413): The seed of kudzu is almost semicircular, the scar in a slight depression about midway on the long edge and surrounded by an upstanding collar of white corky tissue, the scar often obscured by a thin layer of white tissue; length 3 mm. or less, width 4 to 5 mm.; color creamy white to light reddish brown variously streaked and mottled with black, occasional seeds light reddish brown without mottling.

Adapted to the Southeastern States where it is useful for hay, soil improvement, and erosion control; it is a poor seeder and the seed is not in commercial production in this country.

SESBANIA

Sesbania exaltata, sesbania (pl. XXI, 414): Seed of sesbania is about 2 to 2½ mm. long, 4 mm. wide; oblong, slightly flattened, the thickness uniform throughout its entire length; scar about ¾ mm. long, concave, with a narrow white rim around the margin; color greenish to light brown, variously streaked and mottled with black.

Sesbania is planted as a soil-improvement crop in irrigated sections of the Southwest, and may occur as an impurity in rice in Louisiana.

STIZOLOBIUM

Stizolobium deeringianum, velvetbean (pl. XXI, 415): There are several varieties of velvetbean in cultivation, but only one variety, the Deering velvetbean, is in production in this country. The plant is semitropical and adapted to the southern part of the United States.

Seeds of velvetbean are oval, creamy white or gray copiously mottled with black; length 10 mm., width 14 to 15 mm. The scar is slightly off-center on the longer axis of the seed, about 5 mm. in length, width 1 mm. or more, surrounded by a thick collar of white corky tissue with minute folds at the outer margins. The seeds are readily recognized by the large size and characteristic collar around the scar. The species is also known as Deering or Florida velvetbean.

STROPHOSTYLES

Strophostyles leiosperma (*S. pauciflora*), smooth-seeded wild bean (pl. XXI, 416): The seeds are oblong and slightly flattened, length 2½ mm., width 3 mm.; glossy, gray, densely spotted with black so that seed appears almost black; the scar, about 2 mm. long, is obscured

by a thick layer of white corky tissue, the seed coat forming a prominent ridge around the margins; the chalaza is prominent, knoblike, at one end of the scar, as shown in the side view of seed in the illustration.

The seed may occur incidentally with lespedeza or similar crops.

SWAINSONA

Swainsona salsula, Austrian peaweed (pl. XXI, 417): Seeds of peaweed are circular or broadly oval, slightly flattened, length 2 to 2½ mm. in diameter, dull olive green; scar less than ½ mm. long, usually with a collar of whitish tissue, lies in a broad shallow indentation.

The seed may occur as an impurity in Turkestan alfalfa.

TRIFOLIUM—CLOVER

(Pl. XXI, 418–435; pl. XXII, 436–450)

Thirty-four species of the genus *Trifolium* are described. The species may be grouped on the basis of their current place in agriculture in the United States, as follows:

Species of major agricultural importance are:

T. dubium, suckling or small hop clover.
T. fragiferum, strawberry clover.
T. hybridum, alsike clover.
T. incarnatum, crimson clover.
T. pratense, red clover.
T. procumbens, large hop clover.
T. repens, white clover (including the variety Ladino).
T. resupinatum, Persian or shaftal clover (*T. suaveolens* Willd.).
T. subterraneum, sub clover.

Species that form productive stands under more restricted local conditions; some of them not yet in commerce or just coming into use are:

T. ambiguum, kura or Pellett clover.
T. carolinianum, Carolina clover.
T. glomeratum, cluster clover.
T. hirtum, rose clover.
T. lappaceum, lappa clover.
T. medium, zigzag clover.
T. michelianum, big-flowered clover.
T. nigrescens, ball clover.
T. striatum, striate or knotted clover.

Crimson clover may contain incidental seeds of *T. striatum*. Seeds of the latter average smaller and rounder than crimson clover, and they may be distinguished chiefly by the minute whitish stipples evident beneath the semitranslucent seed surface. There is a white-seeded strain of crimson clover, but this is not in production in this country.

Seeds of *T. resupinatum* and *T. michelianum* are somewhat similar, and seed lots of the latter which have come to the writer's attention have carried an admixture of *T. resupinatum*. Seeds of *T. resupinatum* are glossy, usually pointed at one end, with the scar at about the middle of the broader end, at the base of a small projection. Seeds of *T. michelianum* are dull, with the scar in an indentation at one end, the distinct projection at one end of the scar lacking; the base of seed not pointed.

Zigzag clover (*T. medium*) resembles red clover somewhat, but the seeds are thicker and broader at the point of the scar, with a

short curved white line below the scar between the radicle and cotyledons. The purple color common to red clover has not been observed in this species.

Seeds of *T. ambiguum*, kura or Pellett clover, are large and flat and resemble sweetclover in some respects. Compared with sweetclover, seeds of *T. ambiguum* are longer and broader, and the portion toward the tip of the cotyledons is markedly thicker.

Productive native species in experimental plantings are:

T. variegatum, whitetip clover.

T. wildenovii or *T. wormskoldii*, seaside clover (including *T. fimbriatum* and *T. involucratum* in part).

Species of experimental interest or which may occur incidentally with crop seeds are:

T. agrarium, hop clover.
T. alexandrinum, berseem or Egyptian clover.
T. angulatum, crooked clover.
T. arvense, rabbit-foot clover.
T. bifidum, pinole clover.
T. cernuum, drooping-flowered clover.
T. depauperatum, poverty clover.
T. gracilentum, pin-point clover.
T. microcephalum, small-headed clover.
T. microdon, thimble clover.
T. ornithopodioides, no common name.
T. parviflorum, teasel clover.
T. reflexum, buffalo clover.
T. tridentatum, tomcat clover.

GENERAL DISTINGUISHING FEATURES

There are many horticultural varieties among the nine major agricultural species, particularly in the red, crimson, sub, and white clovers. Usually it is not possible to distinguish the horticultural variety of a species by seed character alone.

Seeds of *T. dubium* and *T. procumbens* are very similar. Typical seeds, as described in the seed key, are readily recognized; but some intergrading forms may be encountered that are difficult to identify accurately.

Cluster clover (*T. glomeratum*) may be confused with drooping-flowered clover (*T. cernuum*), which is not in cultivation in this country. As pointed out in the seed key, seeds of *T. cernuum* are more pointed at one end and the surface is a little rougher than that of *T. glomeratum*. This difference in surface becomes evident when the periphery of the seeds is viewed under a magnification of about 20. However, individual seeds may be indistinguishable.

Seeds of *T. ornithopodioides* may occur in importations of white clover from New Zealand. Some authors refer this species to the genus *Trigonella* or to *Falcatula*. The seeds may be recognized by the warped heart-shape, small size, and glossy, green-mottled surface.

Seeds of the species under consideration may be grouped on the basis of seed coat into two major divisions: (A) Seed surface roughened; and (B) seed surface smooth. Seven species are described which have a more or less roughened surface. The protuberances are microscopic and vary in character with the species from very minute points to wartlike elevations. In general, the degree of roughness, from minute to coarse, progresses in about the following

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order: *T. angulatum; T. glomeratum; T. cernuum; T. carolinianum; T. reflexum; T. parviflorum; T. depauperatum.*

Within group (B) (seed surface smooth), the seeds may be further divided according to size as small, medium, and large. The sizes stated in the seed key represent the sizes most commonly found, but allowance should be made for natural variation when the individual seed is considered.

KEY TO THE SEED GROUPS

Seed surface roughened.
- Group I. Seeds yellow, scar in shallow indentation at or near one end.
- Group II. Seeds light to dark greenish yellow.

Seed surface smooth.
- Group III. Seeds small, length 1¼ to 1½ mm., width ¾ to 1 mm.
- Group IV. Seeds intermediate, length 1½ to 2 mm., width 1¼ to 1¾ mm.
- Group V. Seeds large, length 2½ to 3 mm., width 2 to 2¾ mm.

SEED KEY

Group I—

a. Tubercles very fine, not close-spaced, the minute projections usually evident at the periphery; seeds mostly heart-shaped, occasionally oval.
T. cernuum, drooping-flowered clover (pl. XXI, 420).

b. Tubercles very fine, more numerous than in *T. cernuum* but flatter, the projections not evident at the periphery; seeds broadly oval; occasionally somewhat pointed below the scar.
T. glomeratum, cluster clover (pl. XXI, 419).

c. Tubercles more prominent than above, the projections distinct at the periphery; seeds heart-shaped or oval.
T. parviflorum, teasel clover (pl. XXI, 423).

Group II—

a. Broadly oblong, somewhat warped in *T. angulatum.*
Scar in shallow indentation at one end; very minutely roughened; length 1½ mm., width 1 mm.
T. angulatum, crooked clover (pl. XXI, 418).
Scar in distinct notch at one end; tubercles large, wartlike; length 2 mm., width 1½ mm.
T. depauperatum, poverty clover (pl. XXI, 424).

b. Broadly oval, a marked depression between radicle and cotyledons; tubercles minute, flattened, not evident at the periphery; scar in a sharp notch at one end; length and width about equal, 1 to 1¼ mm.
T. carolinianum, Carolina clover (pl. XXI, 422).

c. Broadly oval, thick, a dark line between radicle and cotyledons but not a distinct depression; tubercles distinct, flattened, not evident at the periphery; scar in shallow indentation at one end; length 1¾ mm., width 1½ mm———— *T. reflexum*, buffalo clover (pl. XXI, 421).

Group III—

a. Glossy, light yellow to brownish; scar near one end, scarcely indented.
Broadly oval, somewhat rotund.
T. dubium, suckling clover (pl. XXI, 427).
Narrowly oval, flatter and more pointed than *T. dubium.*
T. procumbens, large hop clover (pl. XXI, 428).

b. Dull, oval to ovate; scar near one end, scarcely indented.
Deep yellow at scar end, greenish below.
T. agrarium, hop clover (pl. XXI, 425).
Light yellow to brownish.
T. nigrescens, ball clover (pl. XXI, 430).

c. Dull, broadly oval, rotund, yellowish green; scar in shallow indentation near one end_____*T. arvense*, rabbit-foot clover (pl. XXI, 426).

Group IV—

a. Yellowish to brownish yellow.

Heart-shaped, flattened, dull; scar in shallow indentation between the lobes at the broader end; length 1¼ to 1½ mm., width 1 to 1¼ mm_____*T. repens*, white clover (pl. XXI, 432).

Broadly oval, rotund, slightly glossy, minute whitish stipples evident beneath the semitranslucent seed surface; scar near one end, scarcely indented; length 2 mm., width 1¾ mm.

T. striatum, striate clover (pl. XXI, 433).

b. Yellow shading to purple toward the broader end, to almost entirely purple or entirely yellow; seeds ovate, flattened, lustrous; scar in broad, shallow notch or indentation near the narrower end; length 2¼ to 2½ mm., width 1½ to 1¾ mm.

T. pratense, red clover (pl. XXI, 431).

c. Pale to dark rose-purple, dull, partially adhering whitish tissue produces a minutely veiny effect; roughly oblong and angular; scar in a slight indentation near one end; length 2 mm., width 1½ mm.

T. lappaceum, lappa clover (pl. XXI, 429).

d. Light to dark olive green, occasionally deep yellow, glossy; ovate, rotund; scar at the broader end at the base of a small projection, pointed toward opposite end; length 1½ to 1¾ mm., width 1¼ mm. or more_____ *T. resupinatum*, Persian clover (pl. XXI, 435).

e. Yellowish brown, dull; oval, flatter than *T. resupinatum;* scar in shallow indentation at one end or below, projection at end of scar lacking; the opposite end not pointed; length 1½ to 1¾ mm., width 1¼ mm. or more.

T. michelianum, big-flowered clover (pl. XXI, 434).

f. Variously streaked or mottled with black or dark green; glossy.

Roughly heart-shaped but variously compressed and obtusely angular; yellowish to light reddish brown, finely spotted with black; scar in fine notch, off-center at the broader end; length 1½ mm., width 1¼ mm.

T. ornithopodioides, no common name (not illus.).

Symmetrically oval; yellowish and sparingly or copiously stippled or flecked with black, occasional seed not mottled; scar in shallow indentation at one end; length 2 mm., width 1½ mm.

T. tridentatum, tomcat clover (pl. XXII, 442).

g. Variously streaked or mottled with black or dark green; dull or lustrous.

aa. Broadly to narrowly heart-shaped; scar in shallow indentation at the broader end (a distinct notch in *T. wildenovii*).

Bright yellow with small black flecks, especially on lower portion, with a white line below the scar; seed in bulk has yellowish aspect; length 2 mm., width 1½ mm.

T. fragiferum, strawberry clover (pl. XXII, 437).

Yellowish or grayish brown and copiously spotted with black, seed appears almost black; length 2 mm., width 1½ mm.

T. variegatum, whitetip clover (pl. XXII, 443).

Yellowish or gray, copiously streaked and spotted with black so seed appears almost black; length 1½ to 1¾ mm., width 1¼ to 1¾ mm.

T. wildenovii, seaside clover (pl. XXII, 444).

Greenish, copiously mottled with dark green so that seed appears almost black, occasional seeds dull green and not mottled, white line below scar lacking or obscure in the lighter seeds; length 1½ mm., width 1¼ mm.

T. hybridum, alsike clover (pl. XXII, 439).

bb. Narrowly ovate; scar in indentation at one side, near the narrower end.
Greenish and obscurely stippled with black; length 1½ to 1¾ mm., width 1 mm.
T. microcephalum, small-headed clover (pl. XXII, 440).
Yellowish and copiously mottled with black, occasional seed not mottled; chalaza above scar distinct; length 2 to 2¼ mm., width 1¼ mm.
T. bifidum, pinole clover (pl. XXII, 436).

cc. Narrowly oblong or oval, radicle often forming an angle at the base of the cotyledons; scar in notch or indentation near one end.
Yellowish and obscurely streaked or finely spotted with black, with a short white line below the scar; length 2 to 2¼ mm., width 1¼ to 1½ mm.
T. microdon, thimble clover (pl. XXII, 441).

Group V—

a. Yellow to brownish yellow.

aa. Shape oval.
Glossy, symmetrical, rotund, scarcely indented at the scar; length 2½ mm., width 2 mm.
T. incarnatum, crimson clover (pl. XXII, 448).
Dull, flattened, scar in broad indentation near one end; length 3 mm., width 2 mm. or more.
T. ambiguum, kura clover (pl. XXII, 445).

bb. Ovate, lustrous, scarcely flattened; scar in slight indentation near the pointed end; the light-colored line below the scar sharply curved inward below; length 2½ to 3 mm., width 2 mm——*T. alexandrinum*, berseem clover (pl. XXII, 446).

cc. Orbicular or broadly oval, rotund, dull; scar in a slight indentation at one end or near it; seed coat with a few short, longitudinal wrinkes at the top of the cotyledons; length 2¾ mm., width 2¼ mm——*T. hirtum*, rose clover (pl. XXII, 447).

dd. Broadly heart-shaped or ovate, flattened, dull; scar in a broad, shallow indentation near the broader end; length 2½ mm., width 2 mm. or more.
T. medium, zigzag clover (pl. XXII, 449).

b. Yellowish or greenish variously streaked or mottled with purple or black; broadly oval, flattened, glossy; scar in shallow indentation near one end; length 3 mm., width 2 mm. or more.
T. gracilentum, pin-point clover (pl. XXII, 438).

c. Black or nearly so; orbicular or broadly oval, rotund, dull; scar in narrow notch or shallow indentation; length 2½ to 3 mm., width 2½ to 2¾ mm——*T. subterraneum*, sub clover (pl. XXII, 450).

TRIGONELLA—TRIGONELLA

(Pl. XXII, 451–452)

Seeds of the numerous species of *Trigonella* vary widely in size and shape, as well as in surface character. Only one species, fenugreek, is in limited cultivation in the United States. Other species are sometimes found as incidental seeds with crop seeds of European or Asiatic origin, one of which (*T. polycerata*) is described below.

Trigonella foenum-graecum, fenugreek (pl. XXII, 451): The seed is oblong and slightly flattened, with a deep groove between the radicle and cotyledons; length 5½ to 6 mm., width 3 to 3½ mm.; color light grayish brown; surface finely roughened by minute tubercles or short

raised lines; scar within a prominent notch well below one end on the long axis of the seed. The seed has the characteristic odor of fenugreek.

Trigonella polycerata, no common name (pl. XXII, 452) : The seed is narrowly oblong, length 2 to 2½ mm., width 1 mm. or more, the surface roughened by minute blisterlike elevations; scar position as in fenugreek. The seeds may occur with such crops as alfalfa or black medic.

Trigonella ornithopodioides (*Falcatula ornithopodioides*) (not illus.) has been referred to *Trifolium ornithopodioides* and is described under that genus. This seed may occur in white clover of New Zealand origin.

VICIA—VETCH

(Pl. XXII, 453–459; pl. XXIII, 460–466)

GENERAL DISTINGUISHING FEATURES

Fifteen species of vetch are of interest either as cultivated crops or as incidental seeds occurring with them or with similar crops. The species may be separated into two major groups by the position of the chalaza, which is usually evident with a hand lens as a minute, dark-colored spot or protuberance on the seed surface. In one group the chalaza is located on the back of the seed, opposite the scar, as on plate XXII, 455. In the other group the chalaza is near one end of the scar, as shown on plate XXIII, 463.

Four species are represented in the group having the chalaza on the back; *Vicia pannonica*, Hungarian vetch; *V. lutea*, yellow vetch; *V. melanops*, no common name; and *V. hybrida*, no common name. Of these four species, Hungarian vetch is the only one cultivated as a crop in the United States. Seeds of the other three species may occur in varying quantity as incidental seeds in importations of hairy and common vetch. Although the size of seeds within a species may vary considerably, seeds of these three species are markedly larger than those of the other species under consideration. They may be variously compressed so that they do not roll readily on a plane surface, and the scars frequently appear to lie in an oblique position. The chief distinguishing characters are the relative length, width, and shape of the scar. There is, however, some intergrading of these features and some seeds may be difficult to identify with certainty.

Eleven species are included in the group having the chalaza near one end of the scar. The species listed below are cultivated crops: Narrowleaf vetch, *V. angustifolia;* hairy vetch, *V. villosa;* smooth vetch, *V. villosa* var. *glabrescens;* common vetch, *V. sativa;* woollypod vetch, *V. dasycarpa;* purple vetch, *V. atropurpurea;* and monantha vetch, *V. articulata.*

Seeds of hairy vetch and its variety smooth vetch are very similar. No way has been discovered whereby they could be distinguished. Hairy vetch and woollypod vetch may be distinguished chiefly by the scar. As shown on plate XXIII, 465 and 466, the scar or hairy vetch is flush with the seed surface; that of woollypod vetch is depressed

at the edges. Seeds of the Auburn strain of woollypod vetch appear to be indistinguishable from common woollypod.

Seeds of narrowleaf vetch average smaller than those of hairy vetch. The seeds are lustrous and black, or greenish with dark mottling. The black seeds may be distinguished from seeds of hairy vetch by the more wedge-shaped, slightly depressed scar with a raised slit down the center. The narrowleaf vetch having mottled seeds has not been found in seed from other than American sources. Some seeds of narrowleaf vetch appear to be indistinguishable from the smaller seeds of common vetch.

Seed of common vetch is variable in size, form, and color. In some lots the seeds may be large, slightly compressed or angular, in others nearly spherical and smaller. The color varies from cream to black, brown, gray, or mottled, the surface appearing semipolished rather than dull and velvety as in hairy vetch. Light seeds with dark scars and dark seeds with light scars are not uncommon. The seed scar is narrowly wedge-shaped, depressed at the edges, margins of the slit down the center distinctly raised, sometimes the entire scar transversely convex. Three horticultural varieties are in general use at the present time, the Willamette strain, Texas common, and Doark. No attempt has been made to distinguish the seeds of these varieties. Certain seeds of common vetch and narrowleaf vetch are very similar and cannot be distinguished with certainty.

Five species in the group having the chalaza near the scar may occur as weeds with cultivated vetches or other crops. As shown in the illustrations and in the seed key, three of these species, showy vetch (*V. grandiflora*), tiny vetch (*V. hirsuta*), and fourseed vetch (*V. tetrasperma*), have distinctive features whereby they can be readily distinguished.

There are several species of vetch having long and narrow scars, ¼ to ½ the circumference of the seed in length. Two species of this group may occur incidentally with cultivated vetches: Bird vetch (*V. cracca*) (pl. XXIII, 460); and American vetch (*V. americana*), not illustrated. It has not been determined to what extent the two species may be distinguished by seed character alone. Seed of American vetch appears to average larger in size, the scar broader and expanded at one end. Doubtless there are intergrading forms.

SEED KEY

A. Chalaza on the back, opposite the scar.

a. Scar approximately 4 mm. long, narrowly oblong.

Width ½ to ¾ mm., slightly depressed around the edge; seed 6 to 6½ mm. long, variously compressed.
V. lutea, yellow vetch (pl. XXII, 457).

Width 1 mm. or more, flush with surface of seed or nearly so; seed 4½ to 5 mm. long, slightly flattened.
V. melanops, no common name (pl. XXII, 456).

b. Scar approximately 2 mm. long, flush with surface of seed or nearly so.

Width ½ to ¾ mm., narrowly oblong; seed 4 to 4½ mm. long, slightly flattened.
V. pannonica, Hungarian vetch (pl. XXII, 455).

Width 1¼ mm., oval; seed approximately 5 mm. long, slightly flattened----------*V. hybrida*, no common name (pl. XXII, 458).

B. Chalaza near one end of the scar.

a. Seeds 2 to 2½ mm. long; reddish brown or lighter with dark mottling.
Spherical; scar narrowly oblong, length 1¼ mm., width ½ mm. or less_____*V. tetrasperma*, fourseed vetch (pl. XXII, 454).
Lens-shaped; scar linear, length about ⅓ of the circumference of seed, width less than ½ mm., obscured by persisting stalklike appendage_____*V. hirsuta*, tiny vetch (pl. XXII, 453).

b. Seeds 3 to 5 or 6 mm. long.

aa. Scar ⅔ the length of the circumference of seed, linear, with a minute frill of white tissue around the margins; seed lens-shaped, reddish, faintly mottled, lustrous, 4 mm. long.
V. grandiflora, showy vetch (pl. XXIII, 461).

bb. Scar ⅓ to ½ the length of the circumference of seed, linear; seed spherical.
Scar approximately ½ mm. wide; seed black, lustrous, 3 to 3½ mm. long_____ *V. cracca*, bird vetch (pl. XXIII, 460).
Scar approximately ¾ mm. wide, expanded at one end; seed dull, black or lighter and mottled, 3½ to 4 mm. long.
V. americana, American vetch (not illus.)

cc. Scar less than ⅕ the length of circumference of seed.

aaa. Seeds mostly spherical, roll readily on a plane surface.
Scar oblong or ovate, flat, flush with surface of seed, length 2 to 2½ mm., width ½ to ¾ mm.; seed dull black, velvety, length 3½ to 4 mm.
V. villosa, hairy vetch (pl. XXIII, 465).
Scar wedge-shaped, depressed at the edges, with raised slit down the center, length 2 mm., width at center ¾ mm.; seed black and lustrous or greenish with dark mottling, length 3½ to 4 mm.
V. angustifolia, narrowleaf vetch (pl. XXIII, 463–464).

bbb. Seeds somewhat flattened, do not roll readily.
Scar oblong or ovate, with a minute ridge around the depressed margins, usually with a light-colored strip along the groove down the center, length 2 mm., width ½ mm.; seed dull black or brownish, sometimes obscurely mottled, length 4 to 5 mm.
V. dasycarpa, woollypod vetch (pl. XXIII, 466).
Scar narrowly wedge-shaped, depressed at the edges, with a distinctly raised, light-colored slit down the center, length 2½ mm. or more, width ½ to ¾ mm.; seed color variable, commonly reddish brown, semi-polished, length 4 to 5 mm., variable.
V. sativa, common vetch (pl. XXIII, 462).

ccc. Seeds lens-shaped or nearly so, 5 to 6 mm. long.
Scar linear or narrowly wedge-shaped, length 1¾ mm., width less than ½ mm.; seed light grayish brown, variously streaked or mottled with black or dark brown____ *V. articulata*, monantha vetch (not illus.).
Scar linear, obscured by white corky tissue, length 3 mm., width less than ½ mm.; seed dull black, velvety.
V. atropurpurea, purple vetch (pl. XXII, 459).

VIGNA—COWPEA

(Pl. XXIII, 467–468)

There are many cultivated varieties of cowpeas (*Vigna sinensis*), the seeds differing widely in color, as well as in size. Colors may range from creamy white, creamy white with a black or purplish area around the scar, light yellowish brown to dark reddish or purplish

brown, black, or variously mottled. Brabham, a variety having mottled seeds, is shown in plate XXIII, 468. Seeds of the more important varieties in common cultivation are described by Morse (*37*).

In general, seeds of cowpeas are slightly flattened, in some varieties almost cylindric; the shape may be oblong, oval, or obtusely angled as in the variety Iron; the surface is smooth, or with fine longitudinal wrinkles, as in Blackeye pea. The most common size is about 6 mm. long and 8 to 9 mm. wide, but some varieties are considerably smaller, such as the variety Rice, for example.

The seed scar averages 2 to 3 mm. long, the width and shape varying somewhat with the variety. The entire scar is depressed and obscured by a persisting thick, corky tissue, which is elevated above the surface of the seed. The character of this appendage is an important distinguishing feature of the species. As shown in the illustration, the whitish inner portion is surrounded by a border of darker, usually greenish, tissue. In some varieties, as in Iron, there is a light-colored band around the scar, or there may be a saddle-shaped black area around the scar as in Blackeye cowpea.

CONVOLVULACEAE (MORNING-GLORY FAMILY)

(Pl. XXVI–XXVII, 549–562)

The fruit of the morning-glory family is a globular two- to six-seeded capsule. The embryo of the seed, except in *Cuscuta*, is large and curved or coiled in the endosperm. The cotyledons are broad, thin, and much folded or convolute. The embryo of *Cuscuta* is spirally coiled and without cotyledons. Seeds of the genera comprising the family vary greatly in size, shape, and surface character, but the scar area is fairly characteristic of the family. It appears as a more or less well-defined, rounded or oval area near one end of the seed.

Four genera are of particular interest as field weeds: *Cuscuta*, dodder; *Ipomoea*, *Convolvulus*, and *Jacquemontia*, the morning-glories and bindweeds.

MORNING-GLORIES AND BINDWEED

SEED KEY

A. Scar area hemispheric or broadly oval, with a knoblike projection at either end of the broad base of scar.

a. Surface roughened by fine tubercles or short wavy lines.

Dull grayish brown; back side convex, lateral sides plane; broadest above the middle, length 4 to 4½ mm.
Convolvulus arvensis, bindweed (pl. XXVI, 549).

b. Surface smooth or minutely roughened.

Black; back side convex, lateral sides plane, each with a large, oval depression; broadly oval; length 5 to 6 mm.; scar area prominent.
Convolvulus sepium, hedge bindweed (pl. XXVI, 550).

c. Surface smooth, densely pubescent on the angles; length 7 to 8 mm.
Ipomoea pandurata, clustered blue morning-glory (pl. XXVI, 554).

B. Scar area oblong or orbicular, with two minute linear projections close together near the base of scar; broadly oval; length 5 to 6 mm.

a. Dull, light grayish brown.

aa. Scar with reddish brown, dense, coarse pubescence; back side rounded, with or without a slight depression down the center, lateral sides plane with a distinct line around the outer margin.

Ipomoea hederacea, ivyleaf morning-glory (pl. XXVI, 552).

bb. Scar relatively smooth; back side rounded, with a broad, shallow depression down the center, lateral sides flat or with obscure, short transverse folds.

Ipomoea purpurea, common morning-glory (pl. XXVI, 553).

b. Semipolished, smooth and horny, black with brownish cast.

Scar smooth, larger than in *hederacea* and *purpurea;* back side rounded, not evidently depressed down the center, lateral sides plane with a distinct line around the margin.

Ipomoea lacunosa, small-flowered white morning-glory (not illus.).

C. Scar area oblong, projections at base obscure or lacking; light brown, roughened by lighter brown blisterlike protuberances; length 2½ to 3 mm.; back side convex, lateral sides plane.

Jacquemontia tamnifolia, hairy morning-glory (pl. XXVI, 555).

CUSCUTA—DODDER

(Pl. XXVII, 556–562)

Seeds of dodder are characterized by a small distinct scar area near one end of the seed, in the middle of which the hilum appears as a raised line, point, or slit. The species are distinguishable chiefly by size and shape, character of the hilum and scar area, and surface texture.

The shape of the seed is largely determined by the number of seeds developed in the capsule. Certain species regularly produce four seeds, others one or two. In a four-seeded capsule the seed will have two flattened inner surfaces and a convex outer surface, as in *Cuscuta planiflora.* When only one or two seeds develop in a capsule the seeds assume a more globular form, as in *C. indecora.* Size is helpful in the determination of a small quantity of seed, but it is too variable in some species to be entirely reliable in application to the individual seeds. A list of characteristic features of seeds of seven species of dodder follows.

List of Characteristic

Species	Length	Form	Color
Cuscuta planiflora. Small-seeded alfalfa dodder (pl. XXVII, 556).	(Approx.) 1 mm	Uniformly oblong, distinctly angled.	Uniformly yellowish or with slight brownish tinge.
C. epithymum. Clover dodder (pl. XXVII, 557).	½ to 1 mm	Globose, occasional seeds angled.	Dull gray or brownish gray; like particles of earth.
C. epilinum. Flax dodder (pl. XXVII, 558).	1 to 1½ mm	Broadly obovate, angled; often stick together in pairs.	Grayish white
C. pentagona. Field dodder (pl. XXVII, 560).	1 to 1¼ mm	Fairly uniform, rounded or ovate; angles usually distinct.	Uniform dusty gray with definite pinkish cast.
C. racemosa var. *chiliana* Chilean dodder (pl. XXVII, 561).	(Approx.) 1½ mm	Rounded or ovate, not sharply angled.	Dull reddish brown, fairly uniform.
C. indecora. Large-seeded alfalfa dodder (pl. XXVII, 559).	1½ mm. or longer	Variable, mostly broader than long, not sharply angled.	Not uniform, light grayish brown, reddish to dark brown.
C. gronovii. Common dodder (pl. XXVII, 562).	1½ mm	Ovate, tends to be less angular than *C. pentagona.*	Uniform reddish brown.

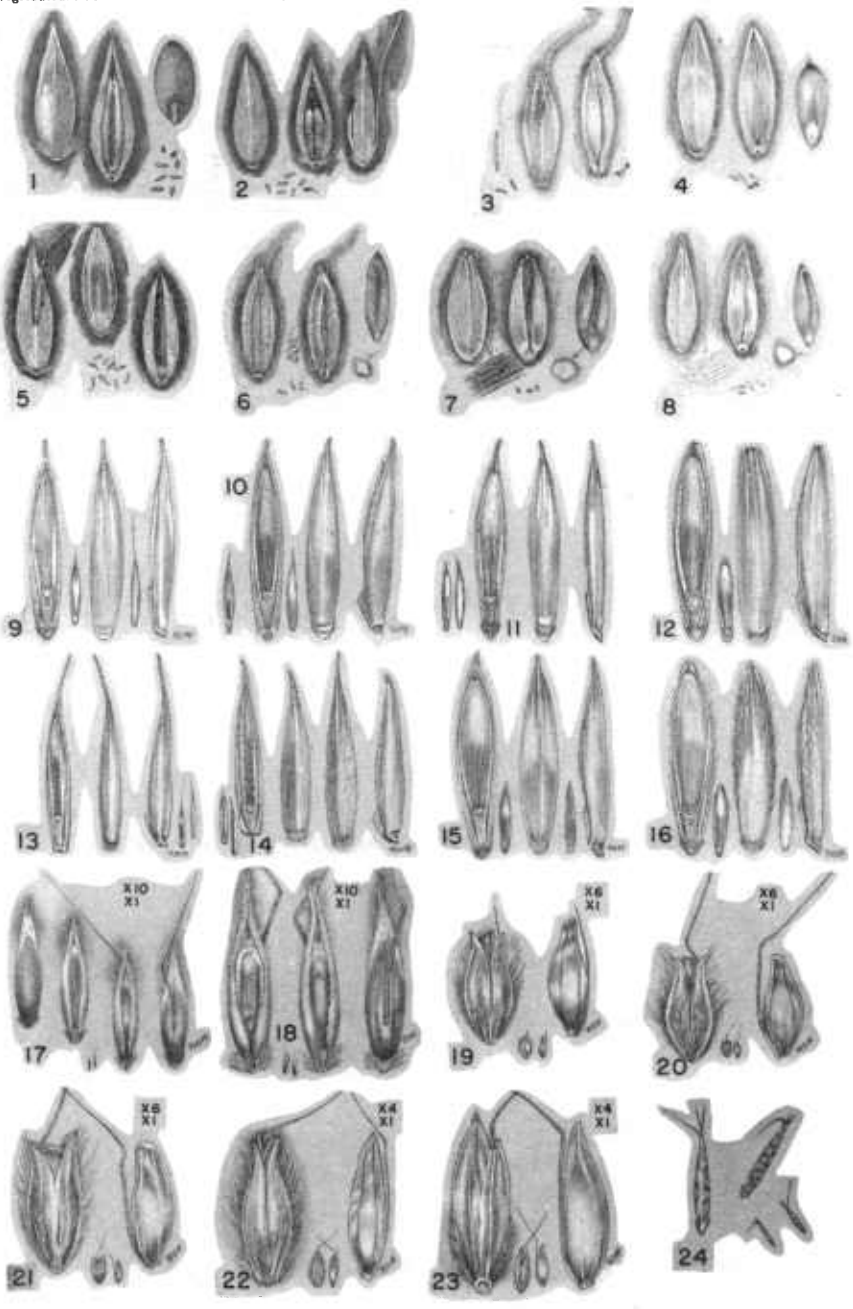
Features of Seeds of Dodder

Scar area	Hilum	Surface	Range
Indistinct	A raised point	Very finely rugose with tendency to reticulations.	Widely distributed in Western States, Washington to Mexico.
Indistinct	A short whitish line	Coarsely granular, somewhat pitted.	Widespread throughout North America.
Distinct, flat, finely striate radially.	A raised point	Coarsely scurfy	In flax sections of the Northwest.
Distinct, flat, finely striate radially.	A raised white line	Finely scurfy, smoothest of the species considered.	Widely distributed in the U. S.
Distinct, large, usually outlined with light rim, radial striations faint or lacking.	A short slit or depressed point.	Slightly rougher than *C. pentagona.*	Scattered across continent; mostly in alfalfa areas.
Indistinct, slightly sunken, margins more or less obscured by scurfy epidermal tissue.	A short slit in the depression at center.	Coarsely scurfy, rugose, bordering on reticulations.	Common in alfalfa regions of the Western States.
Distinct, flat, finely striate, margins often outlined with light scurfy tissue.	A short slit or whitish line, not raised as in *C. pentagona.*	Evenly and finely scurfy; coarser than *C. pentagona;* smoother than *C. indecora.*	Widespread throughout eastern North America.

ILLUSTRATIONS OF CROP AND WEED SEEDS

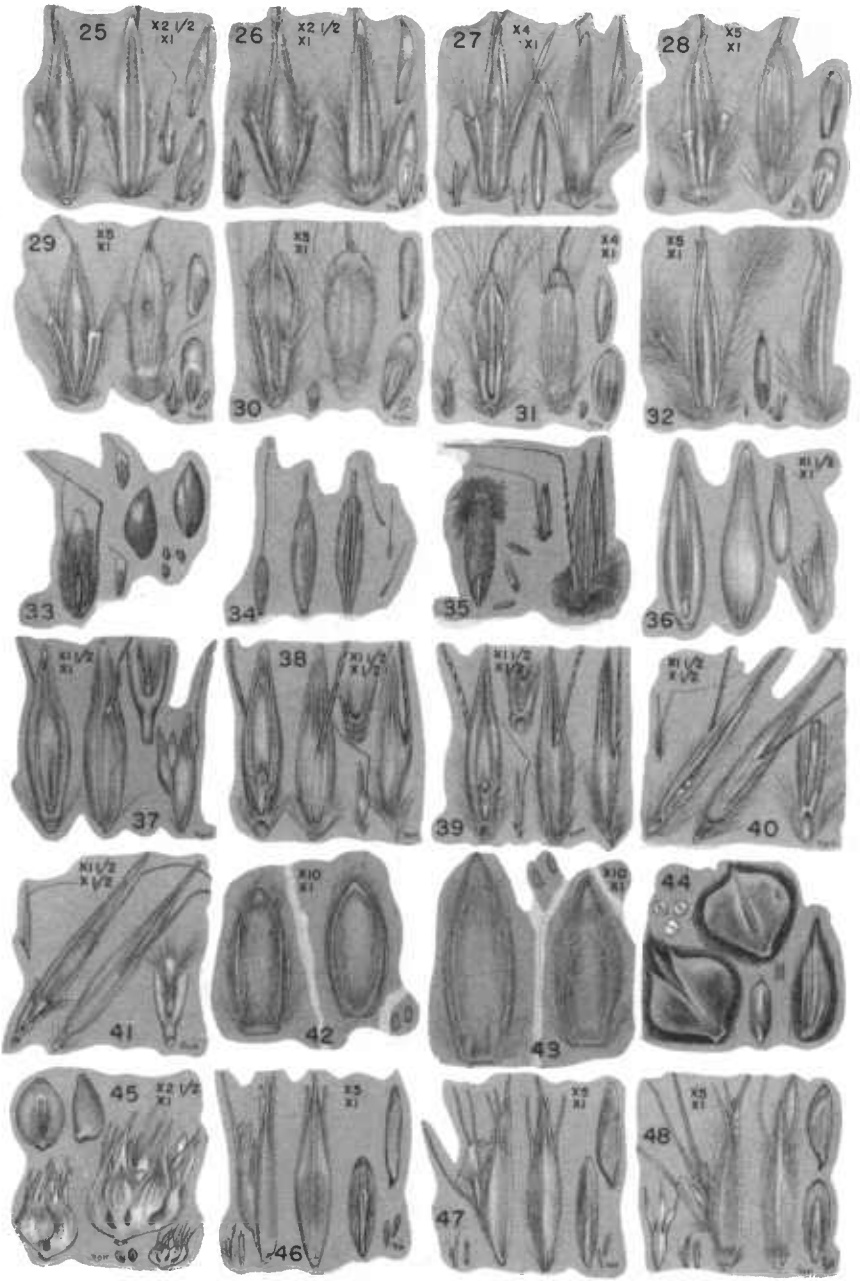
(Pls. I–XXXIV)

Gramineae (pls. I–XII).
Cyperaceae (pl. XII).
Commelinaceae (pl. XII).
Juncaceae (pl. XII).
Liliaceae (pl. XIII).
Iridaceae (pl. XIII).
Cannabinaceae (pl. XIII).
Urticaceae (pl. XIII).
Polygonaceae (pls. XIII–XIV).
Chenopodiaceae (pl. XIV).
Amaranthaceae (pls. XIV–XV).
Nyctaginaceae (pl. XV).
Aizoaceae (pl. XV).
Portulacaceae (pl. XV).
Caryophyllaceae (pls. XV–XVI).
Ranunculaceae (pl. XVI).
Papaveraceae (pl. XVI).
Fumariaceae (pl. XVI).
Cruciferae (pls. XVI–XVIII).
Resedaceae (pl. XVIII).
Rosaceae (pl. XVIII).
Leguminosae (pls. XVIII–XXIII).
Geraniaceae (pl. XXIII).
Oxalidaceae (pl. XXIII).
Linaceae (pl. XXIII).
Zygophyllaceae (pl. XXIII).
Euphorbiaceae (pls. XXIII–XXIV).
Malvaceae (pl. XXIV).
Sterculiaceae (pl. XXIV).
Hypericaceae (pl. XXIV).
Violaceae (pl. XXIV).
Loasaceae (pls. XXIV–XXV).
Lythraceae (pl. XXV).
Onagraceae (pl. XXV).
Umbelliferae (pls. XXV–XXVI).
Primulaceae (pl. XXVI).
Apocynaceae (pl. XXVI).
Asclepiadaceae (pl. XXVI).
Convolvulaceae (pls. XXVI–XXVII).
Polemoniaceae (pl. XXVII).
Hydrophyllaceae (pl. XXVII).
Boraginaceae (pls. XXVII–XXVIII).
Verbenaceae (pl. XXVIII).
Labiatae (pls. XXVIII–XXIX).
Solanaceae (pl. XXIX).
Scrophulariaceae (pls. XXIX–XXX).
Pedaliaceae (pl. XXX).
Plantaginaceae (pl. XXX).
Rubiaceae (pl. XXX).
Caprifoliaceae (pl. XXX).
Valerianaceae (pl. XXXI).
Dipsacaceae (pl. XXXI).
Campanulaceae (pl. XXXI).
Lobeliaceae (pl. XXXI).
Compositae (pl. XXXI–XXXIV).



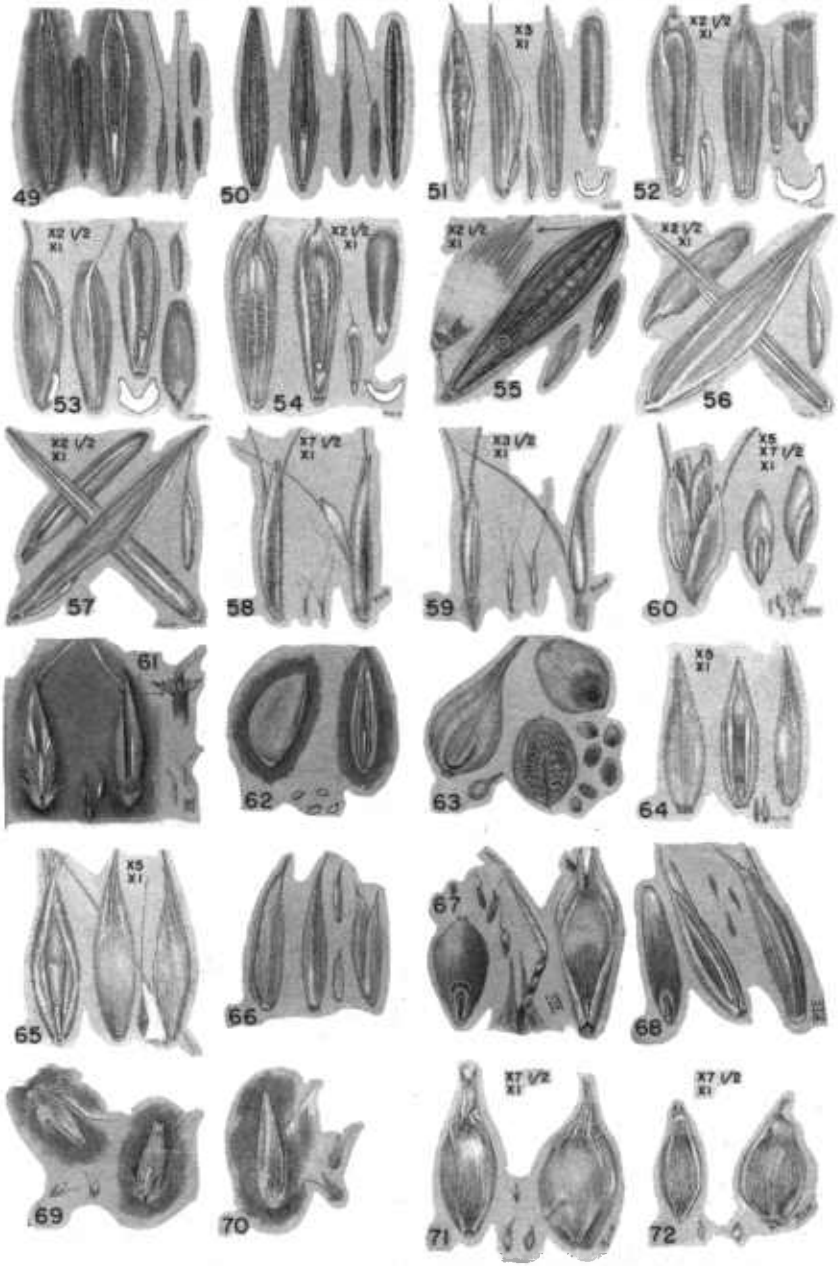
Gramineae (1-24)

1. *Agrostis alba*
2. *Agrostis tenuis*
3. *Agrostis exarata*
4. *Agrostis exarata*
5. *Agrostis canina*
6. *Agrostis elliottiana*
7. *Agrostis hiemalis*
8. *Agrostis scabra*
9. *Agropyron repens*
10. *Agropyron smithii*
11. *Agropyron trachycaulum*
12. *Agropyron elongatum*
13. *Agropyron cristatum*
14. *Agropyron desertorum*
15. *Agropyron intermedium*
16. *Agropyron trichophorum*
17. *Aira elegans*
18. *Aira caryophyllea*
19. *Alopecurus aequalis*
20. *Alopecurus carolinianus*
21. *Alopecurus geniculatus*
22. *Alopecurus pratensis*
23. *Alopecurus myosuroides*
24. *Aristida dichotoma*



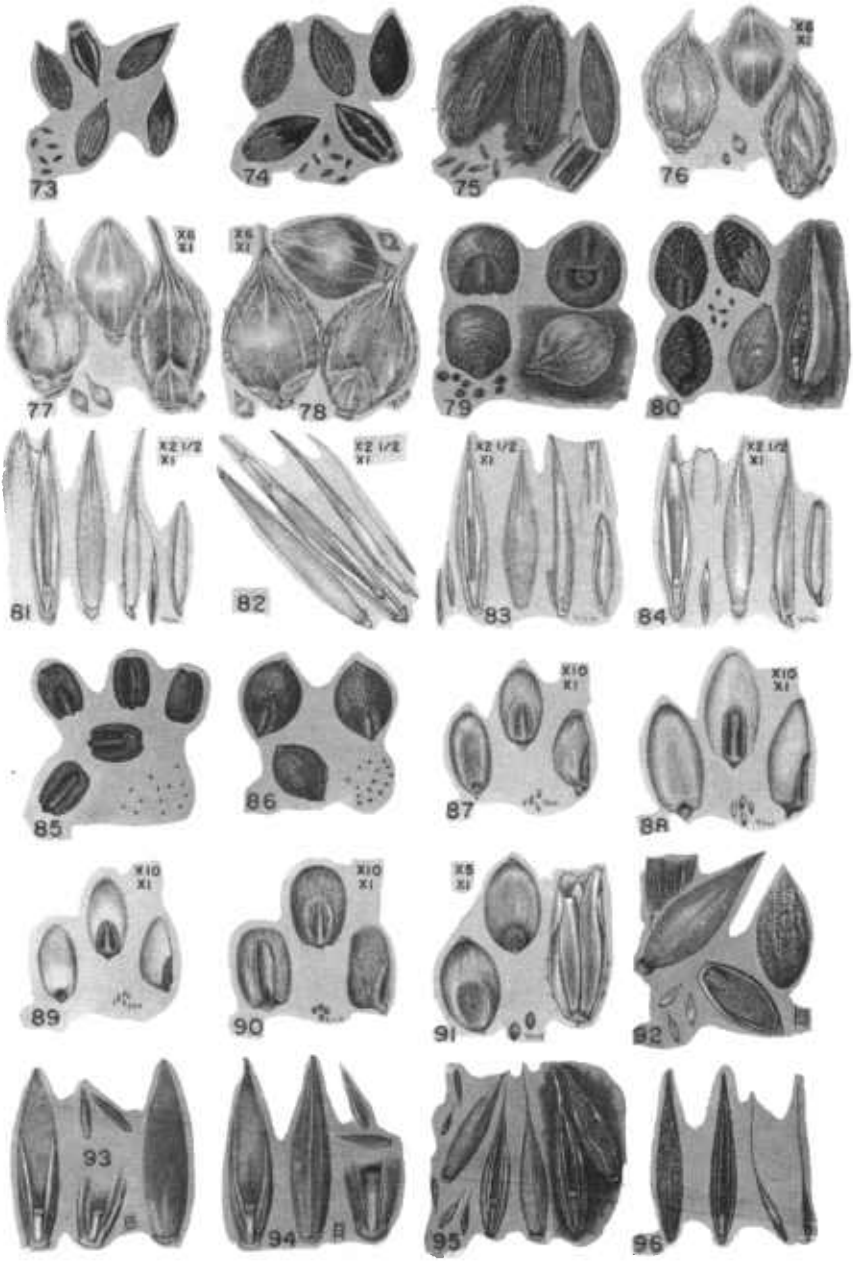
Gramineae (25–48)

25. *Andropogon gerardi* (*A. furcatus*)
26. *Andropogon hallii*
27. *Andropogon scoparius*
28. *Andropogon ischaemum*
29. *Andropogon intermedius*
30. *Andropogon nodosus*
31. *Andropogon sericeus*
32. *Andropogon virginicus*
33. *Anthoxanthum odoratum*
34. *Apera spica-venti*
35. *Arrhenatherum elatius*
36. *Avena sativa*
37. *Avena byzantina*
38. *Avena* (homozygous fatuoid)
39. *Avena fatua*
40. *Avena barbata*
41. *Avena strigosa*
42. *Axonopus affinis*
43. *Axonopus compressus*
44. *Beckmannia syzigachne*
45. *Buchloë dactyloides*
46. *Bouteloua curtipendula*
47. *Bouteloua gracilis*
48. *Bouteloua hirsuta*



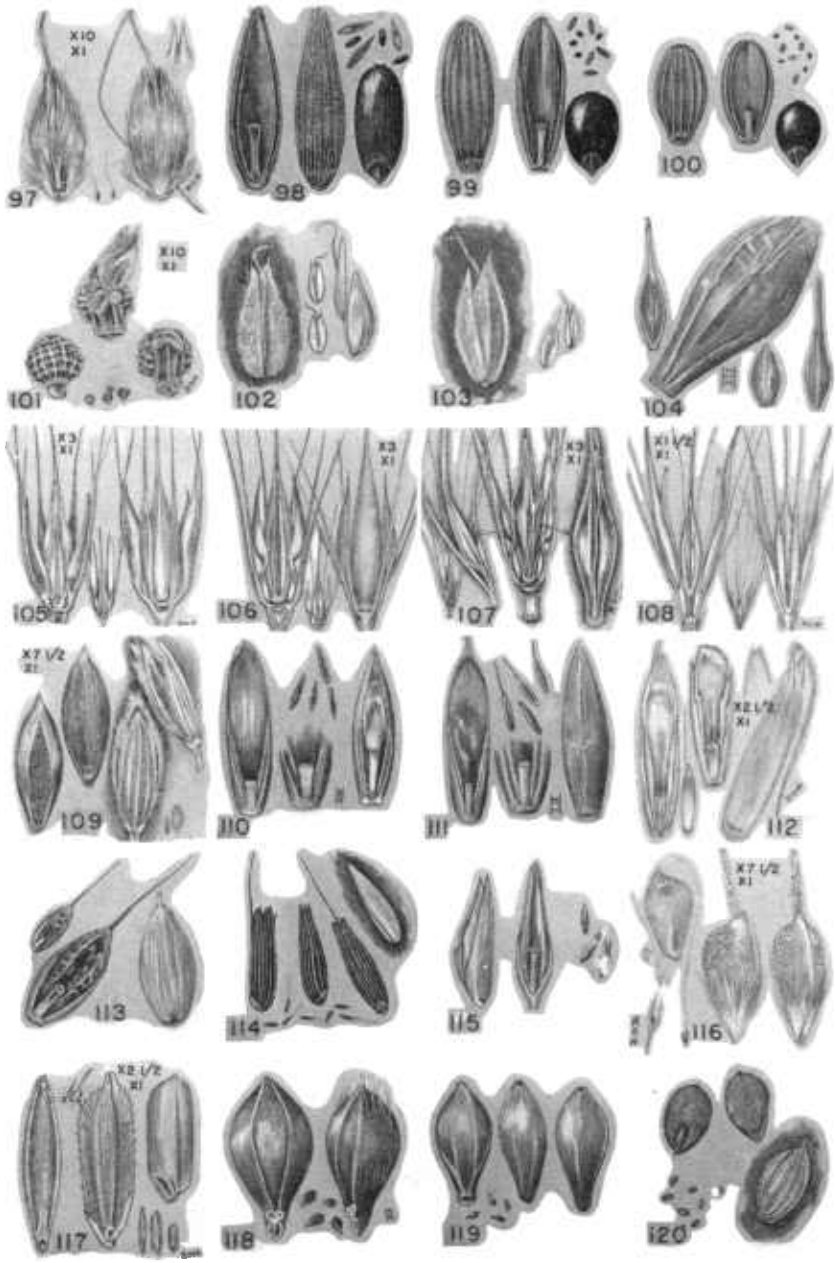
Gramineae (49–72)

49. *Bromus tectorum*
50. *Bromus sterilis*
51. *Bromus japonicus*
52. *Bromus commutatus*
53. *Bromus secalinus*
54. *Bromus mollis*
55. *Bromus inermis*
56. *Bromus catharticus*
57. *Bromus marginatus*
58. *Chloris divaricata*
59. *Chloris aciculatis*
60. *Chloris gayana*
61. *Corynephorus canescens*
62. *Cynodon dactylon*
63. *Cenchrus pauciflorus*
64. *Cynosurus cristatus*
65. *Cynosurus echinatus*
66. *Dactylis glomerata*
67. *Danthonia spicata*
68. *Danthonia spicata* (Cleistogenes)
69. *Deschampsia caespitosa*
70. *Deschampsia flexuosa*
71. *Distichlis stricta*
72. *Distichlis spicata*



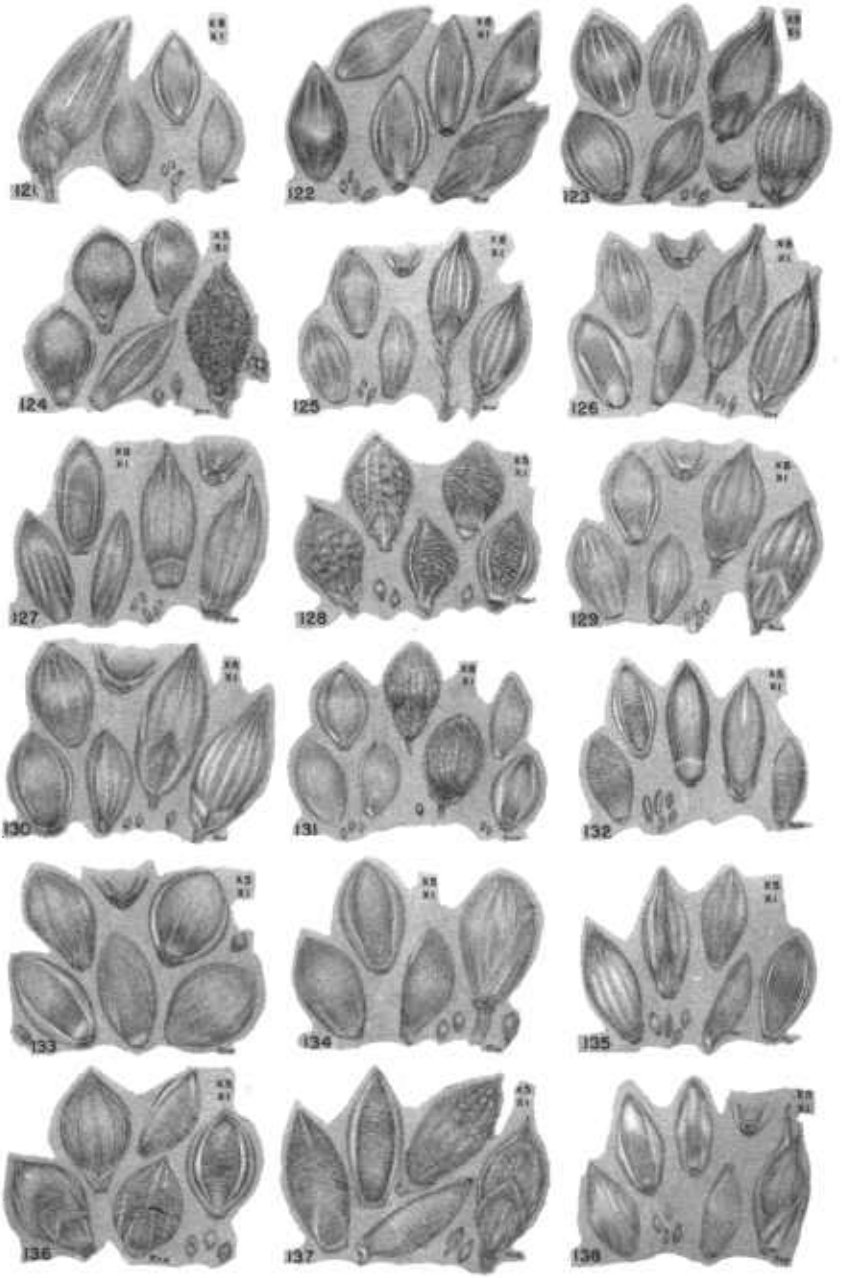
Gramineae (73–96)

73. *Digitaria filiformis*
74. *Digitaria ischaemum*
75. *Digitaria sanguinalis*
76. *Echinochloa colonum*
77. *Echinochloa crusgalli*
78. *Echinochloa crusgalli* var. *frumentacea*
79. *Eleusine coracana*
80. *Eleusine indica*
81. *Elymus canadensis*
82. *Elymus glaucus*
83. *Elymus juncceus*
84. *Elymus virginicus*
85. *Eragrostis capillaris*
86. *Eragrostis cilianensis*
87. *Eragrostis chloromelas*
88. *Eragrostis curvula*
89. *Eragrostis lehmanniana*
90. *Eragrostis trichodes*
91. *Eremochloa ophiuroides*
92. *Eriochloa punctata*
93. *Festuca elatior*
94. *Festuca arundinacea*
95. *Festuca rubra*
96. *Festuca myuros*



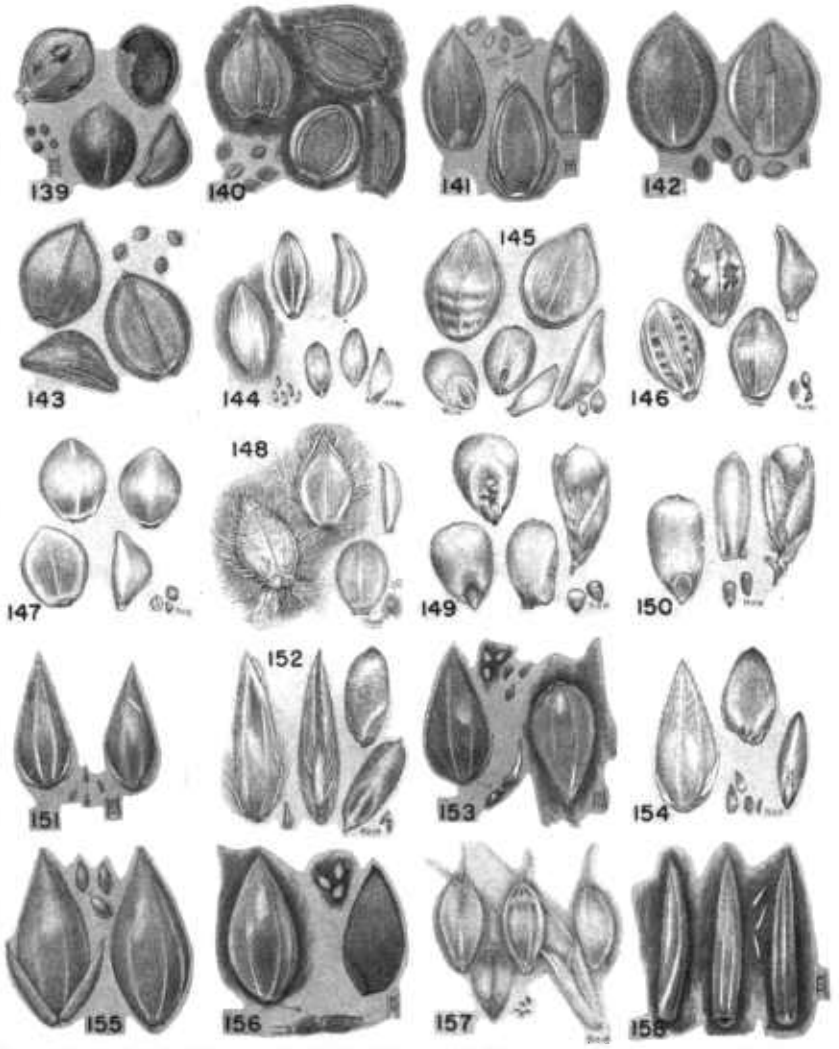
Gramineae (97–120)

97. *Gastridium ventricosum*
98. *Glyceria fluitans*
99. *Glyceria grandis*
100. *Glyceria striata*
101. *Hackelochloa granularis*
102. *Holcus lanatus*
103. *Holcus mollis*
104. *Hordeum vulgare*
105. *Hordeum pusillum*
106. *Hordeum brachyantherum*
107. *Hordeum jubatum*
108. *Hordeum leporinum* (*H. murinum*)
109. *Leptoloma cognatum*
110. *Lolium perenne*
111. *Lolium multiflorum*
112. *Lolium persicum*
113. *Lolium temulentum*
114. *Melinis minutiflora*
115. *Molinia caerulea*
116. *Nassella trichotoma*
117. *Oryza sativa*
118. *Oryzopsis hymenoides*
119. *Oryzopsis miliacea*
120. *Phleum pratense*



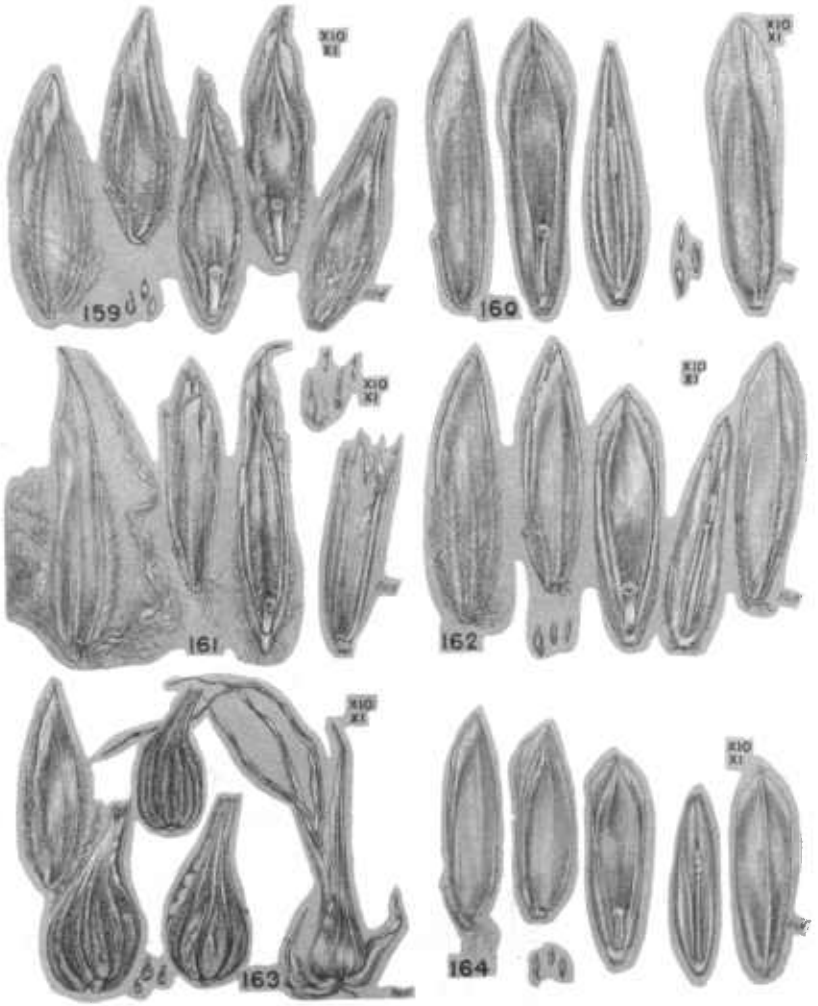
Gramineae (121–138)

121. *Panicum anceps*
122. *Panicum antidotale*
123. *Panicum bergii*
124. *Panicum brachyanthum*
125. *Panicum capillare*
126. *Panicum capillare* var. *occidentale*
127. *Panicum dichotomiflorum*
128. *Panicum fasciculatum*
129. *Panicum gattingeri*
130. *Panicum hillmani*
131. *Panicum huachucae*
132. *Panicum maximum*
133. *Panicum miliaceum*
134. *Panicum obtusum*
135. *Panicum purpurascens*
136. *Panicum ramosum*
137. *Panicum texanum*
138. *Panicum virgatum*



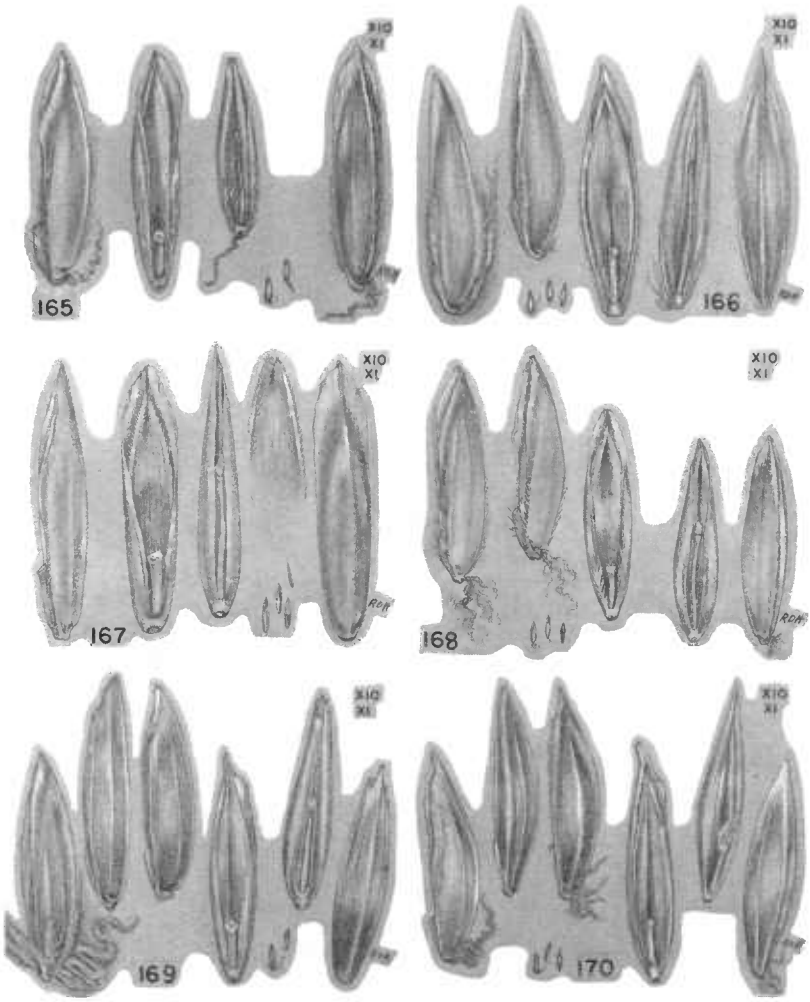
Gramineae (139–158)

139. *Paspalum boscianum*
140. *Paspalum dilatatum*
141. *Paspalum distichum*
142. *Paspalum floridanum*
143. *Paspalum laeve*
144. *Paspalum malacophyllum*
145. *Paspalum notatum*
146. *Paspalum plicatulum*
147. *Paspalum setaceum*
148. *Paspdlum urvillei*
149. *Pennisetum glaucum*
150. *Pennisetum purpureum*
151. *Phalaris angusta*
152. *Phalaris arundinacea*
153. *Phalaris minor*
154. *Phalaris tuberosa* var. *stenoptera*
155. *Phalaris canariensis*
156. *Phalaris paradoxa*
157. *Polypogon monspeliensis*
158. *Schedonnardus paniculatus*



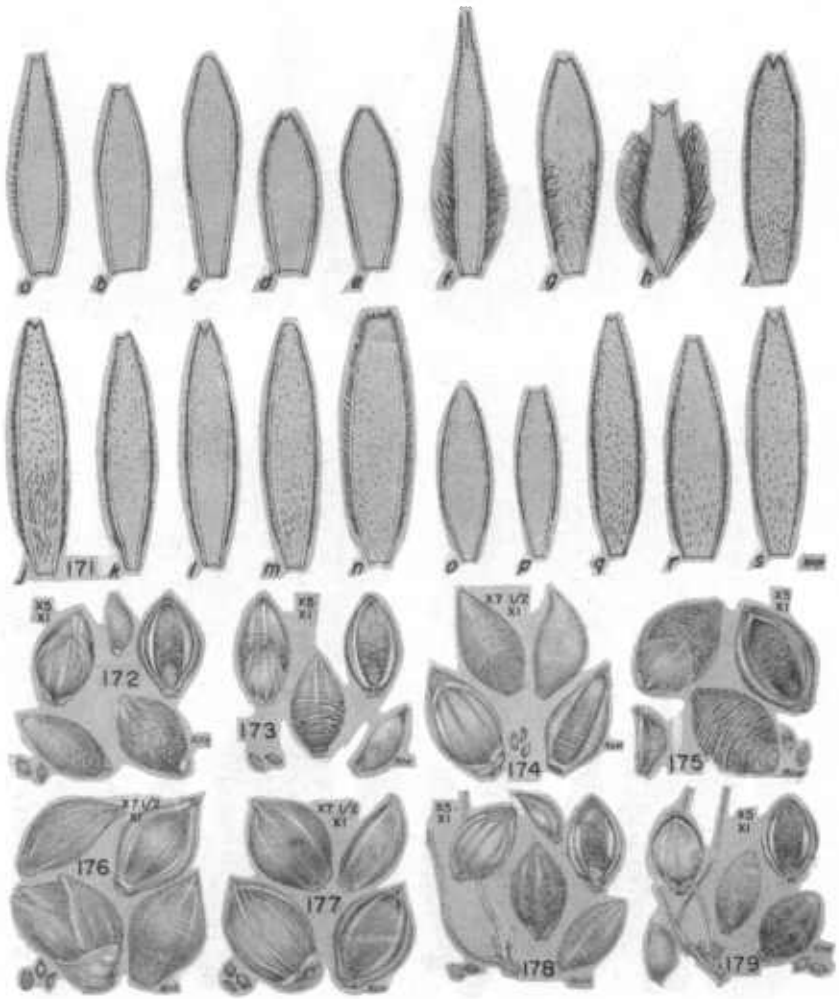
Gramineae (159–164)

159. *Poa annua*
160. *Poa ampla*
161. *Poa arachnifera*
162. *Poa arida*
163. *Poa bulbosa*
164. *Poa compressa*



Gramineae (165–170)

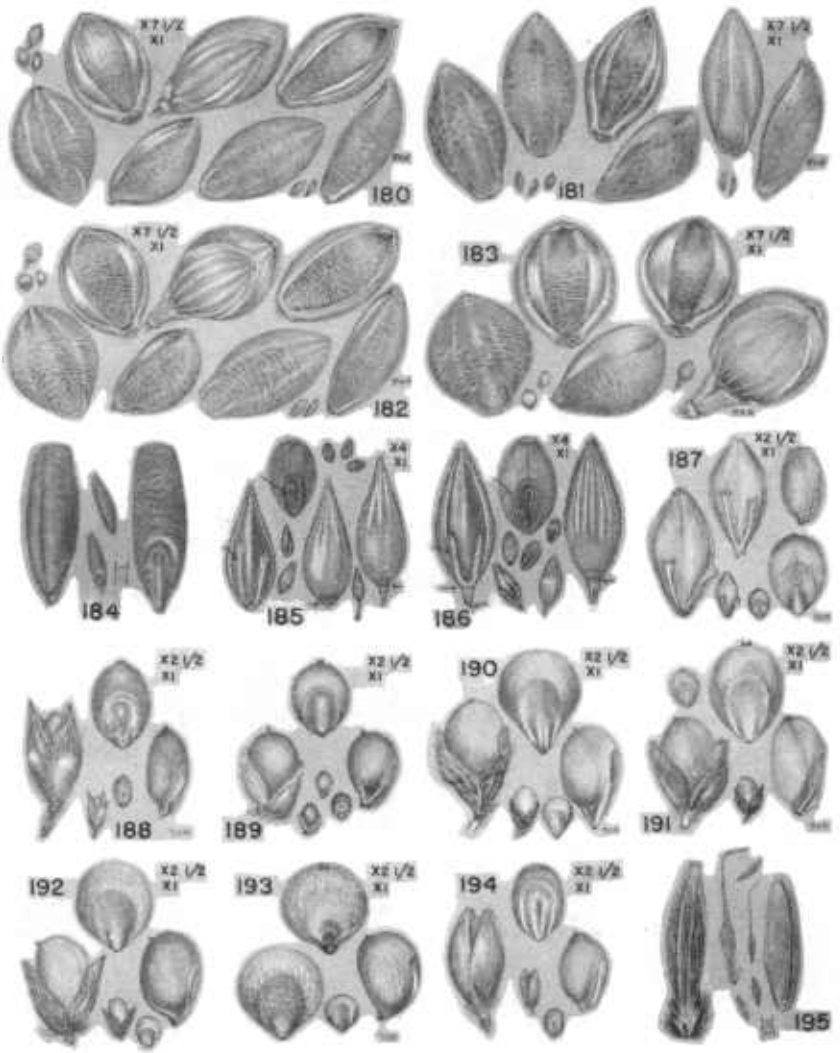
165. *Poa interior*
166. *Poa nemoralis*
167. *Poa nevadensis*
168. *Poa palustris*
169. *Poa pratensis*
170. *Poa trivialis*



Gramineae (171–179)

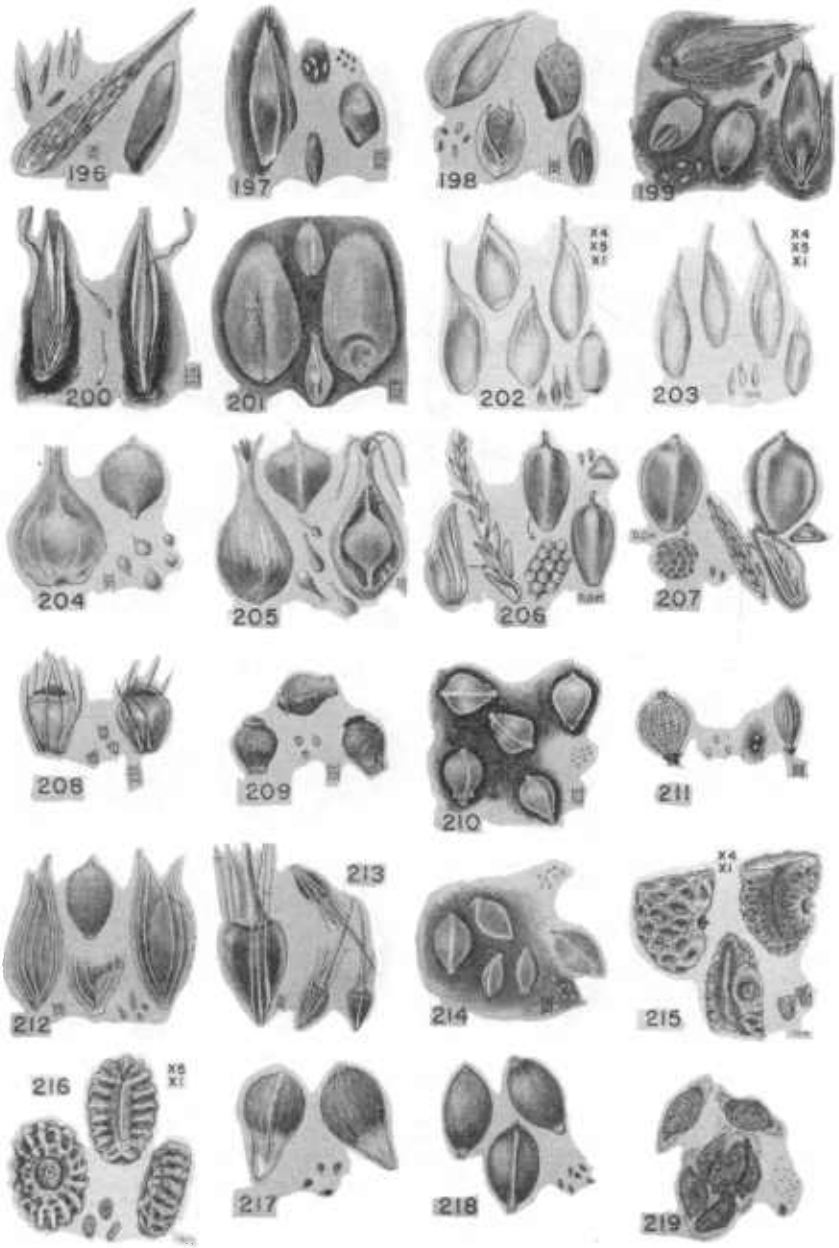
171. *Poa* spp. Shape and pubescence of paleas.
- *a. P. pratensis*
- *b. P. trivialis*
- *c. P. nemoralis*
- *d. P. compressa*
- *e. P. palustris*
- *f. P. arachnifera*
- *g. P. arida*
- *h. P. annua*
- *i. P. juncifolia*
- *j. P. secunda*
- *k. P. nevadensis*
- *l. P. ampla*
- *m. P. canbyi*
- *n. P. cusickii*
- *o. P. glaucifolia*
- *p. P. interior*
- *q. P. longiligula*
- *r. P. fendleriana*
- *s. P. stenantha*

172. *Setaria faberi*
173. *Setaria geniculata*
174. *Setaria grisebachii*
175. *Setaria lutescens*
176. *Setaria macrostachya*
177. *Setaria magna*
178. *Setaria verticillata*
179. *Setaria viridis*



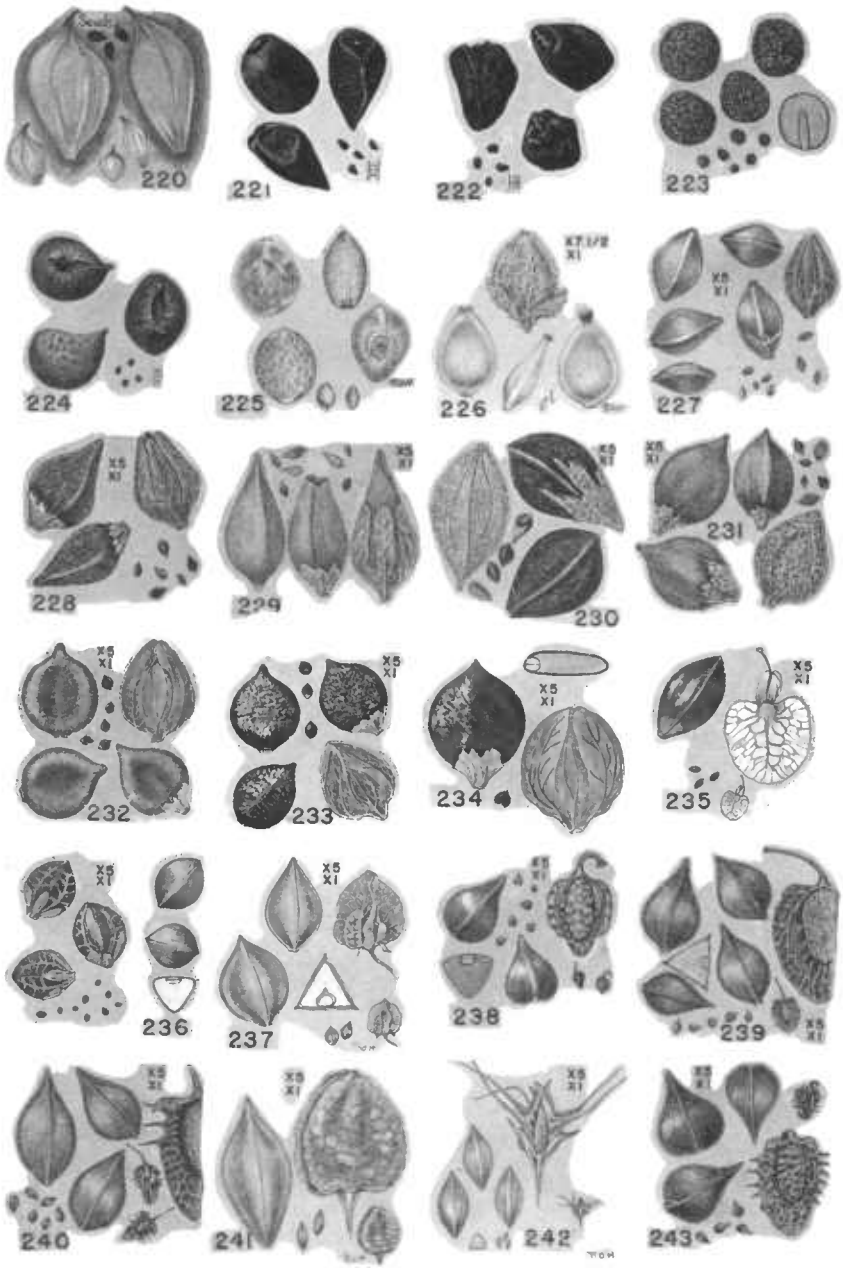
Gramineae (180–195)

180. *Setaria italica* (Common)
181. *Setaria italica* (Hungarian)
182. *Setaria italica* (German)
183. *Setaria italica* (White Wonder)
184. *Secale cereale*
185. *Sorghum halepense*
186. *Sorghum sudanense*
187. *Sorghum-Sudan* hybrids
188. *Sorghum vulgare* (Black Amber)
189. *Sorghum vulgare* (Sumac)
190. *Sorghum vulgare* (Milo)
191. *Sorghum vulgare* (Kafir)
192. *Sorghum vulgare* (Hegari)
193. *Sorghum vulgare* (Feterita)
194. *Sorghum vulgare* (Broomcorn)
195. *Stipa viridula*



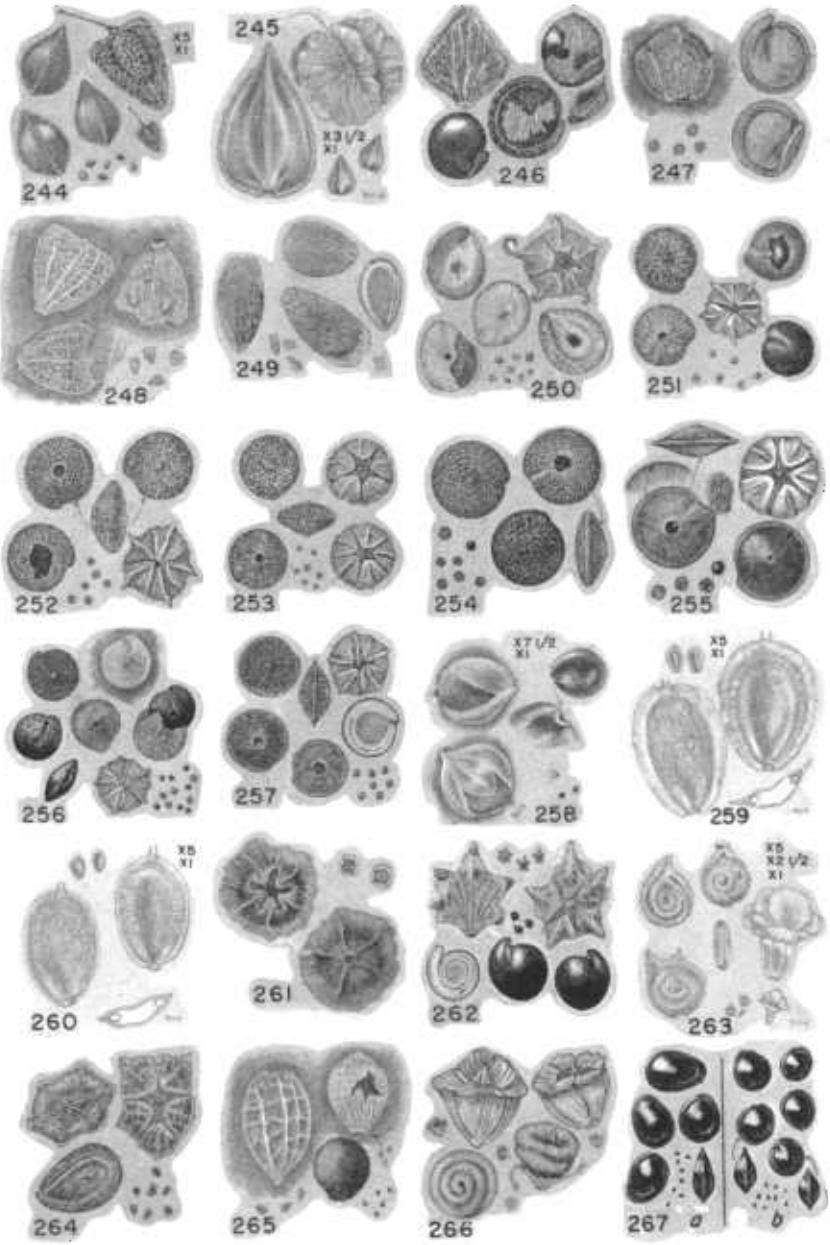
Gramineae (196–203), Cyperaceae (204–214), Commelinaceae (215–216), Juncaceae (217–219)

196. *Sporobolus clandestinus*
197. *Sporobolus cryptandrus*
198. *Sporobolus neglectus*
199. *Tridens flavus*
200. *Trisetum flavescens*
201. *Triticum aestivum*
202. *Zoysia japonica*
203. *Zoysia matrella*
204. *Carex festucacea*
205. *Carex trichocarpa*
206. *Cyperus esculentus*
207. *Cyperus rotundus*
208. *Eleocharis obtusa*
209. *Eleocharis tenuis*
210. *Fimbristylis autumnalis*
211. *Fimbristylis baldwiniana*
212. *Kyllinga* sp.
213. *Rhynchospora macrostachya*
214. *Scirpus* sp.
215. *Commelina communis*
216. *Tradescantia virginiana*
217. *Luzula campestris*
218. *Luzula luzuloides*
219. *Juncus tenuis*



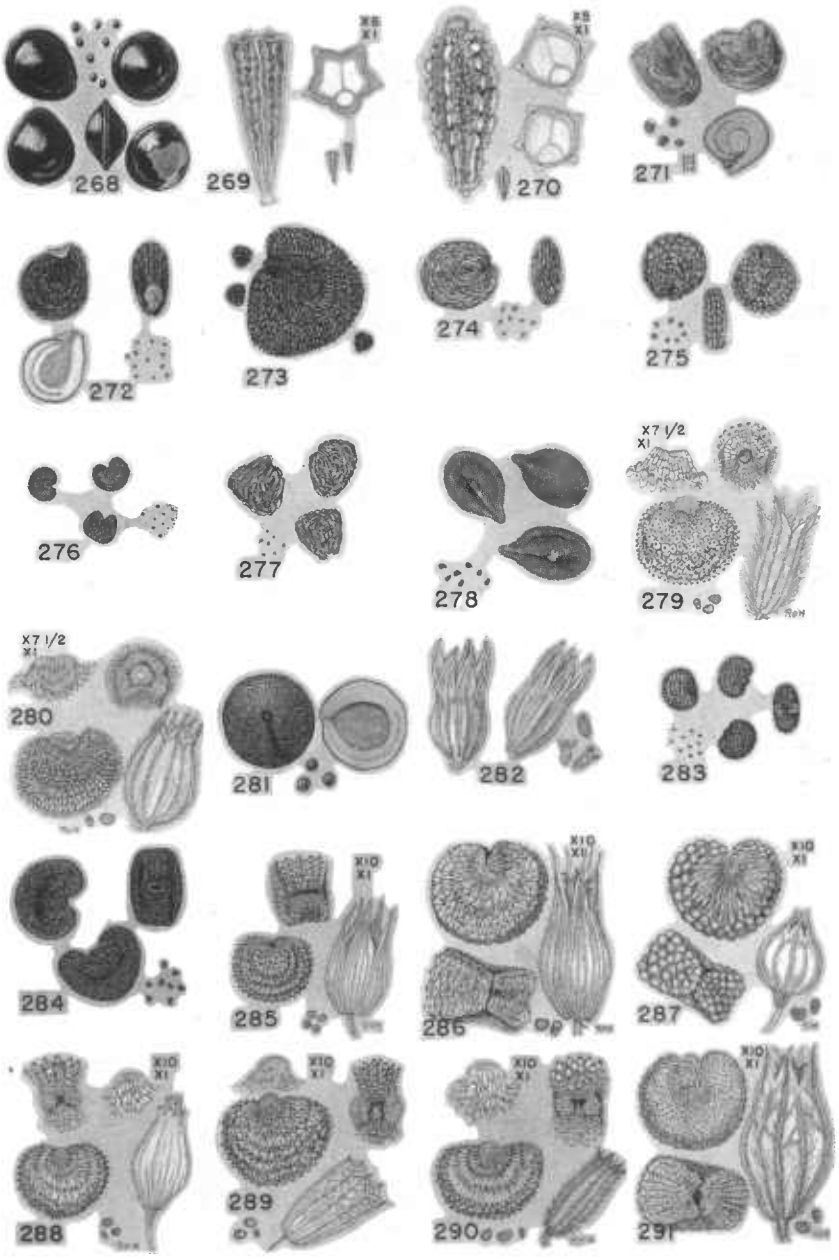
Liliaceae (220–223), Iridaceae (224), Cannabinaceae (225), Urticaceae (226), Polygonaceae (227–243)

220. *Allium vineale*
221. *Brodiaea coronaria*
222. *Brodiaea grandiflora*
223. *Muscari comosum*
224. *Sisyrinchium* sp.
225. *Cannabis sativa*
226. *Urtica dioica*
227. *Polygonum argyrocoleon*
228. *Polygonum aviculare*
229. *Polygonum aviculare* (Cleistogenes)
230. *Polygonum convolvulus*
231. *Polygonum hydropiper*
232. *Polygonum lapathifolium*
233. *Polygonum persicaria*
234. *Polygonum pensylvanicum*
235. *Rumex acetosa*
236. *Rumex acetosella*
237. *Rumex altissimus*
238. *Rumex conglomeratus*
239. *Rumex crispus*
240. *Rumex obtusifolius*
241. *Rumex occidentalis*
242. *Rumex persicarioides*
243. *Rumex pulcher*



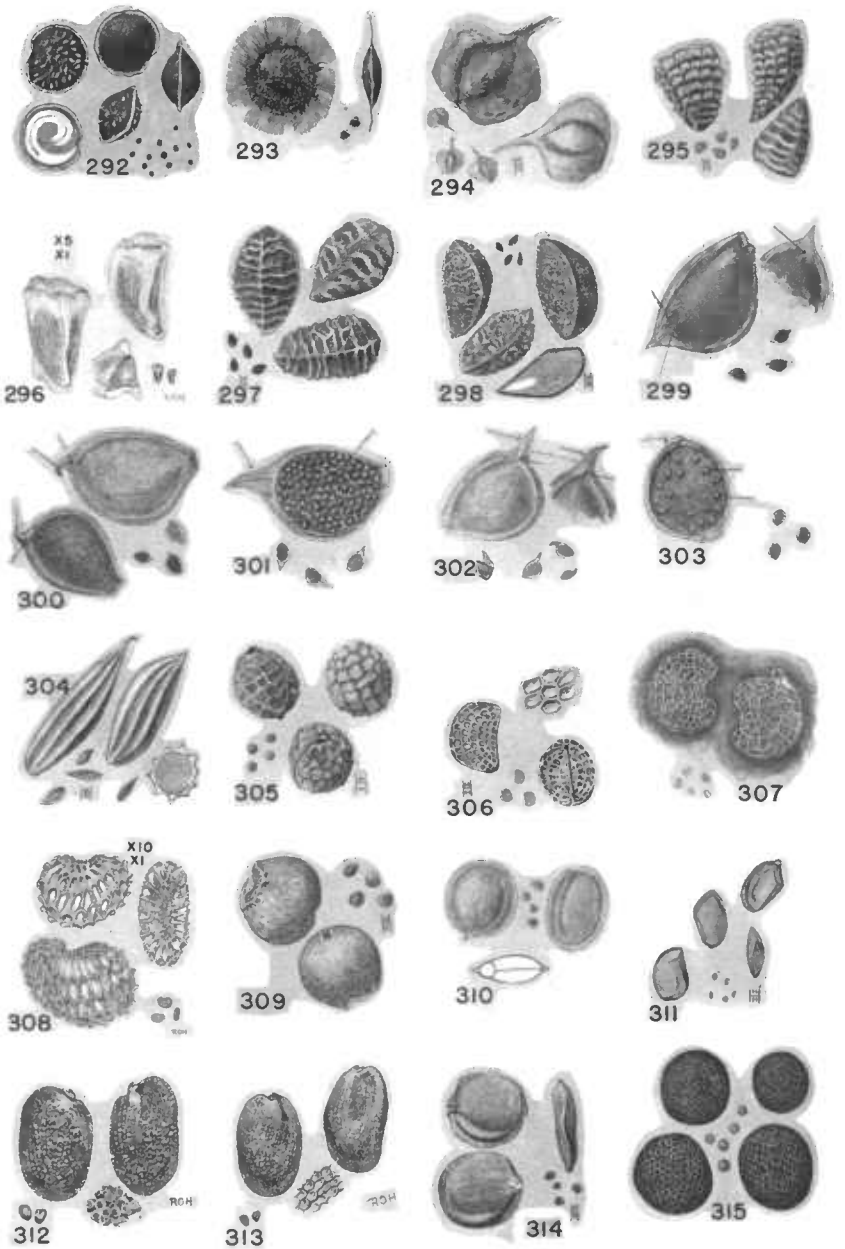
Polygonaceae (244–245), Chenopodiaceae (246–266), Amaranthaceae (267)

244. *Rumex salicifolius*
245. *Rumex venosus*
246. *Atriplex patula* var. *hastata*
247. *Atriplex rosea*
248. *Atriplex truncata*
249. *Axyris amaranthoides*
250. *Bassia hyssopifolia*
251. *Chenopodium album*
252. *Chenopodium berlandieri*
253. *Chenopodium hircinum*
254. *Chenopodium hybridum*
255. *Chenopodium hybridum* var. *gigantospermum*
256. *Chenopodium leptophyllum*
257. *Chenopodium murale*
258. *Chenopodium rubrum*
259. *Corispermum hyssopifolium*
260. *Corispermum villosum*
261. *Cycloloma atriplicifolium*
262. *Suaeda depressa* (*Dondia depressa*)
263. *Halogeton glomeratus*
264. *Kochia scoparia*
265. *Roubieva multifida*
266. *Salsola kali* var. *tenuifolia*
267. *a. Amaranthus retroflexus*
b. Amaranthus albus



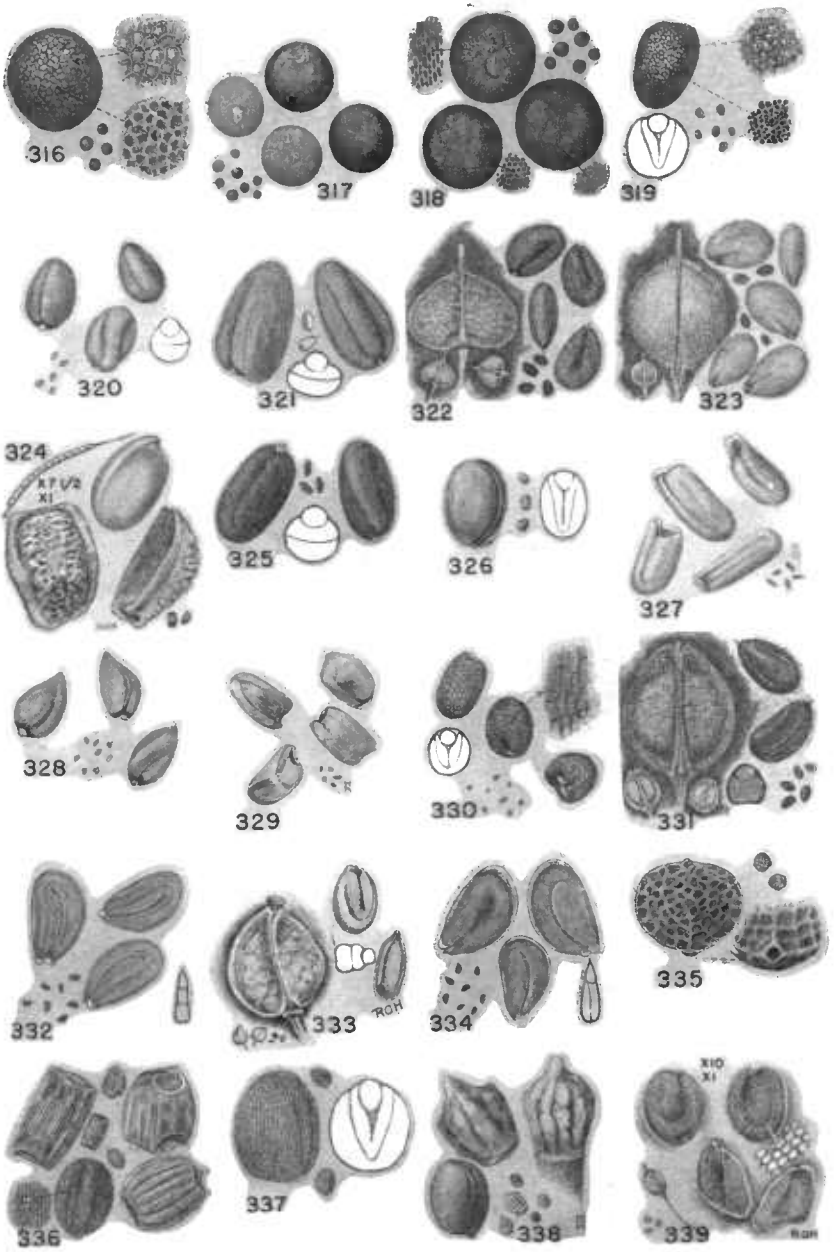
Amaranthaceae (268). Nyctaginaceae (269–270). Aizoaceae (271). Portulacaceae (272). Caryophyllaceae (273–291)

268. *Amaranthus graecizans* (*A. blitoides*)
269. *Boerhaavia erecta*
270. *Mirabilis nyctaginea* (*Allionia nyctaginea*)
271. *Trianthema portulacastrum*
272. *Portulaca oleracea*
273. *Agrostemma githago*
274. *Stellaria graminea*
275. *Stellaria media*
276. *Arenaria serpyllifolia*
277. *Cerastium vulgatum*
278. *Dianthus armeria*
279. *Lychnis alba*
280. *Lychnis dioica*
281. *Saponaria vaccaria*
282. *Scleranthus annuus*
283. *Silene antirrhina*
284. *Silene gallica* (*S. anglica*)
285. *Silene conica*
286. *Silene conoidea*
287. *Silene cretica*
288. *Silene exerei* (*S. fabaria*)
289. *Silene cucubalus* (*S. latifolia*)
290. *Silene dichotoma*
291. *Silene noctiflora*



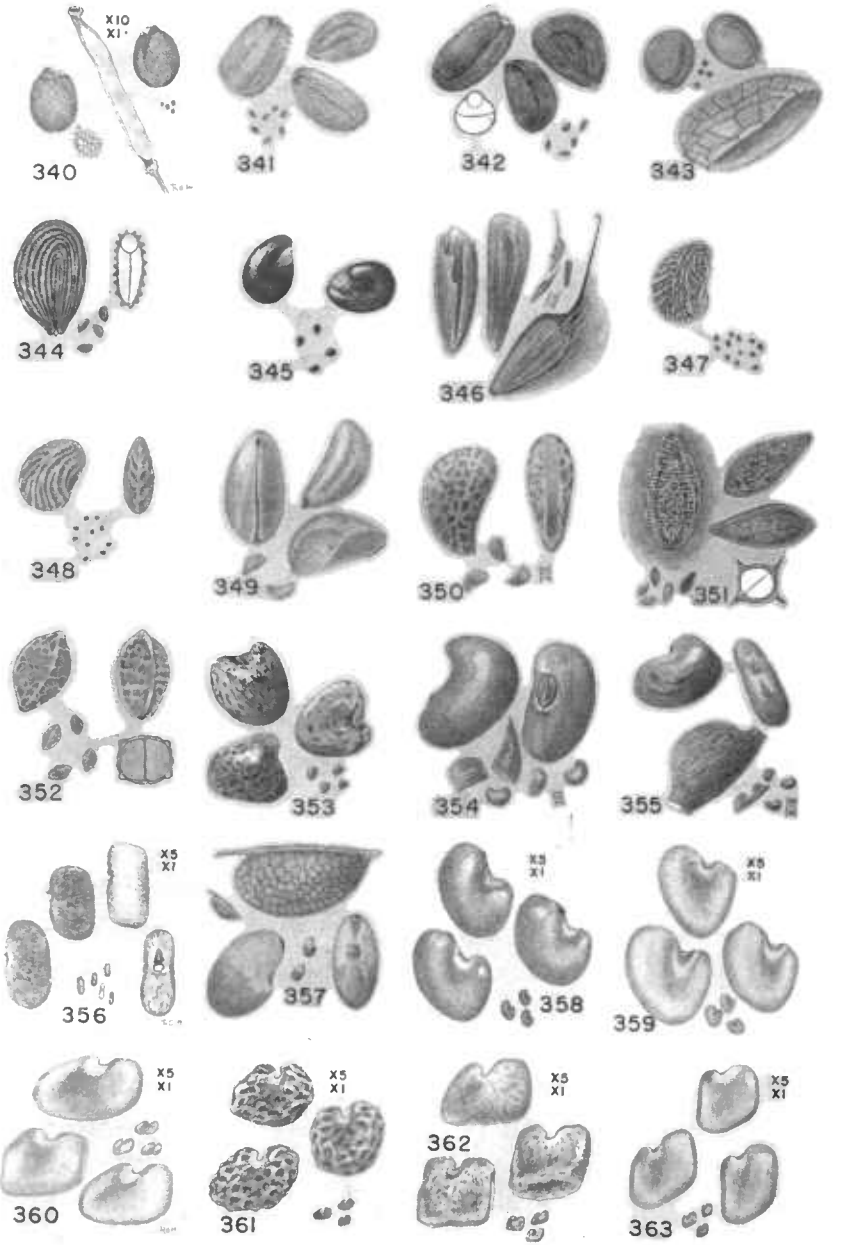
Caryophyllaceae (292–293), Ranunculaceae (294–304), Papaveraceae (305–308), Fumariaceae (309), Cruciferae (310–315)

292. *Spergula arvensis*
293. *Spergula pentandra*
294. *Anemone canadensis*
295. *Delphinium consolida*
296. *Delphinium menziesii*
297. *Nigella damescena*
298. *Nigella sativa*
299. *Ranunculus acris*
300. *Ranunculus bulbosus*
301. *Ranunculus parviflorus*
302. *Ranunculus repens*
303. *Ranunculus sardous* (*R. parvulus*)
304. *Thalictrum* sp.
305. *Eschscholtzia californica*
306. *Glaucium corniculatum*
307. *Papaver somniferum*
308. *Roemeria refracta*
309. *Fumaria officinalis*
310. *Alyssum alyssoides*
311. *Arabis glabra*
312. *Barbarea verna*
313. *Barbarea vulgaris*
314. *Berteroa incana*
315. *Brassica campestris*



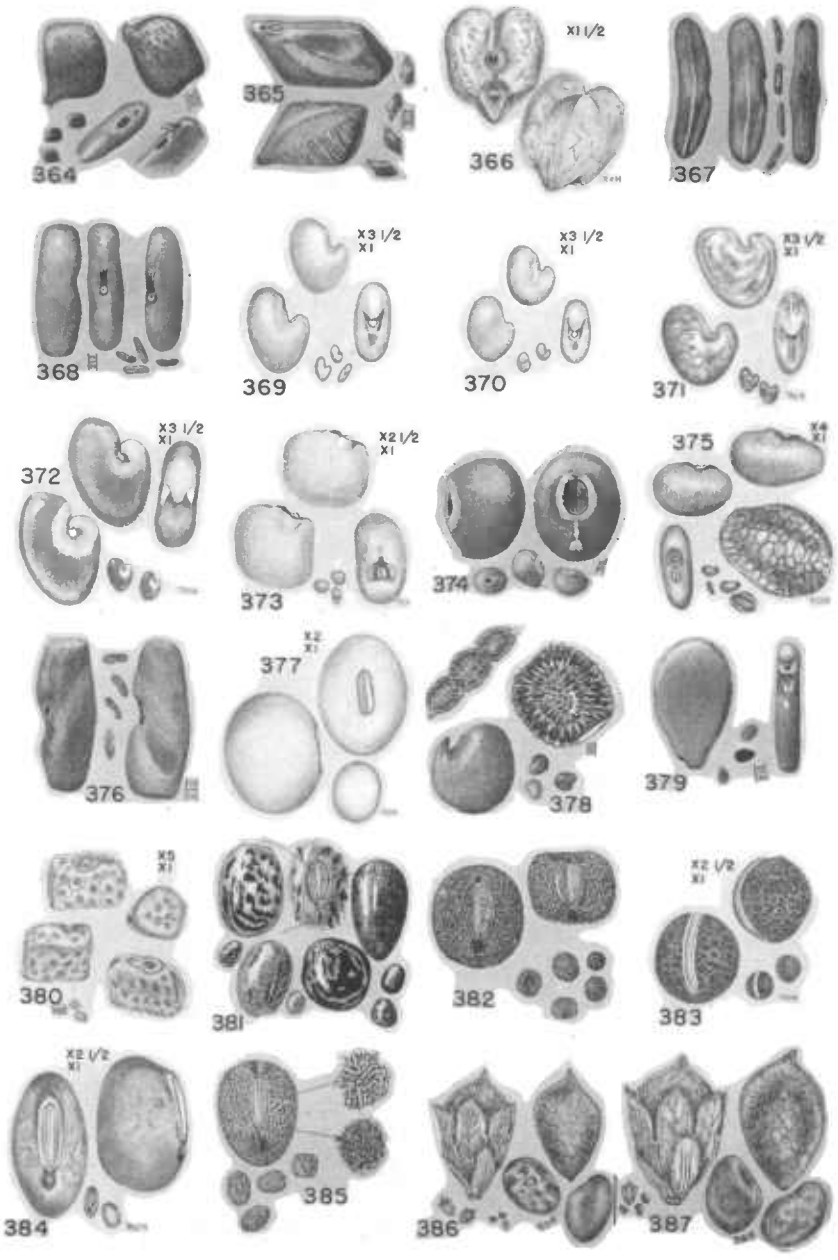
Cruciferae (316–339)

316. *Brassica juncea*
317. *Brassica kaber* (*B. arvensis*)
318. *Brassica napus* var. *biennis*
319. *Brassica nigra*
320. *Camelina microcarpa*
321. *Camelina sativa*
322. *Cardaria draba*
323. *Cardaria pubescens* (*Hymenophysa pubescens*)
324. *Chorispora tenella*
325. *Conringia orientalis*
326. *Eruca sativa*
327. *Erysimum asperum*
328. *Erysimum cheiranthoides*
329. *Erysimum inconspicuum* (*E. parviflorum*)
330. *Hirschfeldia incana* (*Brassica adpressa*)
331. *Lepidium campestre*
332. *Lepidium densiflorum*
333. *Lepidium latifolium*
334. *Lepidium virginicum*
335. *Neslia paniculata*
336. *Raphanus raphanistrum*
337. *Raphanus sativus*
338. *Rapistrum rugosum*
339. *Rorippa austriaca*



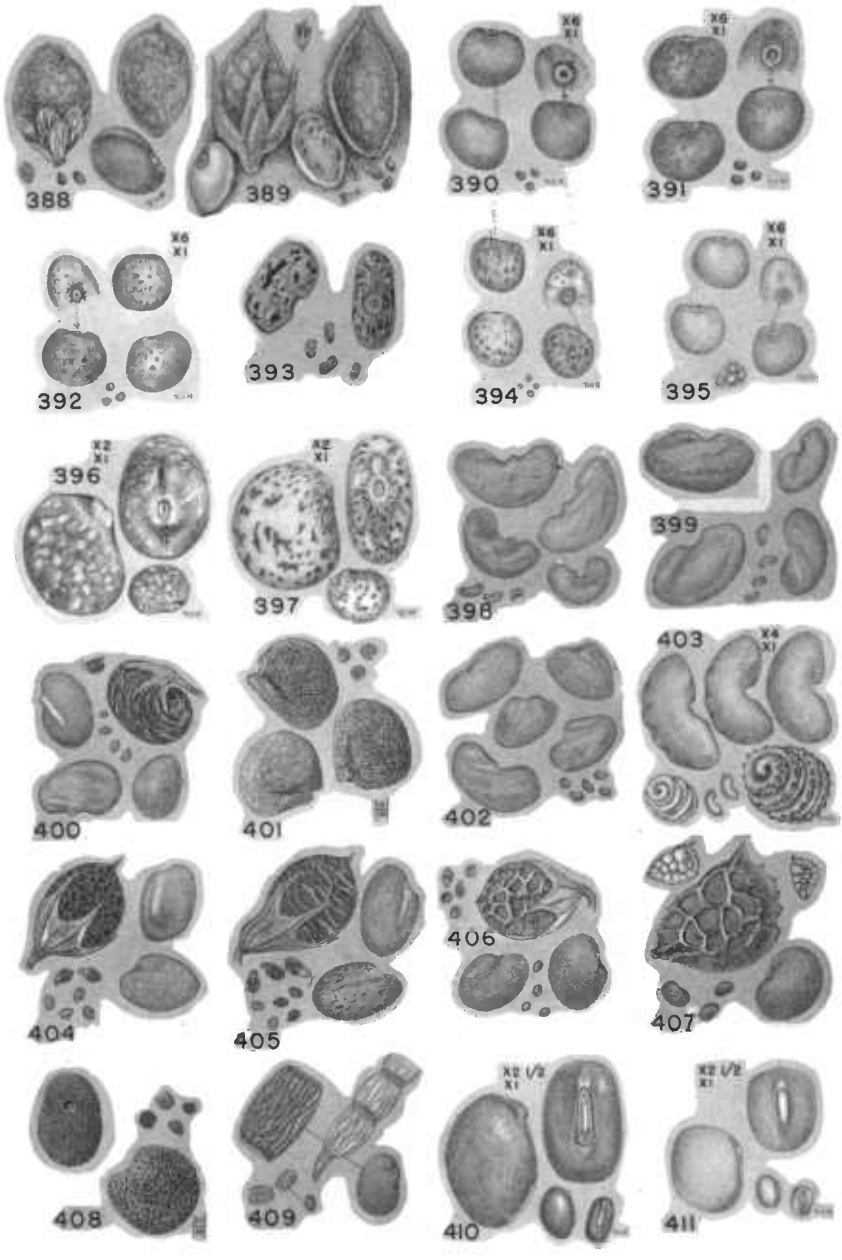
Cruciferae (340–344), Resedaceae (345), Rosaceae (346–352), Leguminosae (353–363)

340. *Rorippa sylvestris*
341. *Sisymbrium altissimum*
342. *Sisymbrium officinale*
343. *Tecstalia nudicaulis*
344. *Thlaspi arvense*
345. *Reseda lutea*
346. *Geum* sp.
347. *Potentilla canadensis*
348. *Potentilla monspeliensis*
349. *Rosa* sp.
350. *Rubus* sp.
351. *Sanguisorba annua*
352. *Sanguisorba minor*
353. *Adesmia muricata*
354. *Aeschynomene virginica*
355. *Alhagi pseudalhagi*
356. *Alysicarpus vaginalis*
357. *Anthyllis vulneraria*
358. *Astragalus chinensis*
359. *Astragalus cicer*
360. *Astragalus falcatus*
361. *Astragalus flexuosus*
362. *Astragalus nuttallianus*
363. *Astragalus rubyi*



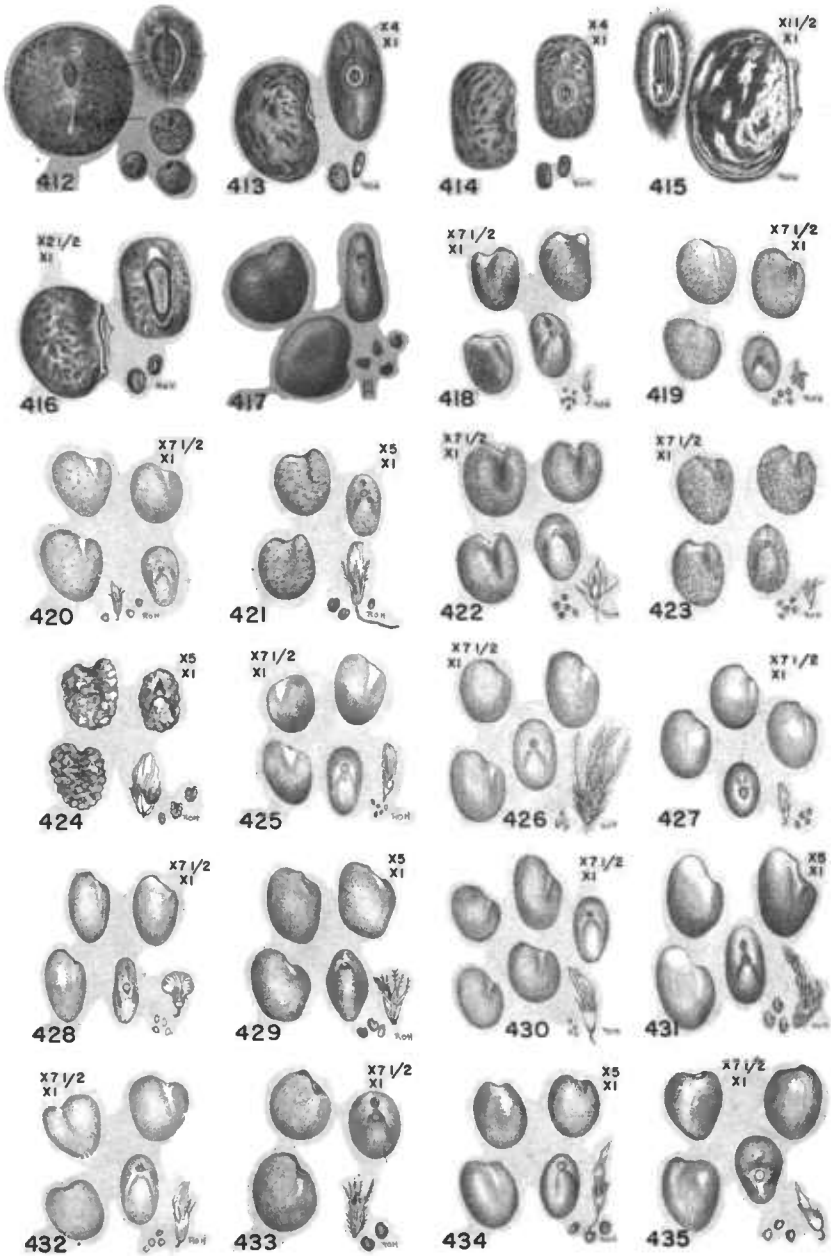
Leguminosae (364–387)

364. *Cassia nictitans*
365. *Cassia tora*
366. *Cicer arietinum*
367. *Coronilla scorpioides*
368. *Coronilla varia*
369. *Crotalaria intermedia*
370. *Crotalaria lanceolata*
371. *Crotalaria mucronata* (*C. striata*)
372. *Crotalaria spectabilis*
373. *Cyamopsis tetragonoloba*
374. *Daubentonia texana*
375. *Desmodium tortuosum*
376. *Galega officinalis*
377. *Glycine max*
378. *Hedysarum coronarium*
379. *Hoffmanuseggia sp.*
380. *Indigofera hirsuta*
381. *Lathyrus aphaca*
382. *Lathyrus hirsutus*
383. *Lathyrus sylvestris*
384. *Lathyrus tingitanus*
385. *Lathyrus tuberosus*
386. *Lespedeza striata*
387. *Lespedeza striata* (Kobe)



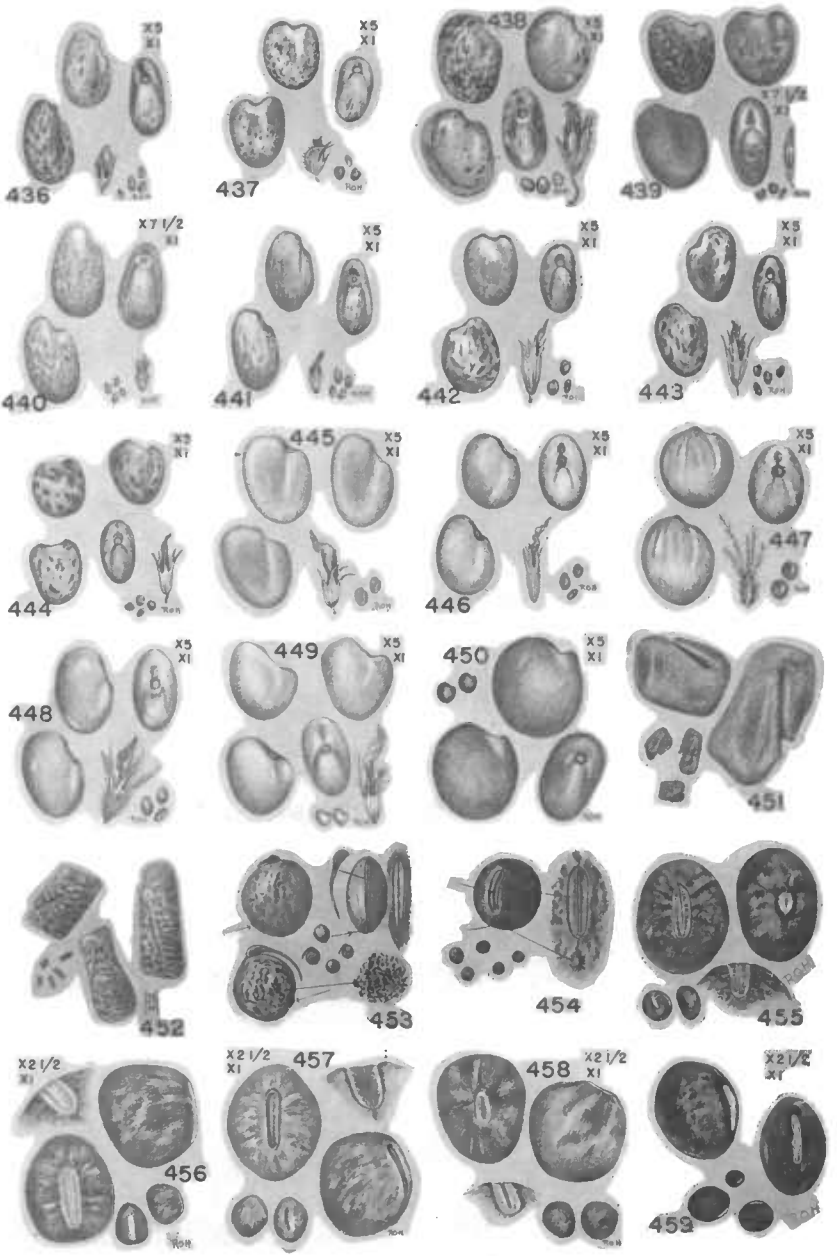
Leguminosae (388–411)

388. *Lespedeza stipulacea*
389. *Lespedeza cuneata*
390. *Lotus angustissimus*
391. *Lotus corniculatus*
392. *Lotus hispidus*
393. *Lotus purshianus* (*L. americanus*)
394. *Lotus uliginosus* var. *xillosus*
395. *Lotus uliginosus* var. *glabriusculus*
396. *Lupinus augustifolius*
397. *Lupinus luteus*
398. *Medicago arabica*
399. *Medicago hispida*
400. *Medicago lupulina*
401. *Medicago orbicularis*
402. *Medicago sativa*
403. *Medicago tuberculata*
404. *Melilotus alba*
405. *Melilotus officinalis*
406. *Melilotus indica*
407. *Onobrychis viciaefolia*
408. *Ononis repens*
409. *Ornithopus sativus*
410. *Phaseolus angularis*
411. *Phaseolus aureus*



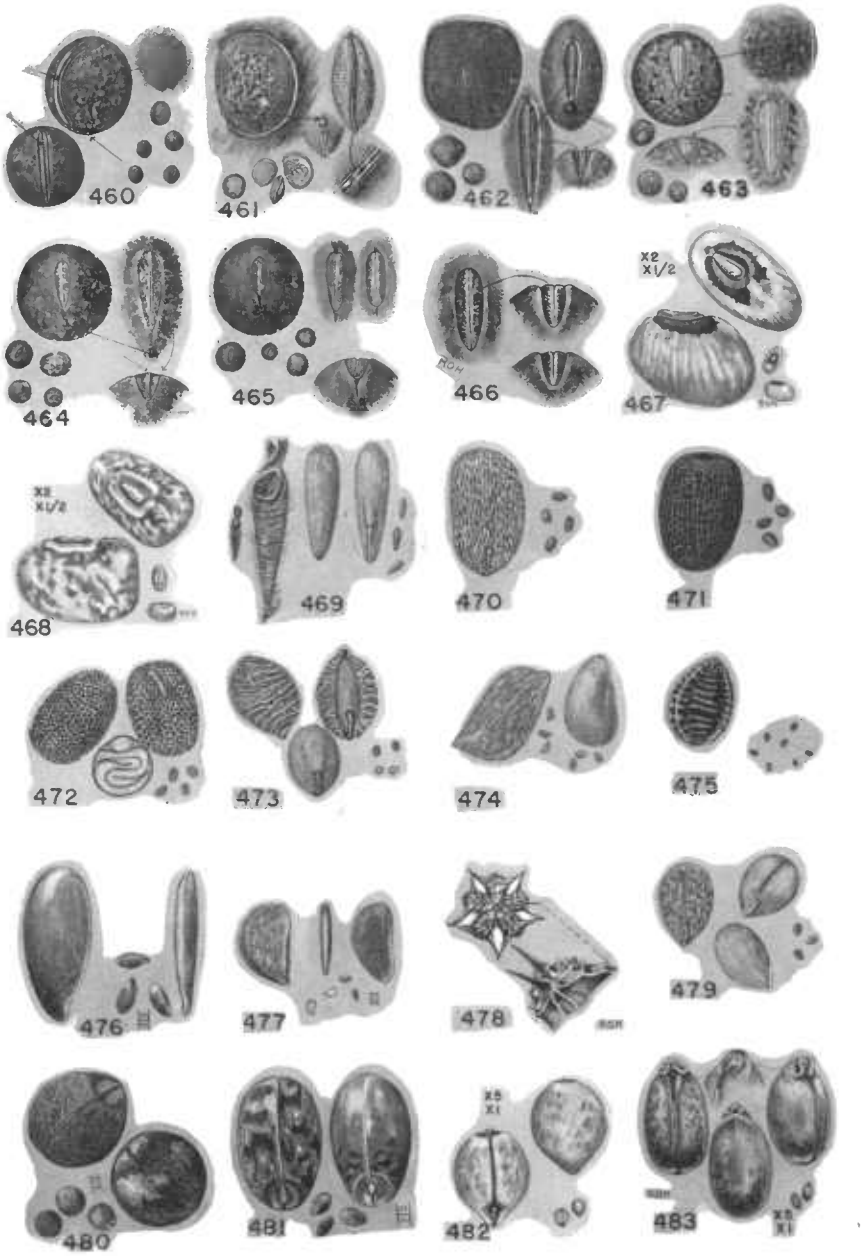
Leguminosae (412–435)

412. *Pisum satirum* var. *arrense*
413. *Pueraria thunbergiana*
414. *Sesbania exaltata*
415. *Stizolobium deeringianum*
416. *Strophostyles leiosperma* (*S. pauciflora*)
417. *Swainsona salsula*
418. *Trifolium angulatum*
419. *Trifolium glomeratum*
420. *Trifolium cernuum*
421. *Trifolium reflexum*
422. *Trifolium carolinianum*
423. *Trifolium parviflorum*
424. *Trifolium depauperatum*
425. *Trifolium agrarium*
426. *Trifolium arvense*
427. *Trifolium dubium*
428. *Trifolium procumbens*
429. *Trifolium lappaceum*
430. *Trifolium nigrescens*
431. *Trifolium pratense*
432. *Trifolium repens*.
433. *Trifolium striatum*
434. *Trifolium michelianum*
435. *Trifolium resupinatum*



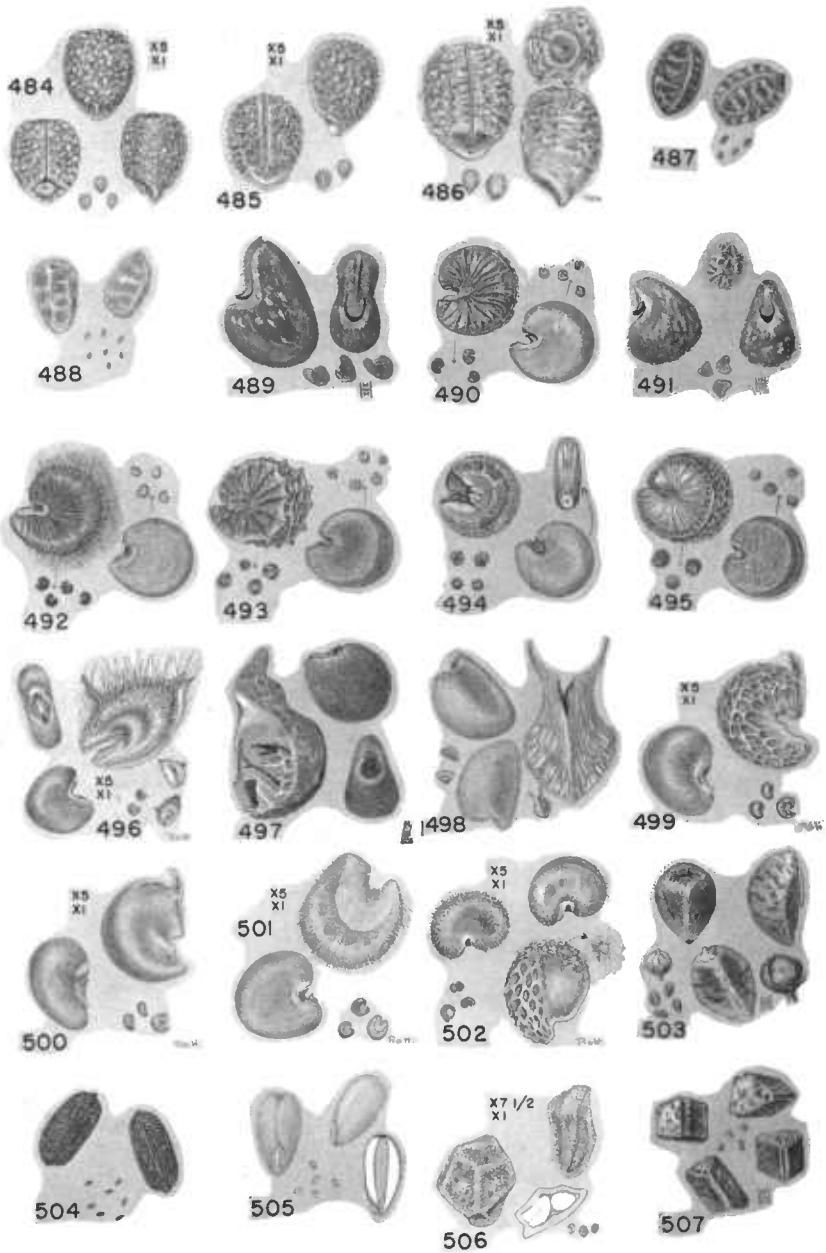
Leguminosae (436–459)

436. *Trifolium bifidum*
437. *Trifolium fragiferum*
438. *Trifolium gracilentum*
439. *Trifolium hybridum*
440. *Trifolium microcephalum*
441. *Trifolium microdon*
442. *Trifolium tridentatum*
443. *Trifolium variegatum*
444. *Trifolium wildenorii*
445. *Trifolium ambiguum*
446. *Trifolium alexandrinum*
447. *Trifolium hirtum*
448. *Trifolium incarnatum*
449. *Trifolium medium*
450. *Trifolium subterraneum*
451. *Trigonella foenum-graecum*
452. *Trigonella polycerata*
453. *Vicia hirsuta*
454. *Vicia tetrasperma*
455. *Vicia pannonica*
456. *Vicia melanops*
457. *Vicia lutea*
458. *Vicia hybrida*
459. *Vicia atropurpurea*



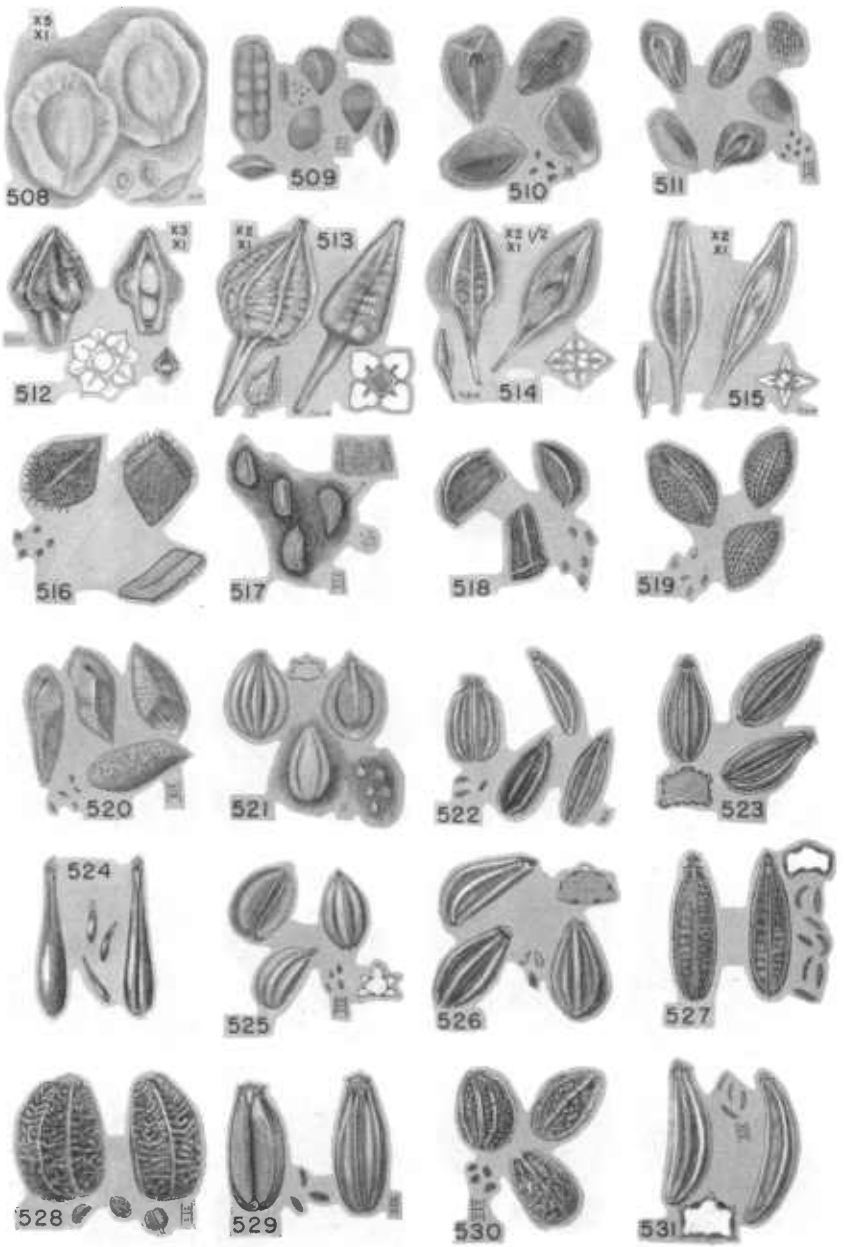
Leguminosae (460–468), Geraniaceae (469–474), Oxalidaceae (475), Linaceae (476–477), Zygophyllaceae (478), Euphorbiaceae (479–483)

460. *Vicia cracca*
461. *Vicia grandiflora*
462. *Vicia sativa*
463. *Vicia angustifolia*
464. *Vicia angustifolia*
465. *Vicia villosa*
466. *Vicia dasycarpa*
467. *Vigna sinensis* (Blackeye)
468. *Vigna sinensis* (Brabham)
469. *Erodium cicutarium*
470. *Geranium carolinianum*
471. *Geranium columbinum*
472. *Geranium dissectum*
473. *Geranium molle*
474. *Geranium pusillum*
475. *Oxalis stricta*
476. *Linum usitatissimum*
477. *Linum virginianum*
478. *Tribulus terrestris*
479. *Acalypha virginica*
480. *Croton* sp.
481. *Eremocarpus setigerus*
482. *Euphorbia corollata*
483. *Euphorbia esula*



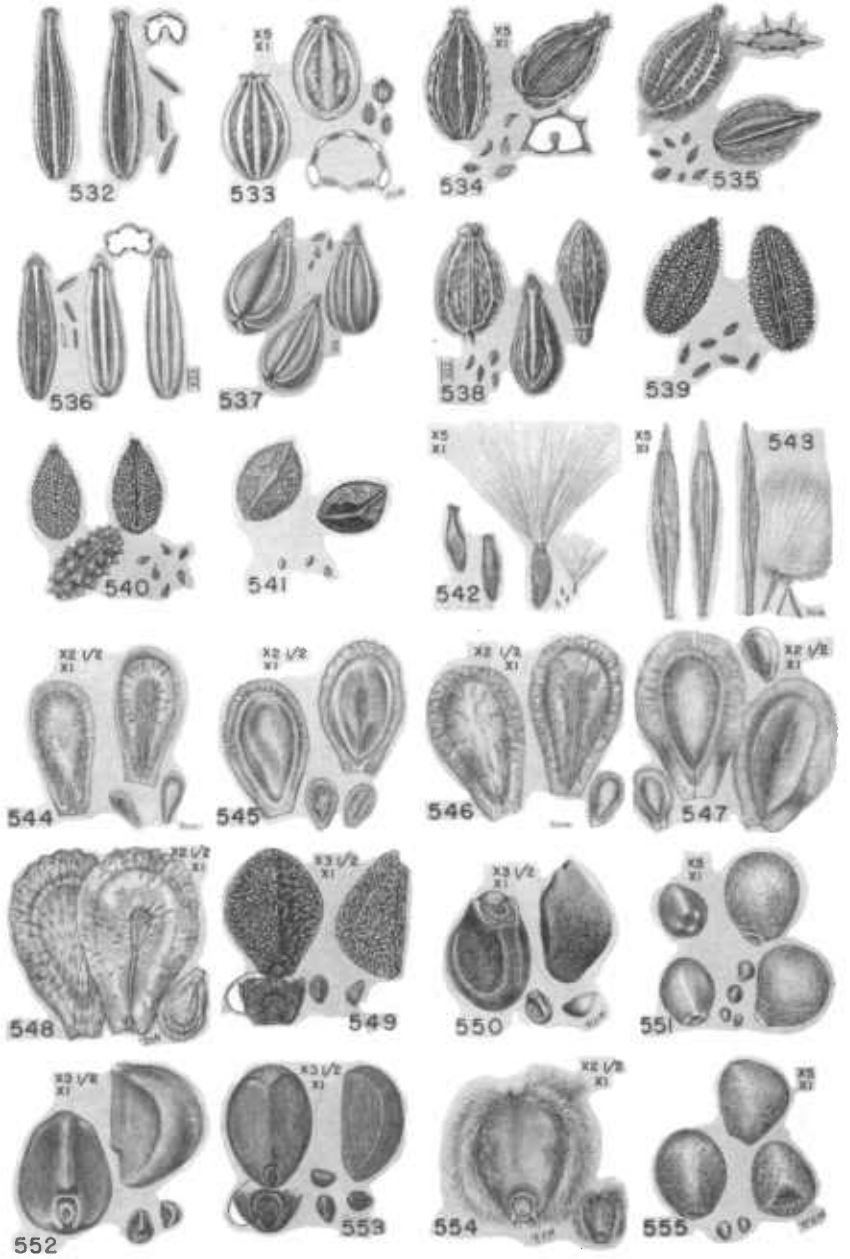
Euphorbiaceae (484–488), Malvaceae (489–502), Sterculiaceae (503), Hypericaceae (504), Violaceae (505), Loasaceae (506–507)

484. *Euphorbia dentata*
485. *Euphorbia helioscopia*
486. *Euphorbia marginata*
487. *Euphorbia nutans*
488. *Euphorbia supina*
489. *Abutilon theophrasti*
490. *Althaea hirsuta*
491. *Hibiscus trionum*
492. *Malva moschata*
493. *Malva parviflora*
494. *Malva rotundifolia*
495. *Malva sylvestris*
496. *Malvastrum coromandelianum*
497. *Sida hederacea*
498. *Sida spinosa*
499. *Sidalcea campestris*
500. *Sidalcea hendersonii*
501. *Sidopsis hispida*
502. *Sphaeralcea coccinea*
503. *Melochia corchorifolia*
504. *Hypericum perforatum*
505. *Viola tricolor*
506. *Mentzelia albicaulis*
507. *Mentzelia dispersa*



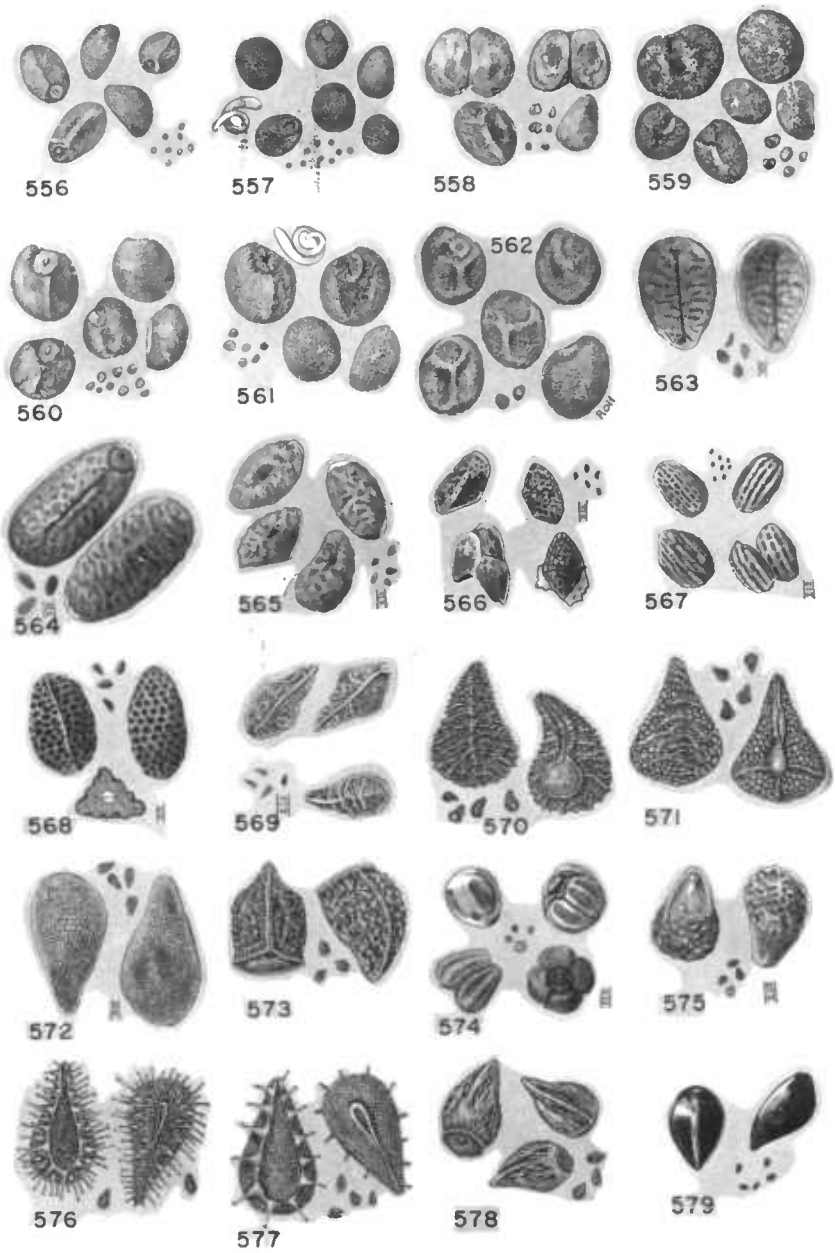
Loasaceae (508), Lythraceae (509), Onagraceae (510–520), Umbelliferae (521–531)

508. *Mentzelia nuda*
509. *Lythrum hyssopifolia*
510. *Boisduvalia densiflora*
511. *Boisduvalia stricta*
512. *Gaura coccinea*
513. *Gaura odorata*
514. *Gaura sinuata*
515. *Gaura villosa*
516. *Godetia tenella*
517. *Ludwigia alternifolia*
518. *Oenothera biennis*
519. *Oenothera laciniata*
(Raimannia laciniata)
520. *Oenothera parodiana*
521. *Aethusa cynapium*
522. *Ammi majus*
523. *Ammi visnaga*
524. *Anthriscus sylvestris*
525. *Apium ammi*
526. *Apium segetum*
527. *Bunium bulbocastrum*
(Carum bulbocastrum)
528. *Bupleurum protractum*
529. *Bupleurum rotundifolium*
530. *Bupleurum tenuissimum*
531. *Carum carvi*



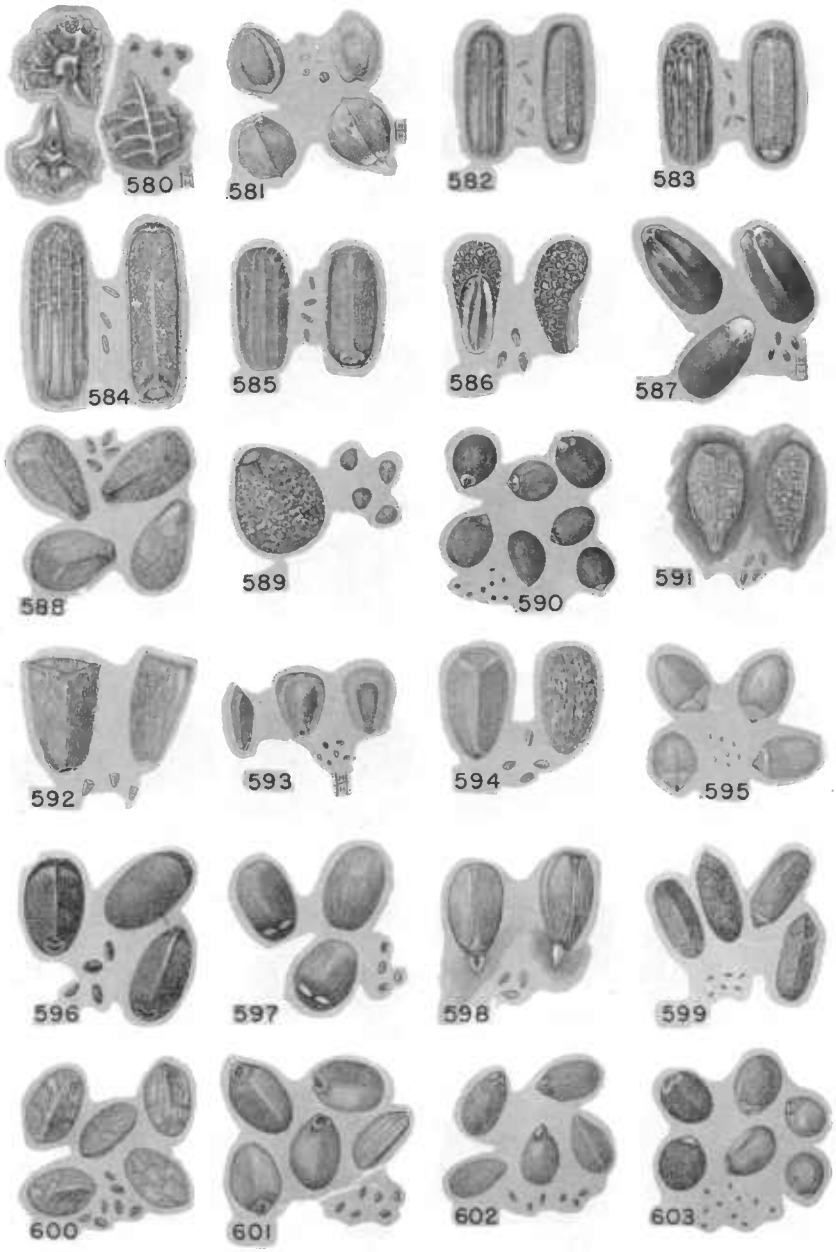
Umbelliferae (532–540), Primulaceae (541), Apocynaceae (542–543), Asclepiadaceae (544–548), Convolvulaceae (549–555)

532. *Chaeraphyllum* sp.
533. *Cicuta maculata*
534. *Conium maculatum*
535. *Daucus carota*
536. *Falcaria rivini*
537. *Petroselinum hortense* (*P. crispum*)
538. *Pimpinella saxifraga*
539. *Torilis anthriscus*
540. *Torilis nodosa*
541. *Anagallis arvensis*
542. *Apacynum andramisaefolium*
543. *Apocynum cannabinum*
544. *Asclepias mexicana*
545. *Asclepias galioides*
546. *Asclepias syriaca*
547. *Asclepias tuberasa*
548. *Gonalobus laevis*
549. *Convolvulus arvensis*
550. *Convalvulus sepium*
551. *Dichondra repens*
552. *Ipomoea hederacea*
553. *Ipomoea purpurea*
554. *Ipamoea pandurata*
555. *Jacquemontia tamnifalia*



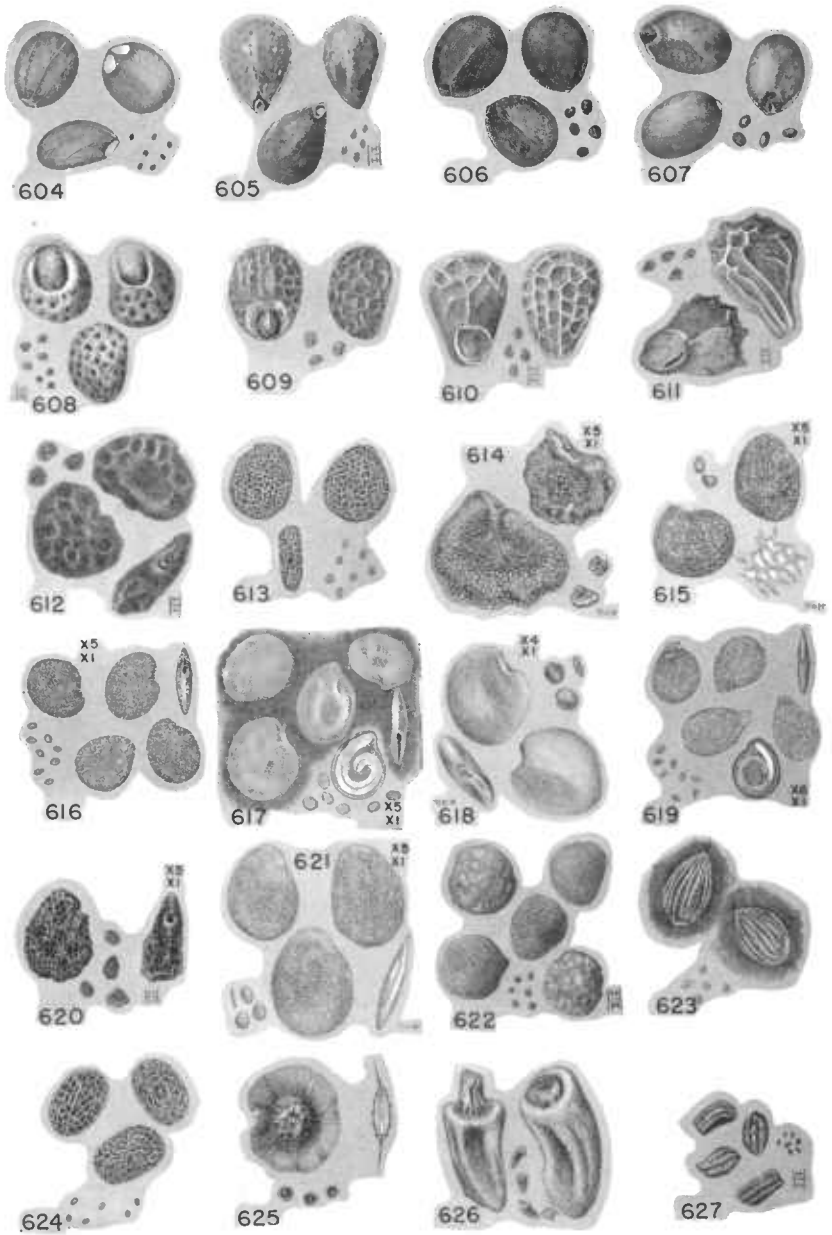
Convolvulaceae (556–562) Polemoniaceae (563–567), Hydrophyllaceae (568), Boraginaceae (569–579)

556. *Cuscuta planiflora*
557. *Cuscuta epithymum*
558. *Cuscuta epilinum*
559. *Cuscuta indecora*
560. *Cuscuta pentagona*
561. *Cuscuta racemosa* var. *chiliana*
562. *Cuscuta gronovii*
563. *Collomia gracilis*
564. *Collomia grandiflora*
565. *Gilia capitata*
566. *Navarretia intertexta*
567. *Navarretia squarrosa*
568. *Phacelia* sp.
569. *Allocarya* sp.
570. *Amsinckia intermedia*
571. *Amsinckia tesselata*
572. *Asperugo procumbens*
573. *Echium vulgare*
574. *Heliotropium curassavicum*
575. *Heliotropium europacum*
576. *Lappula echinata*
577. *Lappula occidentalis*
578. *Lithospermum arvense*
579. *Myosotis arvensis*



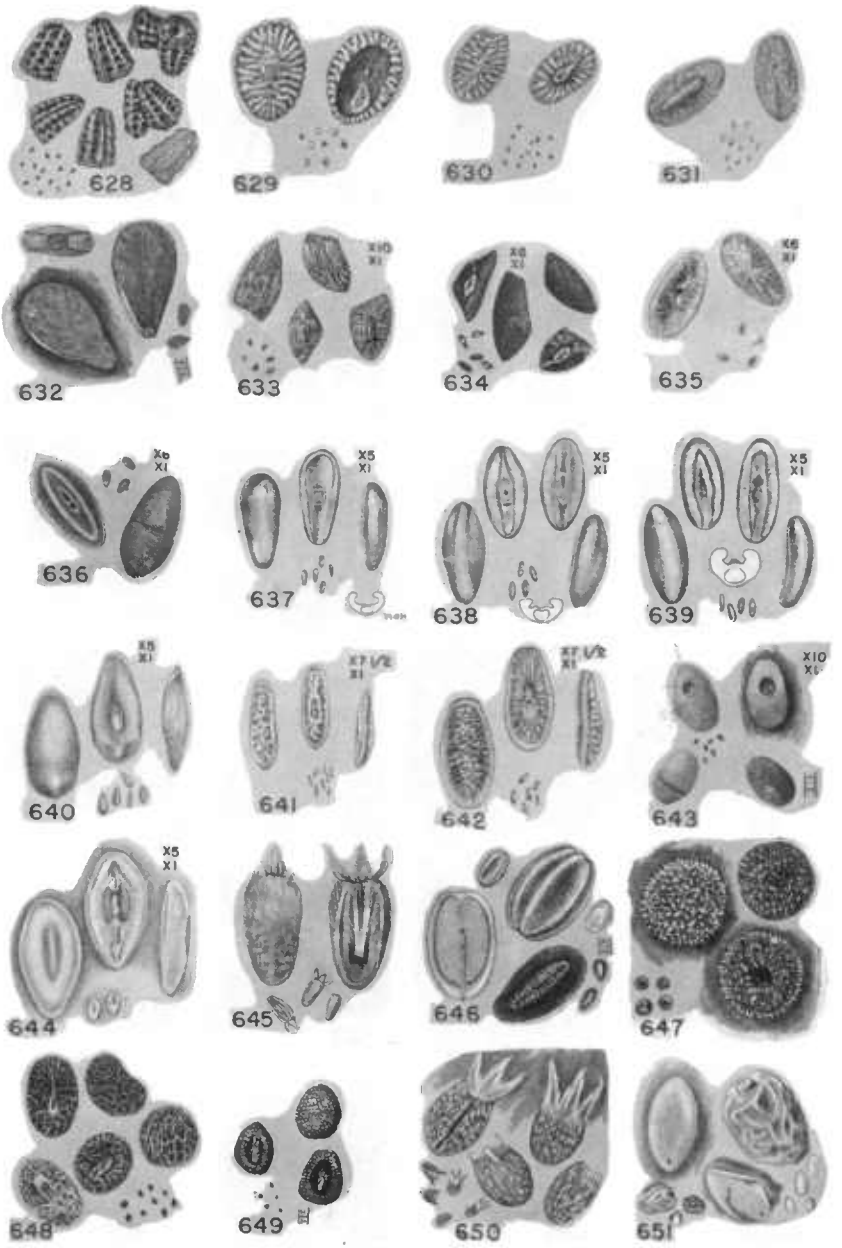
Boraginaceae (580). Verbenaceae (581–585). Labiatae (586–603)

580. *Plagiobothrys* sp.
581. *Lippia nodiflora*
582. *Verbena hastata*
583. *Verbena officinalis*
584. *Verbena stricta*
585. *Verbena urticaefolia*
586. *Ajuga chamaepitys*
587. *Ballota nigra*
588. *Galeopsis ladanum*
589. *Galeopsis tetrahit*
590. *Hedeoma pulegioides*
591. *Lamium amplexicaule*
592. *Leonurus cardiaca*
593. *Lycopus virginicus*
594. *Marrubium vulgare*
595. *Mentha arvensis*
596. *Moldavica parviflora*
597. *Nepeta cataria*
598. *Prunella vulgaris*
599. *Pycnanthemum* sp. (*Koellia* sp.)
600. *Salvia lanceolata*
601. *Salvia verticillata*
602. *Satureja acinos*
603. *Satureja nepeta*



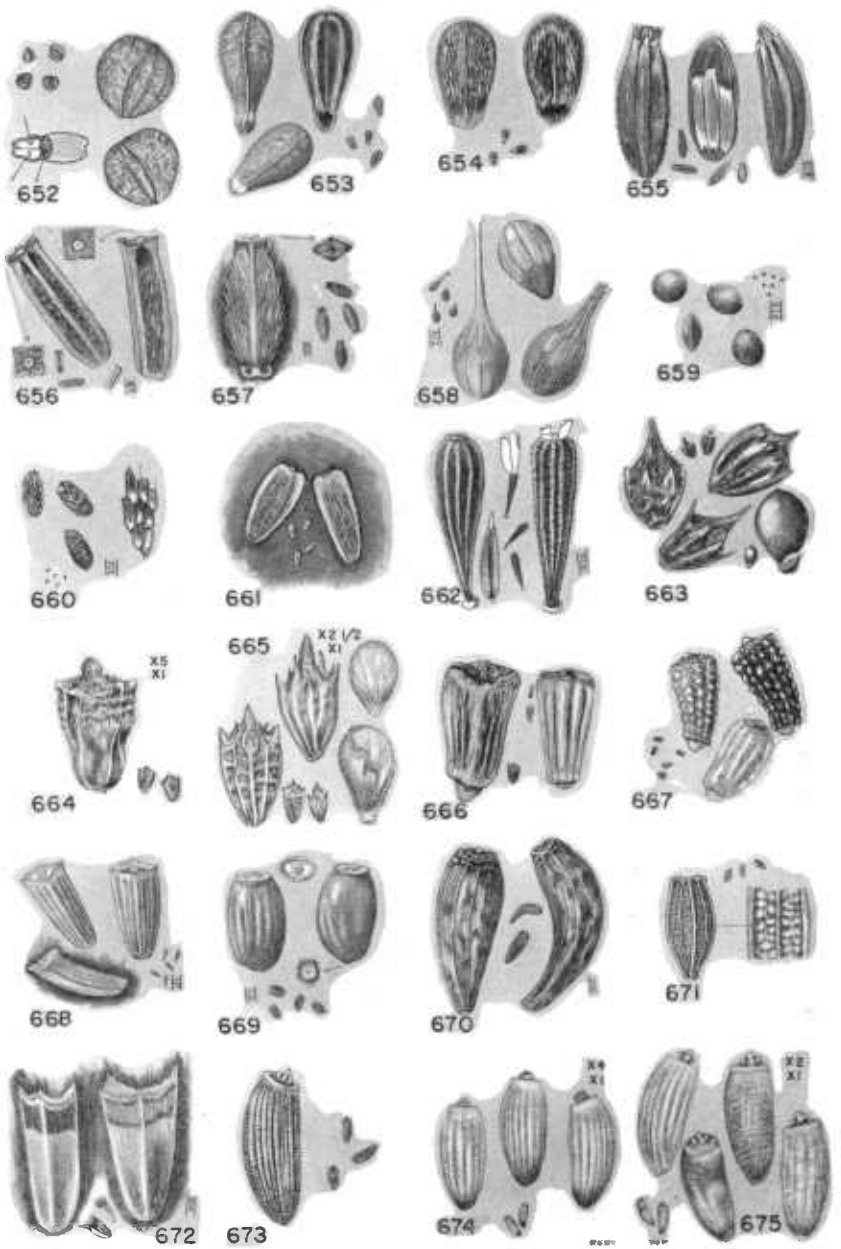
Labiatae (604–611). Solanaceae (612–622). Scrophulariaceae (623–627)

604. *Satureja vulgaris*
605. *Sideritis montana*
606. *Stachys annua*
607. *Stachys palustris*
608. *Teucrium botrys*
609. *Teucrium canadense*
610. *Trichostema dichotomum*
611. *Trichostema lanceolatum*
612. *Datura stramonium*
613. *Hyoscyamus niger*
614. *Physalis lobata*
615. *Physalis longifolia*
616. *Physalis subglabrata*
617. *Solanum carolinense*
618. *Solanum elaeagnifolium*
619. *Solanum nigrum*
620. *Solanum rostratum*
621. *Solanum triflorum*
622. "Stone cells"
623. *Euphrasia* sp.
624. *Kickxia spuria*
625. *Linaria vulgaris*
626. *Melampyrum arvense*
627. *Scrophularia marilandica*



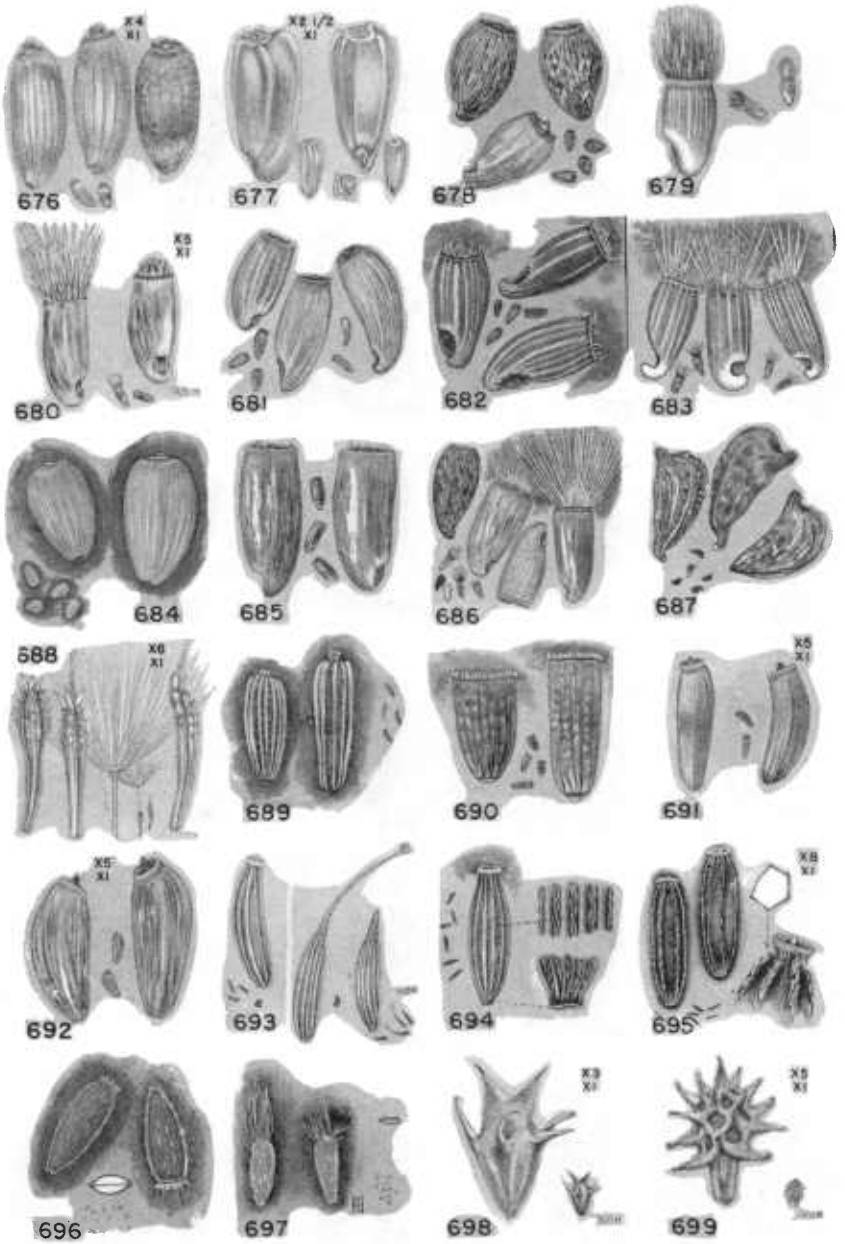
Scrophulariaceae (628–631), Pedaliaceae (632), Plantaginaceae (633–644), Rubiaceae (645–650), Caprifoliaceae (651)

628. *Verbascum thapsus*
629. *Veronica agrestis*
630. *Veronica arvensis*
631. *Veronica peregrina*
632. *Sesamum orientale*
633. *Plantago major*
634. *Plantago rugelii*
635. *Plantago virginica*
636. *Plantago aristata*
637. *Plantago psyllium*
638. *Plantago arenaria*
639. *Plantago lanceolata*
640. *Plantago rhodosperma*
641. *Plantago pusilla* (*P. elongata*)
642. *Plantago hirtella*
643. *Plantago coronopus*
644. *Plantago ovata*
645. *Diodia teres*
646. *Diodia virginiana*
647. *Galium aparine*
648. *Galium mollugo*
649. *Houstonia purpurea*
650. *Sherardia arvensis*
651. *Symphoricarpos occidentalis*



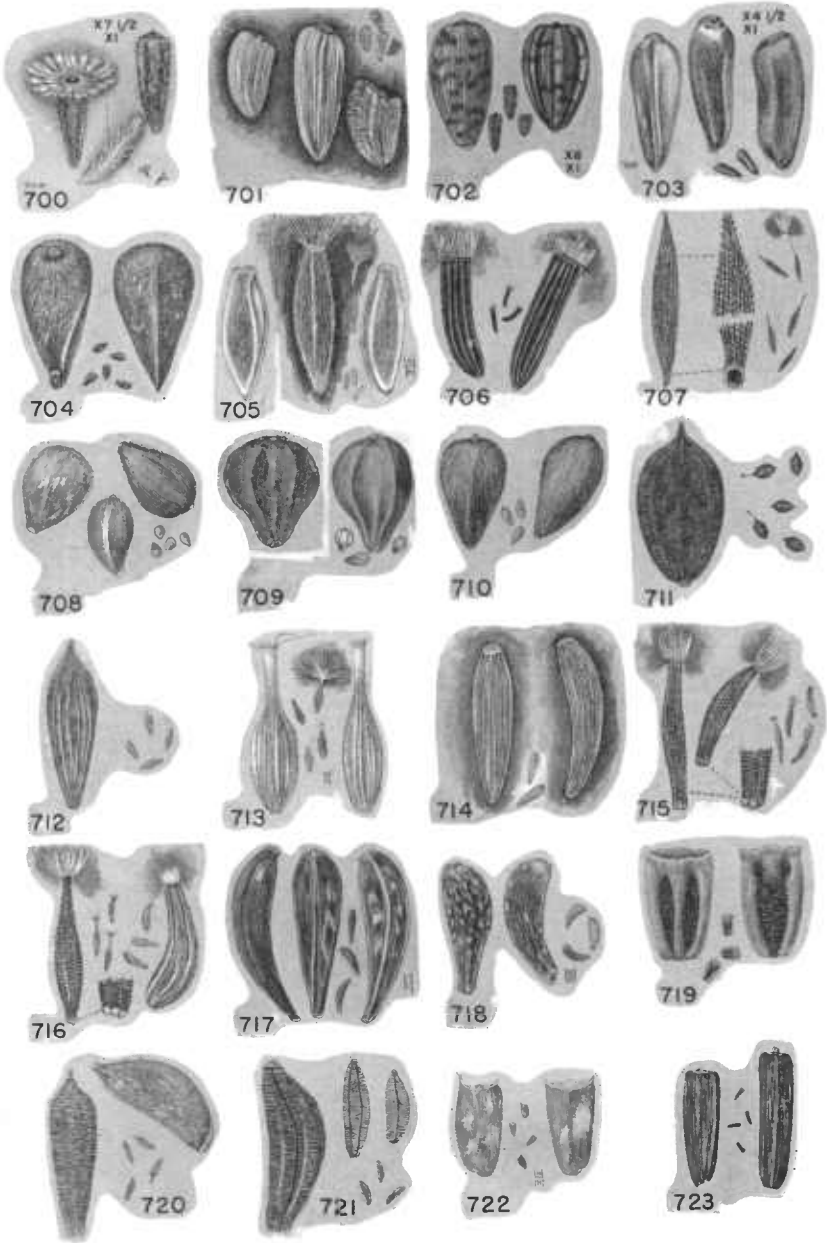
Valerianaceae (652–654), Dipsacaceae (655–658), Campanulaceae (659), Lobeliaceae (660), Compositae (661–675)

652. *Valerianella locusta* var. *olitoria*
653. *Valerianella dentata*
654. *Valerianella eriocarpa*
655. *Cephalaria transylvanica*
656. *Dipsacus sylvestris*
657. *Scabiosa arvensis*
658. *Scabiosa* sp.
659. *Specularia perfoliata*
660. *Lobelia inflata*
661. *Achillea millefolium*
662. *Achyrachaena mollis*
663. *Ambrosia artemisiifolia*
664. *Ambrosia psilostachya*
665. *Ambrosia trifida*
666. *Anthemis arvensis*
667. *Anthemis cotula*
668. *Anthemis tinctoria*
669. *Aplopappus ciliatus* (*Prionopsis ciliata*)
670. *Arctium lappa*
671. *Arnoseris minima*
672. *Brauneria angustifolia*
673. *Carduus crispus*
674. *Carduus acanthoides*
675. *Carduus macrocephalus*



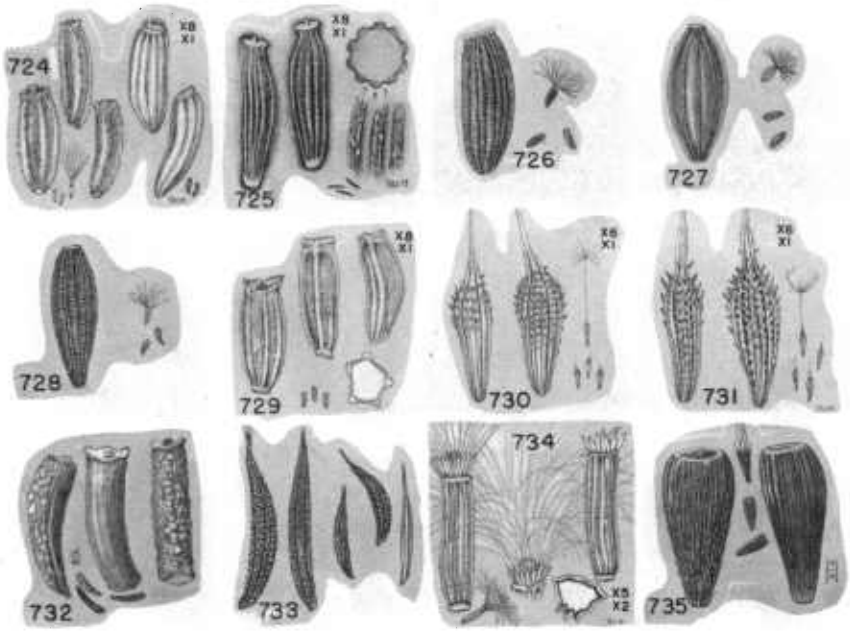
Compositae (676–699)

676. *Carduus pycnocephalus*
677. *Carthamus tinctorius*
678. *Centaurea calcitrapa*
679. *Centaurea cyanus*
680. *Centaurea iberica*
681. *Centaurea jacea*
682. *Centaurea maculosa*
683. *Centaurea melitensis*
684. *Centaurea pieris* (*C. repens*)
685. *Centaurea scabiosa*
686. *Centaurea solstitialis*
687. *Centromadia* sp.
688. *Chondrilla juncea*
689. *Chrysanthemum leucanthemum*
690. *Cichorium intybus*
691. *Cirsium arvense*
692. *Cirsium vulgare* (*C. lanceolatum*)
693. *a. Crepis capillaris*
b. Crepis setosa
694. *Erechtites hieracifolia*
695. *Erechtites prenanthoides*
696. *Erigeron annuus*
697. *Erigeron canadensis*
698. *Franseria discolor*
699. *Franseria tenuifolia*



Compositae (700–723)

700. *Galinsoga parviflora*
701. *Grindelia squarrosa*
702. *Helianthus annuus*
703. *Helianthus ciliaris*
704. *Hemizonia luzulaefolia*
705. *Heterotheca grandiflora*
706. *Hieracium aurantiacum*
707. *Hypochaeris radicata*
708. *Iva axillaris*
709. *Iva ciliata*
710. *Iva xanthifolia*
711. *Lactuca canadensis*
712. *Lactuca scariola* var. *integrifolia*
713. *Lactuca pulchella*
714. *Lapsana communis*
715. *Leontodon autumnalis*
716. *Leontodon nudicaulis*
717. *Madia glomerata*
718. *Madia sativa*
719. *Matricaria inodora*
720. *Picris echioides*
721. *Picris hieracioides*
722. *Ratibida columnaris*
723. *Rudbeckia hirta*



Compositae (724–735)

724. *Senecio jacobaea*
725. *Senecio vulgaris*
726. *Sonchus arvensis*
727. *Sonchus asper*
728. *Sonchus oleraceus*
729. *Tanacetum vulgare*
730. *Taraxacum officinale*
731. *Taraxacum erythrospermum*
732. *Thelesperma* sp.
733. *Tragopogon protensis*
734. *Vernonia noveboracensis*
735. *Xeranthemum cylindraceum*

DEVELOPMENT, STRUCTURE, AND HEREDITARY CHARACTERISTICS OF SEEDS

Our important agricultural and vegetable crops belong to two families of monocotyledons and about 15 families of dicotyledons. The monocotyledons include the grass family (Gramineae) to which belong the cereals, millets, corn, and various grasses, and the lily family (Liliaceae) to which belong onion, chives, and asparagus. The dicotyledons include the remainder of our important agricultural and vegetable crops, for example: The legume or pea family (Leguminosae); mustard or crucifer family (Cruciferae); cucurbit family (Cucurbitaceae); nightshade family (Solanaceae), to which belong tomato, potato, eggplant, and pepper; and the sunflower or composite family (Compositae). The flower, the seed, and the fruit produce new individuals, perpetuate the species, multiply the number of plants of the species, and disperse the species over a wide area.

Ovules and seeds of bluegrass and alfalfa are used to illustrate seed development in monocotyledons and dicotyledons, respectively.

THE FLOWER

A typical flower consists of a receptacle, sepals, petals, stamens, and pistil. In a complete flower, the sepals (collectively called the calyx) form the outermost whorl of flower parts, the petals (collectively called the corolla) the second whorl, the stamens the third whorl, and the pistil or pistils occupy the center of the flower. The calyx and corolla together form the floral envelope or perianth and are not essential in reproduction. The stamens and pistil bear the essential reproductive structures. The stamen consists of two parts: The stalk or filament and an anther containing one to four pollen sacs. The pistil consists of three parts: The tip or stigma, on which the pollen grains alight and germinate; the middle or elongated portion, called a style; and the enlarged basal portion, or ovary.

The ovary is the part of the pistil that contains the ovule or ovules which develop into seeds. The surfaces or areas at which the ovules are attached are known as the placenta. The attachment (placentation) may be to the walls of the ovary (parietal), to a stalklike structure extending up through the center of the ovary (axial and free central), or a single ovule may be attached at the base of the ovary (basal). The young ovule consists of nucellus (a mass of cells which originate as a protrusion of the placenta) surrounded by one or two layers of tissue called integuments (pl. XXXV, *A*).

DEVELOPMENT OF THE OVULE

A specialized cell in the nucellus of the ovule becomes directly or through division the megaspore mother cell. This cell has each chromosome in duplicate (the diploid number or 2n). The spore

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mother cell undergoes two successive cell divisions (meiosis) forming four megaspores, each with a single complement of chromosomes (n). It is during the first division of the spore mother cell into two daughter cells that the chromosome number is reduced to the haploid number (n), or a single complement. Only one of the four megaspores persists, the upper three gradually disappearing while the other enlarges (pl. XXXV, *A*). This cell (megaspore) undergoes a series of three divisions producing an eight-celled structure, called female gametophyte (pl. XXXV, *B*).

Actually the eight nuclei are usually not separated by cell walls; nevertheless they are referred to as cells. Four of these three nuclei or cells lie toward the chalazal end (position on the ovule where the integuments blend with its other parts) and four toward the micropylar end of the embryo sac. One cell from each end moves toward the center, the two being called the polar nuclei. They lie in close contact, usually without fusing, until the time of fertilization. The three cells toward the chalaza are referred to as antipodal cells. In some species there are six or more antipodal cells. The center of the three cells toward the micropyle is the egg cell or megagamete and the two cells near it are called synergids or helper cells. The latter two gradually disappear. At this stage the egg cell is ready for fertilization by a sperm nucleus.

DEVELOPMENT OF THE POLLEN GRAIN AND THE GENERATIVE CELLS

While the above-mentioned changes are taking place in the ovule a similar reduction division is going on in the pollen sac. Here, specialized cells, called microspore mother cells, go through two successive divisions resulting in four young pollen grains (microspores), each with the reduced number (n) of chromosomes. Unlike the situation in the megaspores where only one is functional, each of the four pollen grains is capable of germinating and effecting fertilization. The mature pollen grain or male gametophyte contains a tube nucleus and a generative nucleus.

FERTILIZATION

Subsequent to pollination the mature pollen grain germinates producing a pollen tube which penetrates the style and makes its way into the ovary and finally penetrates the embryo sac. During this time the generative nucleus divides to form two sperm nuclei which move through the pollen tube into the embryo sac. One sperm nucleus unites with the egg nucleus (each with n chromosomes) to form the one-celled embryo with 2n chromosomes. At about the same time there is also a fusion of the other sperm nucleus with the two polar nuclei, each with n chromosomes, to form the 3n endosperm nucleus (pl. XXXV, *C*, *D*). The fusion of one sperm nucleus with the egg cell and the other sperm with the two polar nuclei is commonly known as double fertilization.

TYPES OF OVULES

Such exterior markings of seeds as hilum, micropyle, chalaza or strophiole, and raphe result from the type of ovule and are useful in

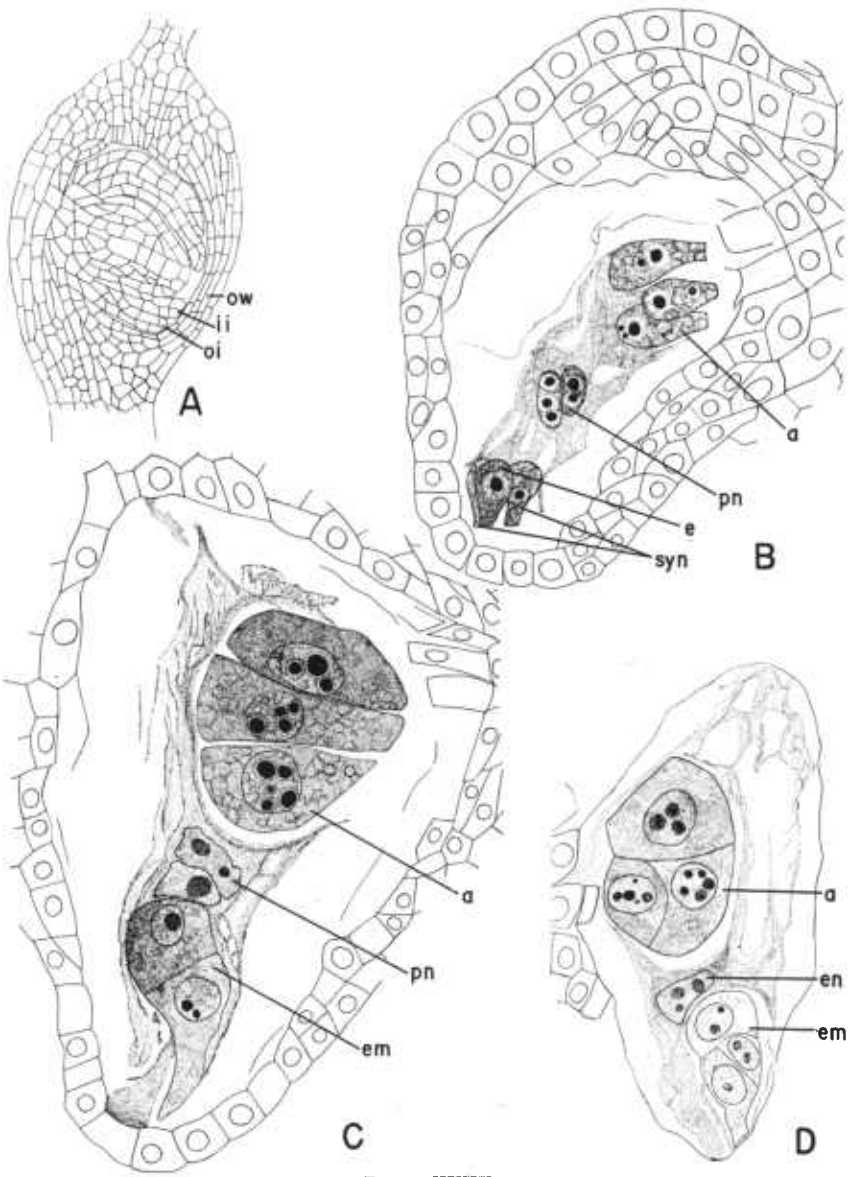


PLATE XXXV

DEVELOPMENT OF THE EGG CELL IN BLUEGRASS

A.—Poa pratensis. Longitudinal section of an immature ovary, showing the ovule attached to the placenta of the ovary wall; the ovule consists of a nucellus having four linear megaspores surrounded by two integuments; the inner and outer integuments each consisting of two layers of cells. × 210

B.—Poa compressa. Longitudinal section of the eight-celled female gametophyte surrounded by the nucellus showing the egg cell or megagamete and two synergids toward the micropyle; two polar nuclei at the center; three antipodals toward the chalaza. × 500

C.—Poa compressa. Longitudinal section of the embryo sac showing a two-celled embryo toward the micropyle; two polar nuclei at the center; three antipodals toward the chalaza. × 500

D.—Poa compressa. Longitudinal section of the embryo sac showing a three-celled embryo toward the micropyle; endosperm nucleus at the center; three antipodals toward the chalaza. × 500

Abbreviations: *a*, antipodals; *c*, egg cell or megagamete; *em*, embryo; *en*, primary endosperm nucleus; *ii*, inner integument; *oi*, outer integument; *ow*, ovary wall or pericarp; *pn*, polar nuclei; *syn*, synergids.

the identification of seeds. As the ovule develops into a seed it may assume one of four positions in respect to its attachment to the placenta. Before describing these types of ovules, some of the technical terms to be used will be defined. The terms "nucellus," "chalaza," and "integuments" have already been introduced. The funiculus is the stalk by which the ovule is attached to the placenta. The raphe is a ridge along one side or edge of some seeds caused by nondivergence of the funiculus with the integuments of an inverted ovule. The hilum is a scar on the seed caused by breaking of the funiculus or seed stalk when the seeds are shed or threshed. The micropyle is the pore extending from the nucellus through the integuments.

An *orthotropous* or straight ovule extends in a straight line from the funiculus, the micropyle and funiculus being on opposite ends of the ovule and seed. Buckwheat and rhubarb seeds are examples of this type of ovule. In the *anatropous* or inverted ovule the nucellus and integuments are inverted alongside the stalk or the funiculus, the micropyle being directed toward the placenta. The integuments remain adnate to the funiculus, thus forming the raphe. Cotton and okra are examples of this type of ovule. The *hemitropous* or half-inverted ovule differs from the *anatropous* type in that the funiculus is adnate to the integuments for only about one-half the distance of the ovule or seed, as in the common mallow. The *campylotropous* or curved ovule is intermediate between the anatropous and orthotropous types. The nucellus grows more on one side than the other forming a kidney-shaped ovule or seed in which the micropylar end is brought down close to the funiculus, as in the clovers, alfalfa, bean, and other legumes (pl. XXXVI, *A*).

DEVELOPMENT OF THE SEED IN MONOCOTYLEDONOUS PLANTS

In the Gramineae (grains and grasses) the so-called seed is a caryopsis or fruit (disregarding the glumes, lemma, and palea). However, the seed of the Liliaceae (onion and asparagus) is a true seed.

EMBRYO

After fertilization the first division of the one-celled embryo of the Gramineae is transverse resulting in a two-celled embryo. There is rapid cell division resulting in a club-shaped embryo (fig. 64, *A*, *B*, *C*, *D*). A lateral notch is first differentiated, in the club-shaped embryo, above which the scutellum or cotyledon develops. Later protuberances or outgrowths are formed which become the coleoptile (leaf sheath) almost completely surrounding the epicotyl (fig. 64, *E*, *F*, *G*, *H*). The epicotyl soon becomes differentiated into a terminal bud and leaves (fig. 65). Then the primary root and root cap, ensheathed by the coleorhiza (root sheath), are differentiated. The outermost regular layer of cells of the scutellum bordering the endosperm is termed the epithelial layer (fig. 65). In the mature embryos of wheat, corn, and oats, two or more adventitious roots arise just above the scutellar node. These are not present in the bluegrass embryos.

ENDOSPERM

The endosperm nucleus undergoes division at about the same time as does the embryo. At first free nuclear division occurs which soon becomes cellular; then cell division is active throughout, but later it is localized to the outer or peripheral region. The outermost layer of endosperm is called the aleurone layer.

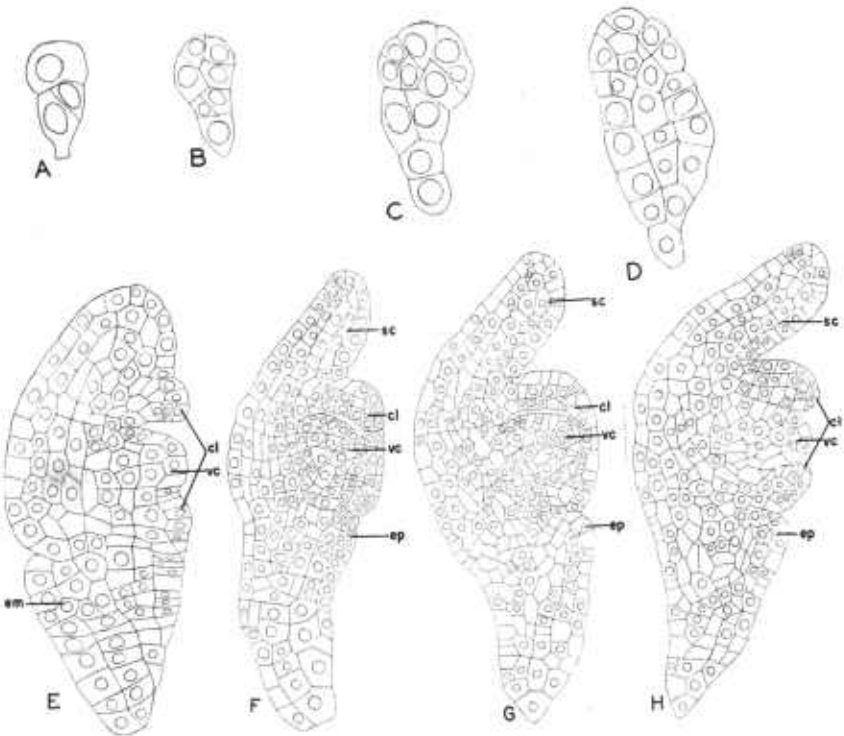


FIGURE 64.

A.—Poa compressa. Longitudinal section of a young embryo composed of 3 cells. × 310

B.—Poa compressa. Longitudinal section of a young embryo composed of 9 or more cells. × 310

C.—Poa pratensis. Longitudinal section of a young embryo composed of 14 or more cells. × 310

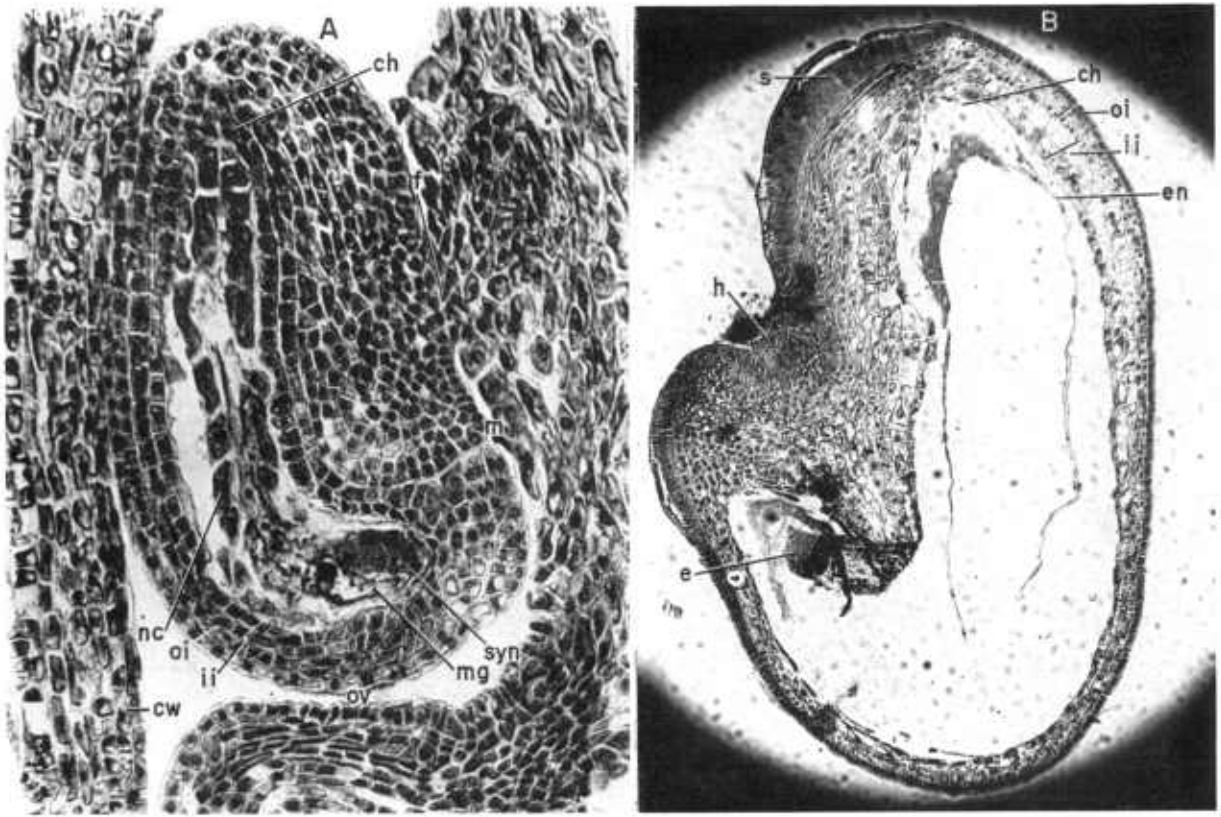
D.—Poa pratensis. Longitudinal section of a young embryo showing indentation which indicates outgrowths above and below it. × 310

E.—Poa compressa. Longitudinal section of a young embryo. The two outgrowths are rudiments of the coleoptile surrounding the vegetative cone, plumule, or epicotyl. A smaller embryo lies over the lower half of the larger embryo. × 310

F.—Poa compressa. Longitudinal section of a young embryo. The coleoptile appears to surround completely the vegetative cone or epicotyl. The epiblast is beginning to be differentiated. ×310

G., H.—Poa compressa. Two consecutive longitudinal sections of the same immature embryo. In one section (*G*), the coleoptile appears to surround completely the vegetative cone, plumule, or epicotyl. In the following section (*H*), the coleoptile does not completely surround the epicotyl. A rudimentary epiblast and scutellum are present. × 310

Abbreviations: *cl*, coleoptile; *em*, embryo; *ep*, epiblast; *sc*, scutellum; *vc*, vegetative cone, plumule, or epicotyl.



OVULES OF ALFALFA

A.—Medicago sativa. Longitudinal section of an ovule and part of another ovule showing the ovary wall on both sides; funiculus; micropyle; chalaza; nucellar cells; egg cell; or magagamete; one of the two synergids; inner and outer integuments each consisting of two or more rows of cells. × 600

B.—Medicago sativa. Longitudinal section of an ovule showing a young embryo with a narrow peripheral band of free nuclear endosperm (torn in sectioning); hilum; chalaza; inner and outer integuments. × 180

Abbreviations: *ch,* chalaza; *cw,* carpel wall or ovary wall; *e,* embryo; *cn,* endosperm; *f,* funiculus; *h,* hilum; *ii,* inner integument; *m,* micropyle; *mg,* megagamete or egg cell; *nc,* nucellar cells; *oi,* outer integument; *ov,* ovule; *s,* strophiole; *syn,* synergids.

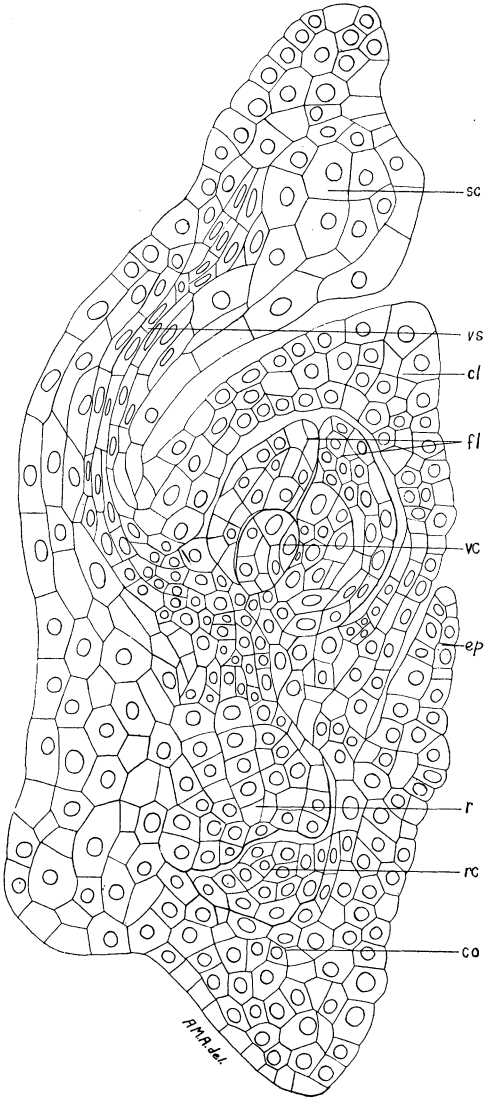


FIGURE 65

Poa pratensis. A composite drawing of successive longitudinal sections of a mature embryo, showing scutellum with a rather poorly defined epithelial layer and with a procambium vascular strand; vegetative cone or epicotyl with the terminal bud and two or three leaves differentiated; coleoptile or sheath surrounding the plumule or epicotyl; primary root terminated by a root cap; the coleorhiza surrounding the root and root cap; epiblast. × 280
Abbreviations: *cl,* coleoptile; *co,* coleorhiza; *ep,* epiblast; *fl,* foliage leaves; *r,* radicle or primary root; *rc,* root cap; *sc,* scutellum; *vc,* vegetative cone, plumule or epicotyl; *vs,* vascular strands.

INTEGUMENTS (SEED COATS) AND OVARY WALL (PERICARP)

The seed coat consists of an ovary wall adnate to the two integuments. In the young fruit (fig. 66, *A*, *B*) the ovary wall consists of an outer row of epidermal cells, four or five rows of starch-containing parenchyma cells and an inner row of chlorophyll-containing cells. The green color of developing and fresh mature seed is attributed to the chlorophyll layer. Each of the two integuments consists of two

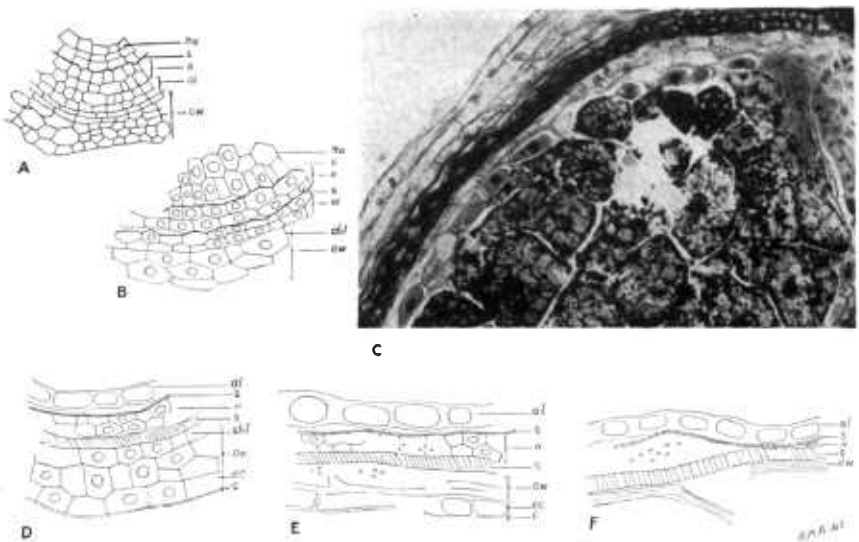


FIGURE 66

A.—Poa pratensis. A portion of a longitudinal section of a very young ovule, showing nucellus; inner integument composed of two rows of cells and its inner wall slightly suberized; outer integument composed of two rows of cells; ovary wall of about five rows of cells, of which the inner layer is the chlorophyll layer. × 310

B.—Poa pratensis. A portion of a longitudinal section of a young ovule, showing nucellus; two integuments, of which the inner layer of the inner and of the outer integuments are slightly suberized; and a part of the cells of the ovary wall. × 310

C.—Poa compressa. Photomicrograph of a portion of a longitudinal section of an immature ovule, showing aleurone cells with thin walls; one or two rows of nucellar cells; inner walls of inner integument suberized; a layer of suberin as the only remnant of the outer integument; ovary wall. × 310

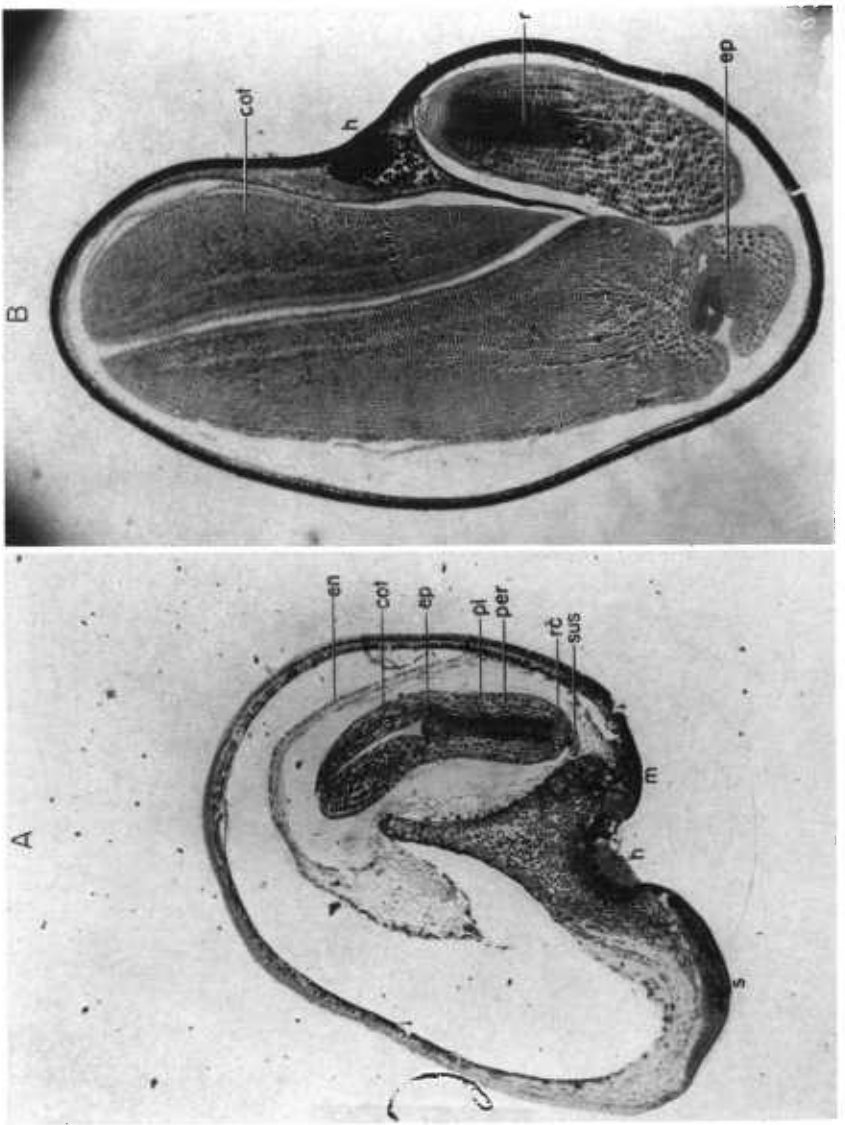
D.—Poa compressa. A portion of a longitudinal section of a slightly older ovule than *C*, showing aleurone cells with thin walls; inner walls of inner integument suberized; a layer of suberin as the only remnant of the outer integument; ovary wall with the epidermis slightly cutinized. × 310

E.—Poa compressa. A portion of a longitudinal section of an ovule almost mature, showing aleurone cells with thick cell walls; inner integument with its inner walls suberized, cells less turgid, somewhat shrunken and collapsed, containing some starch; ovary wall cells beginning to collapse. × 310

F.—Poa compressa. A portion of a longitudinal section of a mature ovule, showing aleurone cells with thick walls; cells of inner integument compressed, and inner layer suberized; outer integument only a thick layer of suberin; ovary wall cells crushed and compressed into a thin layer. × 310

Drawings made from sections of fresh material.

Abbreviations: *al*, aleurone cells; *chl*, chlorophyll layer; *c*, cutin; *ec*, epidermal cells; *ii*, inner integument; *nu*, nucellus; *oi*, outer integument; *ow*, ovary wall; *s*, suberin.



OVULES OF ALFALFA

A.—Medicago sativa. Longitudinal section of an ovule showing a well-developed embryo with root (plerome, periblem, root cap, and suspensor); epicotyl; cotyledons; endosperm; inner and outer integuments; hilum; strophiole. × 80

B.—Medicago sativa. Longitudinal section of a mature ovule or seed showing the embryo with portions of the two cotyledons; epicotyl with the terminal bud and one or two leaves differentiated; root differentiated into plerome, periblem, root cap and suspensor; hilum. × 60.

Abbreviations: *cot,* cotyledons; *ep,* epicotyl; *en,* endosperm; *h,* hilum; *m,* micropyle; *per,* periblem; *pl,* plerome; *r,* root; *rc,* root cap; *s,* strophiole; *sus,* suspensor.

rows of cells except toward the micropyle and chalaza where there are more layers. All the cell walls of the inner and outer integuments contain pectin and some also contain suberin.

When the caryopsis of bluegrass is fully grown and mature, the seed coats are greatly modified in regard to both structure and composition. The cells of the ovary wall are tightly compressed and disorganized. The outer walls of the epidermal layer of the ovary wall are slightly cutinized and a thick layer of suberin is formed on the inner row of cells of the outer integument. The cells of the inner integument are mainly compressed leaving a narrow band of suberin formed from their walls. The cell identity of the inner integument can be seen where the seed coat is torn (fig. 66, *C*, *D*, *E*, *F*).

The seeds of most grasses and some of the grains (oats and barley), are enclosed in one or two pairs of glumes which persist after threshing. The cell walls of the glumes usually contain such substances as lignin, suberin, and cutin in addition to pectin and cellulose which are the usual constituents of cell walls. Suberin and cutin are waxy and water repellent, therefore prevent water from entering the seeds.

DEVELOPMENT OF THE SEED IN DICOTYLEDONOUS PLANTS

The seed of commerce of most of our economic, dicotyledonous plants is either a true seed or a dry indehiscent fruit. The seed of alfalfa has been selected to represent the seed of a dicotyledonous plant.

EMBRYO

The one-celled embryo of alfalfa (*Medicago sativa*) divides transversely, thus forming a two-celled proembryo; a linear row of six cells is developed by further division. The embryo is developed from the apical cell of the six-celled proembryo whereas the remaining cells produce the suspensor. The cotyledons, epicotyl, root, and root cap are differentiated early (pl. XXXVI, *A*, *B*; XXXVII, *A*). In the mature seed the embryo, consisting of two fleshy cotyledons, a small differentiated epicotyl, and a well-developed root, practically fill the entire seed (pl. XXXVII, *B*).

ENDOSPERM

The endosperm cells develop in a free parietal layer similar to that described for bluegrass but are apparently used as food by the growing embryo prior to maturity as the mature seed contains only one or two rows of endosperm cells (pl. XXXVI, *B*; pl. XXXVII, *A*, *B*). The mature embryo consisting of a small epicotyl, two large cotyledons, a well differentiated root, and two or three rows of endosperm within the seed coat constitutes the mature seed in alfalfa and many other dicots. However, in some dicotyledonous plants (Amaranthaceae, Chenopodiaceae, Polygonaceae, and others) the endosperm develops and is present in the mature seed similar to that described for the monocotyledonous plants.

INTEGUMENTS OR SEED COATS

The seed coat consists of two integuments. The inner integument consists of two or more rows of cells and the outer integument of three or more rows (pl. XXXVI, *A*; pl. XXXVIII, *A*). The outermost cells of the outer integument in legume seeds are termed Malpighian

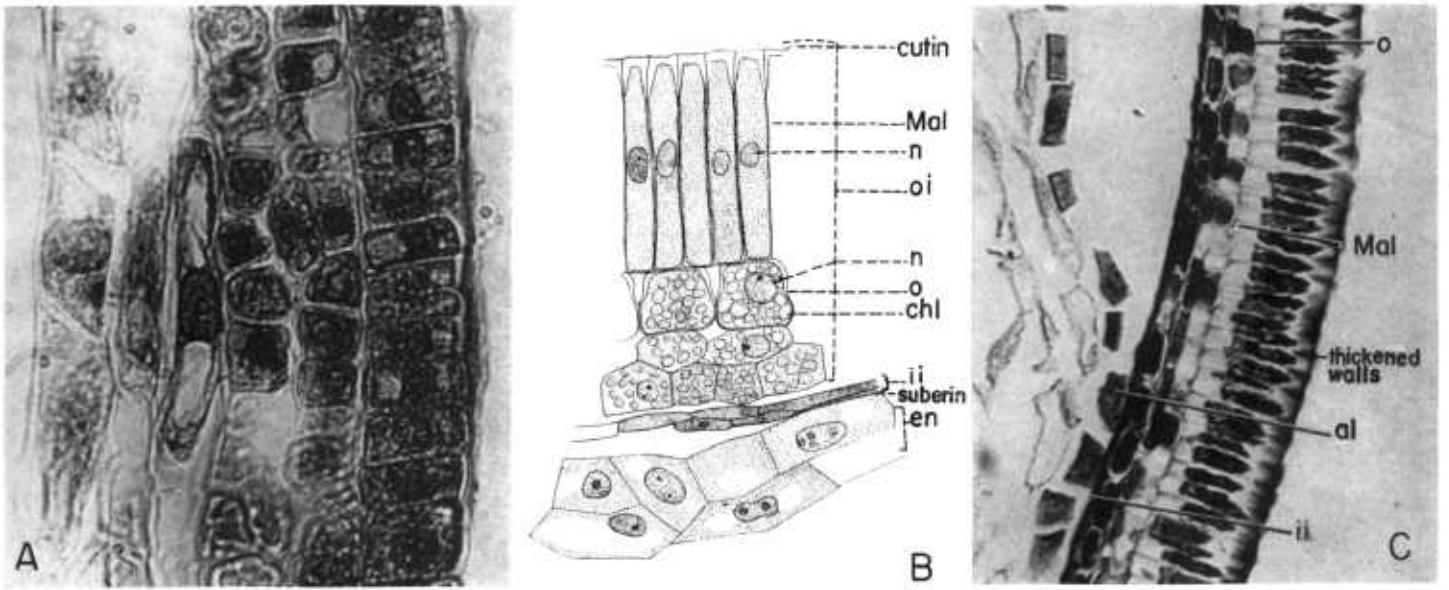
cells. The cells beneath them are the osteosclerid or hourglass cells. When the ovule is immature, as shown in plate XXXVI, *A*, all the cell walls contain pectin. In addition, a thin layer of cutin is present on the outer tangential walls of the Malpighian cells as well as a layer of suberin on the tangential walls of the innermost cells of the inner integument.

When the ovule is immature and green and the embryo is differentiated (pl. XXXVI, *B*; pl. XXXVII, *A*; pl. XXXVIII, *B*, *C*) but not fully grown, the upper parts of the radial walls and the outer tangential walls of the Malpighian cells have thickened. These thickenings appear as V-shaped plugs extending in between the cells. In the mature seeds these radial walls are not visible and appear as a continuous layer, variously referred to as the cuticularized layer and the subcuticular layer. The upper radial and outer tangential walls of the osteosclerid cells have also thickened leaving a space between the upper portions of the cells. All the cell walls of the inner and outer integuments, including the V-shaped plugs of the Malpighian cells and the thickened walls of the osteosclerid cells, contain pectin and certain walls contain cellulose. In addition, a thin layer of cutin is present on the outer tangential walls of the Malpighian cells and a layer of suberin is present on the tangential walls of the cells of the inner integument adjacent to the nucellus.

When the seed is mature and the embryo occupies practically all the space within the integuments (pl. XXXVII, *B*; pl. XXXIX, *A*, *B*) the Malpighian cell walls are greatly thickened. All the cell walls of the inner and outer integuments contain pectin and certain walls contain cellulose. A slightly thicker layer of cutin is present on the outer tangential walls of the Malpighian cells in the mature seed than in the walls of immature seed. A layer of suberin is present on the tangential walls of the cells of the inner integument adjacent to the nucellus. Suberin is also present in the so-called cones and light line. The aleurone cells in the mature seed have very thick walls which are considered mucilaginous.

The greatly thickened, cutinized, and suberized walls of the seed coats of the Leguminosae are presumably the reason for the large number of hard seeds found at the termination of the germination tests of some species of this group.

Treating mature seeds of alfalfa with a 1-percent solution of osmic acid reveals a blackened area on the other side of the hilum from which the micropyle is located. It is the portion of the seed coat covering the chalaza and is considered by some investigators to be the area where water enters, thus resulting in a permeable seed. The Malpighian cells directly covering the chalazal region is referred to by some research investigators as the strophiole and by others engaged in seed identification as the chalaza. There is a cleft in the center of this area. A section through it reveals the Malpighian cells directly beneath as very straight and the cells appear as though they might split apart quite readily when the seeds receive a sharp blow, thus resulting in a permeable seed. Whether water enters at this area (strophiole or chalaza) and not at the hilum or micropyle has not been definitely established (pl. XXXVII, *A*; pl. XXXIX, *C*). However, the hilum contains much suberin in alfalfa seed.



SEED COAT OF ALFALFA

A.—*Medicago sativa.* Portion of the seed coat enlarged from plate XXXVI, *B*. The outer integument consists of the three outermost rows of cells: Malpighian or palisade cells, osteosclerid cells and one row of parenchymatous cells. The inner integument consists of the three innermost rows of parenchymatous cells. × 1,200.

B.—*Medicago sativa.* Drawing of a longitudinal section of a young ovule of about the same age as plate XXXVII, *A*. The upper radial walls and the outer tangential walls of the Malpighian cells have thickened and appear as V-shaped plugs; the upper radial and outer tangential walls of the osteosclerid cells have thickened; and two rows of parenchymatous cells constitute the outer integument. The two rows of longer cells constitute the inner integument. Aleurone and one or two rows of endosperm cells are also visible.

C.—*Medicago sativa.* Enlarged portion of the seed coat of the longitudinal section of plate XXXVII, *A* showing the same points as stated under *B*. × 600

Abbreviations: *al*, aleurone cells; *chl*, chloroplasts; *en*, endosperm cells; *ii*, inner integument; o, osteosclerid cells; *oi*, outer integument; *Mal*, Malpighian cells; *n*, nucleus.

THE SEED

The seed may be defined as a mature ovule as distinguished from a fruit which is a mature ovary. The seed consists of an embryo with reserve food, as endosperm and nucellar tissue surrounded by one or two integuments or seed coats. However, either or both the endosperm and nucellar tissue may be lacking in which case the reserve food is contained in the cotyledons of the embryo.

The term seed has two different meanings. The botanical definition is based on structure, the seed being a product of the ovule without any additional structures. The other definition (nonbotanical) of seed is based upon the unit commonly used for planting purposes, regardless of structure. It includes the following three types of structures: (1) True seeds as indicated above, such as alfalfa and cucumber; (2) true seeds enclosed by the dry, indehiscent ovary walls (fruits), as the caryopsis in grasses and the achene in lettuce; and (3) true seeds enclosed by ovary walls, surrounded by additional structures or embedded in a mass of tissue as in New Zealand spinach and beet. The first of these three types needs no further mention as the development of the true seed (alfalfa) has been treated in detail.

The second type of "seeds," botanically referred to as single-seeded dry indehiscent fruits, includes four types as follows:

1. The seed of the entire grass family is a caryopsis. In the caryopsis the seed coat is joined to the ovary wall so firmly that they cannot be separated.

2. The achene of the buckwheat, sedge, and composite families and certain genera in other families differs from the caryopsis only in that the pericarp is attached to the seed at the base. Thus, the seed, including seed coat, can be separated from the ovary wall.

3. The fruit in parsnip, parsley, carrot, and celery and other members of the Umbelliferae is a schizocarp. The ovary of the schizocarp contains two seeds. During development of the ovary a longitudinal constriction forms between the two seeds forming two mericarps or half fruits. At maturity the mericarps split apart and are then like the achene in structure.

4. The ovary in the Boraginaceae, Verbenaceae, and Labiatae (borage, vervain, and mint families) divides longitudinally, during development, into four small nutlets, each containing a single seed.

There are a few "seeds" encountered in seed testing which consist of structures additional to single-seeded fruits. In beet there is a fusion of flower parts which enclose one to several seeds. The New Zealand spinach seed is a hard nutlet usually containing several individual seeds, surrounded by a fleshy calyx with hornlike protuberances. There are also other accessory structures which form a part of certain so-called seeds as in cocklebur, ragweed, povertyweed, sandbur, and buffalo grass.

HEREDITARY QUALITIES OF THE SEED

Through reproduction there is a transmission of life from one generation to the next. Certain traits or characteristics are passed from the parents to the offspring. It has previously been stated that the nucleus (germ plasm) of the 1-celled embryo contains 2 sets of chromosomes, 1 set with the haploid number contributed from the

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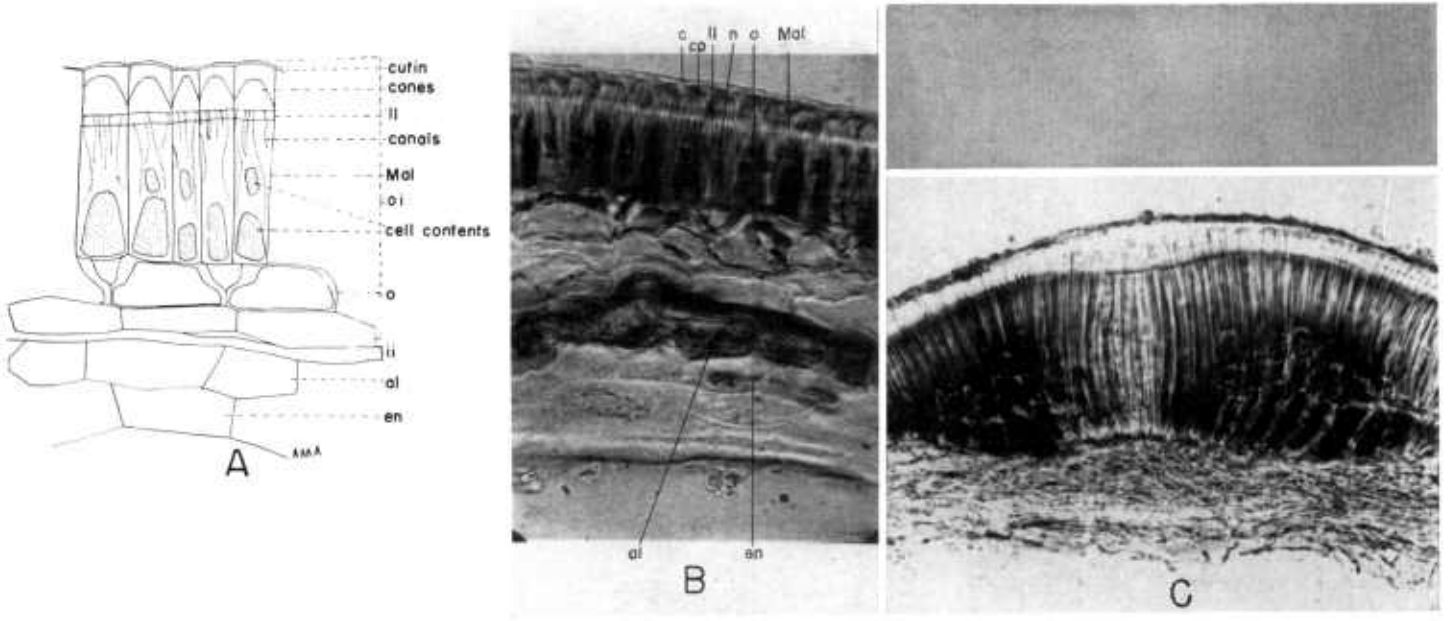
egg nucleus (7 chromosomes in peas) and 1 set, also with the haploid number, contributed by the sperm nucleus (7 chromosomes in peas). The similar chromosomes from each nucleus of the gametes pair in the nucleus of the zygote (a total of 14 chromosomes in peas). The chromosomes are carriers of genes or factors which determine hereditary characters or traits. Each pair of similar or homologous chromosomes has 2 genes which will determine a character or trait.

Mendel showed through his experiments that mating a tall pea plant with a dwarf pea plant resulted in all the plants of the first filial generation (F_1) being tall plants. All the F_1 plants have a gene for tallness and a gene for dwarfness. He called the parental trait which was expressed "the dominant trait" and the parental trait which was not expressed "the recessive trait." The F_1 plants are all tall. The phenotype or appearance is tall but their genotypic constitution is not pure for tallness because the F_1 plants possess both the dominant tall gene and the recessive dwarf gene.

Mendel showed that the F_1 hybrids were not genetically pure through self-pollination and subsequently self-fertilization. The seeds from the F_1 generation produced both tall and dwarf plants in the second filial generation (F_2). They were in the proportion of 3 dominant tall plants to 1 dwarf recessive plant. The F_2 plants were also self-pollinated. Seeds produced from the F_2 plants were grown to obtain the third filial generation of plants (F_3). All the seed from the dwarf F_2 plants produced pure recessive dwarf plants (two genes for dwarfness). The seed from the tall F_2 plants produced one-third pure tall plants (two genes for tallness) and two-thirds plants which were not pure for either the tall or dwarf trait (one gene for tallness and one gene for dwarfness). The seeds from the latter group of plants when self-pollinated produced plants in the ratio of 3 tall plants to 1 dwarf plant which was like the F_1 hybrids that produced a ratio of 3 tall plants to 1 dwarf. Since Mendel's time, other investigators have shown that genes do not always show complete dominance or recessiveness as reported in peas. The genes may be only partially or incompletely dominant and the effect of one gene may be greatly modified by another.

Such genetic principles as cross-fertilization have been used extensively by growers in the production of hybrid corn as well as by many other breeders and producers of seeds, plants, and animals. The most effective method of disease control is through breeding for resistant varieties.



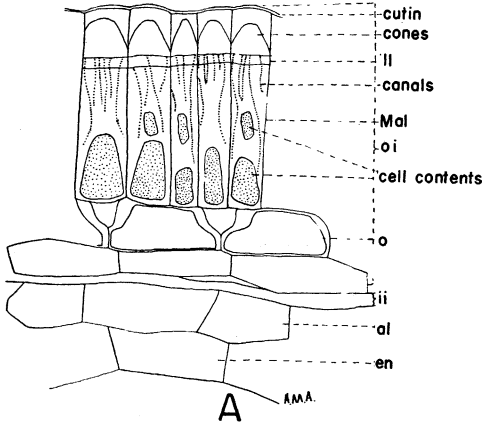
SEED COAT OF ALFALFA

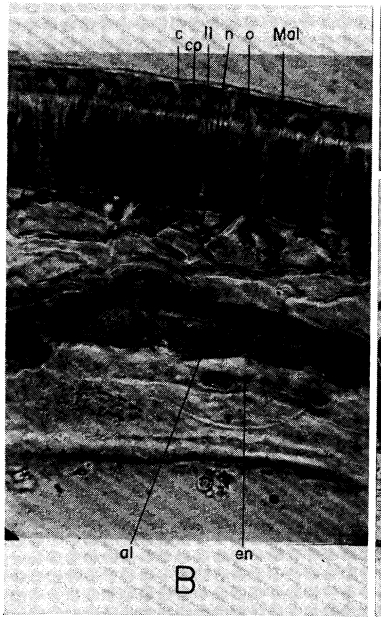
A.—*Medicago sativa.* Drawing of a portion of the seed coat from longitudinal section of a mature seed as shown in plate XXXVII, *B*. The outer integument consists of the Malpighian cells with thickened upper radial and outer tangential walls, cones, light line, cuticle and cell contents; the osteosclerid cells with thickened upper radial and tangential cell walls; and one row of parenchymatous cells. The inner integument consists of two rows of cells which are crushed into a broad band.

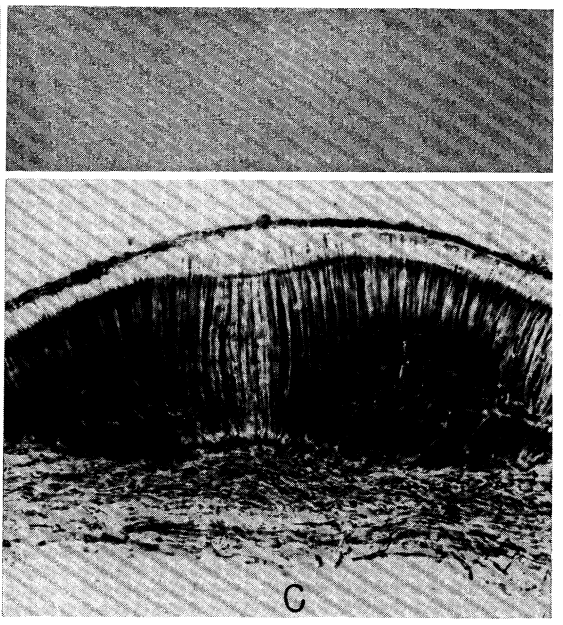
B.—*Medicago sativa.* Portion of the seed coat from a mature living seed sectioned longitudinally showing the parts as stated under *A*.

C.—*Medicago sativa.* Section through the strophiole showing the straight Malpighian cells in the center surrounded by slightly curved cells on either side. × 250

Abbreviations: *al*, aleurone cells; *c*, cutin; *co*, cones; *en*, endosperm cells; *ii*, inner integument; *ll*, light line; *Mal*, Malpighian cells; *n*, nucleus; o, osteosclerid cells; *oi*, outer integument.







SEED COAT OF ALFALFA

PLATE XXXIX

A.—*Medicago sativa.* Drawing of a portion of the seed coat from longitudinal section of a mature seed as shown in plate XXXVII, *B.* The outer integument consists of the Malpighian cells with thickened upper radial and outer tangential walls, cones, light line, cuticle and cell contents; the osteosclerid cells with thickened upper radial and tangential cell walls; and one row of parenchymatous cells. The inner integument consists of two rows of cells which are crushed into a broad band.

B.—*Medicago sativa.* Portion of the seed coat from a mature living seed sectioned longitudinally showing the parts as stated under *A.*

C.—*Medicago sativa.* Section through the strophiole showing the straight Malpighian cells in the center surrounded by slightly curved cells on either side. × 250

Abbreviations: *al,* aleurone cells; *c,* cutin; *co,* cones; *en,* endosperm cells; *ii,* inner integument; *ll,* light line; *Mal,* Malpighian cells; *n,* nucleus; *o,* osteosclerid cells; *oi,* outer integument.

PHYSIOLOGY OF SEEDS [14]

THE RESTING SEED

The resting seed of most of the economic plants contains a well-developed embryo and reserve foods stored in the endosperm or in the cotyledons of the embryo, all of which are enclosed in a more or less modified seed coat. The food reserves present in cereals and legumes are of great economic importance as they provide a large part of the food supply of the world for both humans and animals. Respiration is very low in dry resting seeds and the vital activities of the seeds have almost stopped. The seed coats are very much modified and in some kinds of seed contain impervious substances such as suberin and cutin. These substances prevent the absorption of moisture by the seed and the exchange of gases through the seed coat.

In the resting condition the seed is reasonably resistant to outside environmental conditions as long as it remains dry. This is of great economic importance, as seeds which have been harvested when ripe and kept under favorable storage conditions will retain their viability for a relatively long period and usually can be used for planting from one to several years after harvesting.

THE PROCESS OF GERMINATION

Dry seed in the resting condition requires considerable moisture before germination will take place. Under suitable moisture, temperature, and oxygen supply, the seed coat becomes softened and more permeable to water and gases such as oxygen and carbon dioxide. As water enters the embryo and endosperm the processes of digestion, respiration, and growth are begun.

DIGESTION

The food in the resting seed is in a suitable condition for storage but must be broken down through digestion before it can be used in the germination process. Digestion is the process of chemically breaking down a complex food into a simpler one. It is usually a process of hydrolysis by enzymes wherein water is chemically added to the compound and then broken down into a simpler form.

The starches are digested to sugars by the diastase enzyme system. The sugars are soluble and can diffuse from cell to cell and be assimilated or used in respiration. The fats are digested to fatty acids by the lipase enzymes, and the proteins to amino acids by the proteases before they can be moved to the growing points and used by the actively dividing cells. Assimilation is the process whereby the digested food becomes a part of the living protoplasm.

[14] This section is limited to basic background information with problems and examples taken from crop seed, whenever possible. This subject is discussed in greater detail in a book on seed physiology (Physiology of Seeds by W. C. Crocker and Lela Barton) now in press.

RESPIRATION

Respiration takes place in all living cells regardless of their state of activity or the environmental conditions which may surround them. It is the means by which organisms obtain their energy for growth and other life processes. Much of the energy produced during respiration is dissipated into the atmosphere in the form of heat. The rate of respiration in air-dry seeds is very low but does occur, and in some cases is measurable. In the case of old viable seeds which have been stored at low temperatures and under low moisture conditions, respiration may practically cease. During germination the respiration rate is high. The living protoplasm is continually active and therefore requires energy.

Most respiration in plants and animals requires the presence of free oxygen. It is a process wherein there is a chemical reduction of oxygen or some other substance by living cells, forming organic compounds and releasing energy, both of which are used in various life processes. If free or molecular oxygen is used by the living cells, the process is referred to as aerobic respiration. For example, the chemical combination of glucose sugar and oxygen yields carbon dioxide, water, and energy.

In protoplasm, the respiratory process is much more intricate than may be inferred from this statement. It involves successive reactions, each controlled by an enzyme or enzyme system. The materials from which energy is liberated are mainly the carbohydrates. The proteins are used mainly in constructive metabolism. If used in respiration, they must also be converted to carbohydrates. The fats must be converted to fatty acids and finally to carbohydrates before they are used in respiration.

Anaerobic respiration is generally considered to take place in the absence of free or molecular oxygen. It involves the partial breaking down of chemical compounds with release of energy. Anaerobic respiration commonly takes place in certain lower plants and sometimes in higher ones which are temporarily deprived of oxygen. The alcoholic fermentation of glucose, in the presence of the enzyme, zymase, yields carbon dioxide, ethyl alcohol, and energy without the addition of molecular oxygen.

EMERGENCE OF THE SEEDLING

Subsequent to the processes of metabolism the radicle emerges usually through the micropyle of the seed coat. Some seeds possess structures and secrete substances which aid in removing the seed coat during germination. These include the mucilaginous coats in flax and mustard seeds, the peg in the cucurbits, and the arched hypocotyl in cotton which lifts the convoluted cotyledons out of the seed coat.

During germination the cotyledons of some kinds of seeds remain in or on the ground, the epicotyl elongates and pushes through the soil. This type of seedling development is termed hypogeal and is found in the germination of such seeds as the grasses, cereals, peas, broad bean, runner bean, and vetches. In the germination of certain other kinds of seeds the hypocotyl elongates pushing the epicotyl and cotyledons above the ground. This type of germination is known as epigeal and occurs in beans, clovers, cucurbits, and spinach. In the germination of onion seed the cotyledon, which is the first con-

spicuous aerial part, elongates and elevates the epicotyl above ground. The epicotyl emerges through a pore or slit in the single cotyledon.

Cotyledons may serve primarily as the first leaves as in cotton, radish, and lettuce, or they may be primarily storage organs for food as in beans, peas, or peanuts. In the case of cucurbits, the cotyledons serve both as storage and photosynthetic organs.

ENVIRONMENTAL CONDITIONS AFFECTING GERMINATION

An adequate supply of oxygen and moisture and a favorable temperature are necessary for the germination of all seeds; in addition, some kinds of seeds require light. The germination of some seeds, particularly the grasses, is frequently more rapid and complete when (1) the germination substratum is moistened with a nitrate solution, (2) the glumes, palea, and lemma are removed, or (3) the test is made in light even though the species is usually not light-obligate. In studies of dormancy it is not possible to determine the stage at which after-ripening ceases and germination begins. Thus, although the factors influencing germination are discussed in systematic sequence in the pages that follow, they are also frequently referred to in the discussion of dormancy.

MOISTURE

An adequate supply of water is one of the essential requirements in the germination of seeds before growth can proceed. Water enters the seed by imbibition and is accompanied by swelling and possible rupture of the seed coat. Water is necessary for both the physical and chemical processes that occur in the germinating seeds. During imbibition the dry seed coats become softened and more permeable to water and gases. As the concentrated protoplasm becomes diluted the enzymes are activated. Water is also necessary in digesting the insoluble complex foods to soluble forms and in transporting them to the cells of the growing points of the embryo where they become assimilated into living protoplasm resulting in new growth of the tissues or are used in respiration.

TEMPERATURE

Temperature affects the rate of chemical reactions, the absorption of water, and the intake of oxygen by the seeds. In seed germination work, optimum temperatures are those at which the largest number of seeds of the particular species will grow; maximum and minimum temperatures are those above or below which the seeds will not germinate. The temperatures designated for the germination of seeds, in the rules for seed testing, are regarded as optimum temperatures.

Many kinds of seeds germinate well at constant temperatures. The small grains, vetches, clovers, radish, onion, and others germinate very well at 20° C., unless they are freshly harvested or dormant as is often the case with the small grains. Still lower constant temperatures such as 10° or 15° C. are favorable for the germination of spinach seed and possibly other kinds. High constant temperatures of 30° are favorable to a few kinds of seeds such as cucumber and watermelon, especially if the seed is freshly harvested.

Daily alternating temperatures are necessary to obtain a complete germination of many kinds of grass seeds. Alternations of 20° for 16

to 18 hours and 30° for 6 to 8 hours are also found to be favorable for the germination of seeds of many economic plants which, in nature, require warm temperatures for their growth. Examples of such seed include corn, sorghum, rice, *Brassica* species, and the cucurbits.

OXYGEN

The principal necessity of oxygen is in respiration which supplies energy to maintain life by the oxidation of foods. It has previously been stated that in its moist quiescent condition, the seed carries on respiration. When the embryo resumes growth, as in the germinating seed, respiration is greatly accelerated and oxygen is required for this increased respiration. Seed coats are more permeable to gases when moist than when dry but a film of water around the seed will retard oxygen intake to the extent that seeds fail to germinate. Hence, it is necessary to keep crop seeds moist but not wet in the germination test.

Seed of Canada bluegrass was found to give significantly higher germination results when tested in Petri dishes with the lids ajar for a part of the time each day than when the lids were left on the dishes continuously. The tests were conducted in a uniform temperature chamber, thus there should have been no great difference in temperature between the open and covered containers (Andersen, (*4*)). In laboratory practice the removal of Petri-dish lids at the time of the preliminary counts and when rewatering apparently affords sufficient aeration.

Germination is improved in some kinds of seeds, especially when dormant, by alternately moistening and drying them for about 10 days prior to germination. Griswold (*24*) has found this to be true for 4 kinds of range grasses, and Andersen (*3*) for Canada bluegrass. The alternate moistening and drying of the seeds may make the seed coats more permeable to oxygen and carbon dioxide as well as to water, especially since the seed coats are considered to be of a colloidal nature.

LIGHT

Quick-germinating seeds such as pea, bean, clover, and radish are indifferent to light, germinating equally well in the presence of light or darkness. On the other hand, the germination of some kinds of seeds is inhibited by light whereas most of the grass seeds require light to obtain a complete germination. Seeds that show increased germination when exposed to light are usually referred to as light-sensitive.

Our present knowledge of the effect of light on the germination of seeds is the result of a gradual development in research during the last 70 to 75 years. In 1881 Stebler (*43*) reported that light was effective in the germination of seed of *Poa*. A few years later Cieslar (*11*) reported that yellow light was effective in furthering the germination of grass seed whereas violet light retarded it. Kinzel (*30*) studied the effect of the different regions of the spectrum on many seeds and concluded that the long visible rays promoted germination more than the short rays. Kommerell (*32*) reported that light rays in the region of 5100 AU (Ångström units) were favorable for the germination of tobacco seed and loosestrife seed.

Flint (*22*) reported results of detailed investigations relating to the effect of light on the germination of lettuce seed in which the effects of specific wavelengths were studied. The longer wavelengths in the red, orange, and yellow regions of the spectrum, promoted germination whereas the shorter wavelengths in the green, blue, and violet regions inhibited germination. Maximum promotion of growth occurred in the orange and short red color bands and maximum inhibition of growth in the purple and blue bands. The infra-red region was even more inhibitive than were the green, blue, and violet regions.

NITRATE SOLUTIONS

Gassner (*23*) reported that Knop's nutrient solution would replace light in the germination of seeds of Pampas grass (*Chloris ciliata*). He concluded that the stimulating action was the result of the calcium nitrate in the nutrient solution and not to the nitrogen free salts such as chlorides, phosphates, and sulphates. Some investigators have made comparative tests using soil moistened with water and artificial substrata moistened with nitrogen compounds. On the basis of these investigations it is generally concluded that the soluble nitrogen compounds in the soil are responsible for the stimulating action of soil in germinating light-sensitive seeds. It has been reported that solutions of potassium nitrate were more effective than sodium or calcium nitrate in furthering the germination of *Poa* spp. whereas lead nitrate proved to be a depressant. Many nitrogen compounds (nitrates, nitrites, nitric acid, ammonium salts, urea, and thiourea) have been found to stimulate the germination of light-sensitive seeds.

Much research has been conducted to determine the optimum concentration of nitrate solutions used in moistening the substratum on which light-sensitive seeds are germinated. Tests with different concentrations of potassium nitrate have shown that the solution should be kept as dilute as possible and yet remain stimulating to the dormant seeds. Nitrate solutions may produce root injury to the seedlings, especially 1- or 2-year-old seeds or well-ripened seeds. Very short roots with few or no root hairs and inhibition of roots are symptoms of nitrate injury. Although a 0.2-percent potassium nitrate solution has been found optimum for most kinds of grasses, a 0.1-percent solution is recommended for Kentucky bluegrass seed to avoid injury to the roots. A combination of light, potassium nitrate, and alternating temperatures are necessary for complete germination of *Agrostis*, *Lolium*, *Paspalum*, and *Poa* seeds.

GLUMES (LEMMA AND PALEA) IN GRASSES

Removal of the glumes from such light-sensitive seeds as Pampas grass (*Chloris ciliata*) and *Poa* spp. has been beneficial in their germination. The seed coats or glumes increase the necessity for light. The glumes make *Chloris* light-obligate and increase the need for light in *Poa* spp. Caryopses of Canada bluegrass from which the glumes had been removed and moistened with water, gave equal results to those with glumes intact and moistened with a 0.2-percent potassium nitrate solution. Somewhat lower results were obtained when caryopses without glumes were tested in darkness.

In some instances germination is greatly accelerated if the glumes are removed. This is particularly true in the case of rescue grass (*Bromus catharticus*) and Johnson grass (*Sorghum halepense*). However, this is not regarded as sufficient reason to interfere with the normal seed structure when testing for germination. Removal of the glumes in grasses is not generally a part of the seed-testing procedure for the following reasons: (1) The glumes are difficult to remove; (2) dilute potassium nitrate solutions employed as the moistening agent, or soil tests, will supplant the removal of glumes in most instances; and (3) most seed analysts and seed control officials object to interfering with the structure of the seed unless there is no other known practical method of testing for germination.

One exception, however, has been made to this practice in the rules for seed testing. The glumes (lemma and palea) of *Paspalum notatum* are cutinized and fit together so tightly that a sharp scalpel is required to split them apart. It is presumed that water cannot readily reach the caryopsis. By removing the glumes, a high percentage of the viable seeds will germinate within approximately 10 to 14 days. When the glumes are left intact it usually requires several months for the seeds to germinate.

PHYSIOLOGY OF DORMANCY

Viable seeds of certain economic plants do not always germinate when exposed to conditions considered optimum for the particular kind being tested. They have a persistent rest period and are classified as dormant seeds. Dormant crop seeds may be attributed to the following causes: (1) Impermeable seed coats; (2) physiologically unripe or freshly harvested seeds; (3) dormant embryos; (4) immature embryos; and (5) inhibiting substances.

IMPERMEABLE SEED COATS

Seeds that do not absorb water, when placed in wet or moist surroundings, because of an impermeable seed coat are referred to as hard seeds. Practically all the hard seed encountered in testing crop seeds fall in one of the following plant families: Leguminosae, Malvaceae, Convolvulaceae, and Liliaceae. The seed coat in several genera of legumes has been studied intensively to determine the structure concerned with the intake of water and the cause of hardseededness. The impermeability of the seed coat of alfalfa, red clover, and sweetclover is believed to be due mainly to the presence of cutin and suberin in the walls of certain cells of the seed coat. Hardseededness, especially in the small-seeded legumes, is a real problem in agricultural practices. To overcome this problem seed lots of sweetclover, lespedeza, certain clovers, trefoil, and black medic are frequently passed through mechanical devices designed to scarify or chip small portions from the seed coats. These processes usually render the seed coats permeable to water, but often damage the seeds in varying percentages by breakage.

Large numbers of swollen seeds are present in some samples of subterranean clover and suckling clover when germinated at 20° C. They imbibe water but do not break the seed coat. At lower temperatures (approximately 10° for sub clover and 15° for suckling clover) few swollen seeds are present, which fact suggests that this type of dor-

mancy is due to the effect of temperature on the seed coat. Freshly harvested seed of Alyce clover (*Alysicarpus vaginalis*) requires a germination temperature of 35° C. whereas 1-year-old seed will germinate well at 30°. If the freshly harvested, swollen seeds are pierced, germination takes place immediately—a fact which also suggests that the seed coat, and not the embryo, is the cause of dormancy.

It is believed by some investigators that imbibed seeds stay dormant because oxygen does not pass through the coats sufficiently fast to permit germination of the embryos even when they have good aeration on the outside. In fact, Brown (*9*) found that saturated seed coats of *Cucurbita pepo* permitted carbon dioxide to diffuse through many times as fast as oxygen. The bur of cocklebur (*Xanthium* species) contains two seeds, commonly referred to as the lower and upper seeds. In nature the lower seed germinates the first year and the upper seed the second year. A similar behavior is observed in ordinary laboratory tests. However, upper seeds germinate in a normal manner if the seed coat is pricked or if the oxygen concentration surrounding them during the germination test is increased to 76 cm. or a full atmosphere of pressure. Thus, the seed coat of the lower seed is sufficiently permeable to oxygen to permit germination at ordinary conditions whereas the seed coat of the upper seed is relatively impermeable to oxygen at ordinary pressures and will not germinate unless its permeability is altered or the oxygen pressure is increased.

A complete atmosphere of carbon dioxide for a few days prior to germination will overcome dormancy in Canada bluegrass seed. On the other hand a complete atmosphere of oxygen does not overcome dormancy in this seed (Andersen (*2*)). Thornton (*45*) found that high concentrations of carbon dioxide will induce germination of lettuce seed at high temperatures—seed that was formerly reported to require light and low temperatures for germination. It is generally agreed that in these cases the carbon dioxide either renders the tissues more permeable or brings about changes which result in removing a respiration block. In some cases high concentrations of carbon dioxide appear to give stimulating effects similar to those given by solutions of potassium nitrate. It appears quite possible that both agents cause the same changes within the seed.

PHYSIOLOGICALLY UNRIPE SEED

Freshly harvested seeds of cereals and grasses are frequently dormant due to the fact that they are not completely ripened or that they have been stored under conditions unfavorable to after-ripening and still respond as freshly harvested seed when placed to germinate. The seeds are thought to be morphologically mature but not physiologically after-ripened. Low temperatures are generally considered to overcome this type of dormancy. Ripe seeds of wheat, barley, rye, and oats germinate well at 20° C. whereas freshly harvested seeds germinate well if placed at 10° in a moist substratum for 5 days prior to being placed at 20°. If tested at 15°, they frequently do not require the prechill treatment. Freshly harvested seeds of cereals usually germinate more rapidly, more uniformly, and more completely when prechilled, whereas old seeds usually respond better without prechilling.

A combination of factors is usually required to germinate seeds of many of the grasses such as bentgrasses, bluegrasses, and the rye-

grasses. These factors or conditions include alternation of temperatures, exposure to light, and a dilute potassium nitrate solution. Freshly harvested grass seeds are frequently very exacting in their requirements, but as the seeds age they will often germinate under a variety of conditions. The conditions under which freshly harvested or dormant seeds of certain grasses will germinate are as follows: Low and wide alternating temperatures, high light intensities, and dilute concentrations of potassium nitrate. The duration of dormancy in grass seeds is usually much longer than in cereals, often lasting from one to several years. This has been shown to be the case in seeds of Canada bluegrass, some varieties of Colonial bentgrass, and several of the so-called range grasses or native grasses.

DORMANT EMBRYOS

Embryos of seeds of many species, especially trees, shrubs, weeds, and native plants, are dormant. The seeds of hawthorn, peach, and numerous forest trees require a period of after-ripening by stratification in soil, sand, or other moist substratum at approximately 5° C. for a few months. By isolating the embryos and removing the seed coat and other structures external to the embryo it has been clearly shown that in many instances the dormancy is in the embryo. According to Flemion (*19*, *20*) the dormant portion of the peach embryo is the epicotyl. Low temperature stratification is necessary for normal development; otherwise the epicotyl is dwarfed and remains so for several months before normal growth occurs. There is no dwarfing of the hypocotyl of the non-after-ripened peach seed which develops as rapidly as the hypocotyl of fully after-ripened seeds.

The technique of excising and growing embryos has received much attention in recent years. The technique can be used in research to determine whether the embryo or some other structure is responsible for dormancy. In seed testing the technique can be used as a quick test for certain tree and shrub seeds which ordinarily must undergo a long prechilling period. The viability of some kinds of seeds can be determined within 3 to 14 days; whereas, several months would be required for stratification and germination tests.

RUDIMENTARY EMBRYOS

Seed stocks of several species in the Umbelliferae (anise, caraway, dill, parsley, carrot, fennel, and celery) may contain seeds with normal endosperm and (1) a normal embryo; (2) an immature embryo; or (3) no embryo. Some embryos are morphologically immature and will germinate if kept for long periods under germination conditions. The occurrence of seeds without embryos but with apparently normal endosperm in this family varies but may reach 50 percent in some instances. In the embryoless seeds there is a cavity in the endosperm where the embryo would normally be found. According to Flemion and Olson (*21*) this condition is due to Lygus bugs feeding on the embryos. Some seeds may be completely empty, containing neither embryo nor endosperm, whereas in others both the embryo and endosperm may deteriorate.

Defective seeds in corn containing rudimentary embryos and endosperm are reported to be hereditary. Recessive genes which are lethal or semilethal in character affect the embryo and endosperm between the time of fertilization and maturity. Defective seeds show

a much lower germination than normal seeds and many of those that succeed in germinating produce very weak seedlings which lack vigor and soon die. One type of nonhereditary defective seeds of corn is attributed to imperfect pollination in which the seeds are embryoless but contain a normal endosperm. The second type comprises miniature seeds in which there is both a normal embryo and endosperm but the seeds are greatly compressed—the compression being caused by the pressure of adjacent normal seeds (Mangelsdorf (*35*)).

INHIBITING SUBSTANCES

Seed balls of field beet, sugar beet, and Swiss chard contain an inhibitory substance (nitrogenous compounds) which not only retards germination but which causes discoloration and eventual death of the primary root, especially when it makes contact with the seed balls. The symptoms are caused by ammonia released from the organic nitrogen compounds in the seed balls during germination. In seed testing the seed balls are soaked in water to remove any of the toxic substance which may be present.

Inhibiting substances are present in the fruits of tomato, gourd, and other species which prevent the seeds from germinating within the fruits. When the seeds are planted on substrata moistened with extract from these tissues, germination is suppressed. This suppression can be overcome by heating the extract to 100° C. Randolph and Cox (*41*) found that the endosperm of iris seeds contains a substance which inhibits or retards growth when only a part of the endosperm is left in contact with the embryo. Normal seedlings were produced by excising the embryos and growing them on nutrient agar.

RETENTION OF VIABILITY IN SEEDS

Most crop seeds have a natural resting period subsequent to harvest. There are certain environmental conditions which may change this status. It is well known that during rainy seasons, wheat may start to germinate while still in the field. Increases in moisture or temperature of stored seeds may increase the physiological processes within the seed to a degree insufficient for germination but sufficient enough to weaken the seed and result in loss of viability. The moisture content within the seeds reaches an equilibrium with the moisture of the air in which the seeds are stored. It is well known that seeds stored in the southern part of the United States where the humidity and temperature are relatively high, will deteriorate more rapidly than those stored in the northern States where the temperature and humidity are relatively low.

EFFECT OF TEMPERATURE

Seeds will remain viable for a longer period of time at low temperatures than at high temperatures, especially at high moisture levels. Toole and Toole (*46*) reported that soybean seed with approximately 18 percent moisture was worthless after 1 month of storage at 30° C., and after 2 years at 10° C., but it showed very little decline in viability after 6 years of storage at −10°. By reducing the moisture content of the seeds to approximately 8 or 9 percent there was little loss in viability at 30° within a year, although the viability dropped off rapidly after that time. Similar seed showed no change within 10 years when stored at −10° and at 10°.

EFFECT OF MOISTURE

Different kinds of seed take up different amounts of moisture when stored at the same relative humidity. Peanuts have been known to reach a moisture content of 8 percent, sweet corn 13 to 14 percent, and beans 15 to 16 percent when placed under the same moisture conditions. The fact that seeds should be kept below the critical moisture level for retention of viability was demonstrated several years ago when dried Chewings fescue seed was shipped by boat in both cloth bags and closed canisters from New Zealand to the United States. Upon arrival in the United States the samples in canisters had an average moisture content of 7.3 percent and an average germination of 88.7 percent. The samples shipped in cloth bags had a moisture content of 11.2 percent and an average germination of 54.5 percent.

Thus, for proper storage of a given kind of seed one must take into consideration temperature and humidity of the atmosphere in which the seed is to be stored as well as the initial moisture content of the seed. The practice of drying seeds, such as hybrid corn, to insure favorable moisture conditions, as well as storing them at low temperatures, has greatly aided in keeping seeds of these kinds in good condition for future planting purposes.

NATURE OF SEEDS

It is common knowledge that some kinds of seeds retain their viability much longer than do other kinds. For example, Boswell et al. (*8*) found that under warehouse storage conditions the germination of seeds of peanut and onion dropped 72 and 78 percent, respectively, within approximately a year, whereas the germination of lima bean, kidney bean, tomato, beet, cabbage, and carrot dropped only about 10 percent, on an average.

DURATION OF VIABILITY

The life span of river maple seeds is only a few days unless they fall in water or upon moist soil. The moisture content of the seeds as they fall from the tree is approximately 60 percent. If they fall upon dry earth or leaves, where their moisture content drops below 30 to 35 percent, they usually die within 6 days. The life span of garden and farm seeds is usually regarded to be from about 3 to 15 years. Seeds of certain legumes which have impermeable seed coats have germinated approximately 80 percent after 50 years of storage. Seeds of *Nelumbo nucifera* estimated to be at least 200 years old germinated approximately 100 percent when the fruit coats were filed or otherwise made permeable to water.

It is well known from buried seed experiments that seeds of some weedy species remain viable after having been buried in the soil for 20, 40, 50, and 60 years. Crop seeds found viable after having been buried for 20 years were the small-seeded kinds such as timothy, bluegrass, beet, tobacco, celery, and seeds with impermeable seed coats such as clovers and black locust. Seeds that were dead after 20 years of storage, or with shorter periods, include the grains, crucifers, cucurbits, onion, asparagus, sunflower, and pine.

MECHANICS OF GERMINATION

In nature, seeds are subject to alternating and fluctuating temperatures, alternate freezing and thawing, moistening and drying, influence of light, action of salts and other chemicals, as well as physical effects of the soil. All of these conditions are regarded as forcing agents in the germination of seeds. They probably exert their effects on the semipermeable membranes of the seed coats, thus modifying the colloidal nature, permeability, and mechanical resistance of the coats. Low temperatures for long periods probably aid in the chemical after-ripening of morphologically mature embryos and in the development of immature or rudimentary embryos. High temperatures act as a forcing agent in the germination of some seeds in which the oxygen supply is below the minimum required by the embryo. Because of the low permeability of the seed coat, the minimum oxygen pressure needed for germination of the embryo is lowered by increased temperature.

During the natural rest period of crop seeds grown in the north temperate region in which seeds are harvested in the fall and not planted until the following spring the seed coats dry out, presumably modifying their colloidal nature. During this rest period the seed coat becomes more permeable to water and gases, the seed goes through certain chemical changes known as after-ripening, and in some instances the immature embryos develop further. When these changes have not taken place the seed analyst attempts to apply some of nature's methods, in the laboratory, to bring about the germination of freshly harvested and other types of dormant seeds.

PATHOLOGICAL CONSIDERATIONS IN SEED TESTING

The importance of seed-borne plant diseases is indicated by the time and materials spent on seed treatment and by the efforts of research scientists in learning new and improved methods of control. It can safely be said that the average seed lot in commercial channels is sold without regard to the seed-borne disease organisms which it may carry. No doubt, agricultural production in this country would be greatly increased if the farmer were aware of the sanitary condition of the seed he plants. By sanitary condition is meant the kinds and relative extent of occurrence of seed-borne fungi, bacteria, viruses, eelworms, and insects which cause disease and injury.

Some seed lots showing high germination when tested by official methods are practically valueless when planted under certain weather and soil conditions because they are infected with disease organisms which increase and destroy the seedlings, and plants, or otherwise reduce the yield. *Helminthosporium* on cereals is usually not detected in the regular germination test and a high germination percentage may be reported for infected samples. However, if the germination temperature is increased from 20° to 25° or 30° C. and the seedlings are left in test for 14 or 15 days infected samples may appear as worthless.

Very few seed-testing laboratories in the United States make any attempt at testing for the presence of injury or seed-borne diseases. Perhaps, this situation is due primarily to lack of methods applicable to routine seed testing by which the specific organisms can be identified. Although research in this phase of seed testing has lagged it must be recognized that the development of practical methods will not be an easy task. This should not act as a deterrent to research but as a challenge, especially when the importance of the problem is recognized. In order to introduce and carry out a satisfactory program in this field, seed-testing laboratories will require additional personnel, equipment, and other facilities and certain legislation will need to be enacted. Steps in this direction have been taken by some countries in Europe and by Canada.

SEEDS AS HOSTS AND CARRIERS OF ORGANISMS CAUSING DISEASE AND INJURY

Fungi are a group of plants lacking chlorophyll or green coloring matter and are therefore not able to make their own food. They must obtain food which has already been synthesized. Neither can bacteria, which are one-celled organisms, make their own food. Those organisms which obtain their food from living plants or animals are called parasites. Those organisms which obtain their food from dead plants or animals are termed saprophytes. Micro-organisms which live internally or externally upon seeds are of primary interest in seed testing.

The micro-organisms producing seed-borne diseases may be classified as (1) fungi, (2) bacteria, and (3) viruses. Injury and disease-like conditions may also be caused by nematodes and insects. Fungi that produce plant diseases may be present in the vegetative stage as mycelia within the seed or they may be present externally on the seeds as spores. Bacteria that produce seed-borne diseases have just one form which serves as both the vegetative and spore stages depending upon the conditions. By cell division each bacterium forms two new individuals, each of which is capable of starting fresh infection. Bacteria may divide as frequently as every 20 minutes. Nematodes or eelworms are microscopic worms which are reproduced by eggs. They live within, or on the seeds, but usually form galls which resemble the seed in appearance. Insects whose larval stage feed upon the embryo of seeds, as the pea weevils or beetles, also reproduce by eggs. Viruses are ultramicroscopic bodies, too small to be seen under the compound microscope. They are present in the juice of plants and are transmitted by aphids, leafhoppers, and thrips sucking the juice from infected plants and spreading the viruses to healthy plants.

HOW SEED-BORNE ORGANISMS ARE CARRIED

Internally borne organisms such as fungi which are present in the form of mycelia within the seed produce such seed-borne diseases as Anthracnose of bean, Ascochyta of peas, and root-rot or seedling blight of corn due to *Diplodia*. Bacteria within the seeds produce such diseases as black rot of cabbage and bacterial blight of beans. Nematodes such as *Tylenchus dipsaci* which are present within the seeds produce injury as stem nematode injury of wheat, alfalfa, and red clover. Viruses are reported to be transmitted by seeds as well as by other means. Mosiac due to seed transmission of viruses has been reported for alfalfa, red clover, white clover, lettuce, cucumber, bean, and lima bean.

Externally borne organisms are those in which the spores are present externally on the seeds and which produce such seed-borne diseases as bunt of wheat, covered smut of barley and sorghum, and downy mildew of spinach. Bacteria present on the exterior of seeds produce bacterial pea blight and other diseases. Nematodes may be carried externally on seeds but they are usually carried in gall tissue along with the seeds as in wheat samples.

RELATION OF HOST AND PARASITE

Some diseases have a systemic type of infection. The pathogen lives in the plant throughout its life. Examples are: *Ustilago* spp. which produces loose smut of wheat and barley and *Helminthosporium gramineum* which produces stripe of barley. *Ustilago nuda* (Jens) Rostr. is a deep-seated fungus of the systemic type, and produces the seed-borne disease known as loose smut of barley. The smutted spikes containing chlamydospores emerge from the boot slightly ahead of the healthy spikes. Wind-borne chlamydospores lodge on the healthy barley flowers and germinate, followed by conjugation of the haploid cells of the promycelium that form binucleate mycelia, which penetrate the stigma of the ovary. The mycelium remains dormant where

957116—52——20

it is present chiefly in the scutellum of the infected seed. When the infected seed is sown and germinates, the development of the mycelium is also resumed. The mycelium grows right along with the growing-point tissues of the barley shoot and eventually develops spores in the floral parts prior to emergence of the spike.

Gibberella spp. and *Fusarium* spp. produce a local, nonsystemic type of infection on cereals and grasses. The mycelia, which are carried within the seed infect the seedling and produce seedling blight and root rot. In addition, healthy seedlings may be infected from the mycelia, conidia, and perithecia developed in crop residue. Head blight is usually due to infection from conidia and ascospores of crop residue. Primary infection of the developing seeds occurs early in the flowering stage and in the beginning of the ripening of the seeds. Secondary infection of the seed occurs slightly later in the development of the seed from air-borne conidia and mycelia. The infected seeds are more or less scabby. The scabbiness is due to mycelial tufts growing out from the seed coats. The more severely infected seeds are shrunken and light brown in color.

EFFECT UPON THE HOST SEED

DISEASES AND ORGANISMS WHICH MAY BE IDENTIFIED PRIOR TO GERMINATION

The effects of insects and some seed-borne pathogens can be detected on seeds by microscopic examination and in some instances by the aid of a stereoscopic microscope.

Insect injury.—Insect injury due to weevils, beetles, and moths that spend the larval stage within the seed feeding upon the embryo, can usually be detected by the holes left in the seed as the insects emerge and by the resulting injury to the seedlings upon germination.

Sclerotia.—Sclerotia, which are the overwintering stage of some fungi, are hard bodies consisting principally of mycelia which replace the seed. The ergot sclerotia from the fungus, *Claviceps purpurea* is found in rye, wheat, *Agrostis*, *Holcus*, and timothy. The sclerotium in rye is curved, grayish violet in color, and two or three times as long as the rye kernel. Sclerotia produced by the fungus *Claviceps paspali* and *C. yanagawaensis* have been found in seed samples of *Paspalum dilatatum* and *Zoysia japonica*, respectively. Seeds of red clover, white clover, and possibly other species, may be infected with the fungi *Sclerotinia* and *Typhula*. Small black or dull brown sclerotia and infected seeds that appear immature, shrunken, and grayish pink in color may occur in seed samples.

Diseased seed.—Ryegrass samples frequently contain large percentages of infected seed owing to the fungus *Phialea temulenta* which causes blind-seed disease. Badly infected seeds do not germinate. Healthy ryegrass seeds are bright as compared with diseased seeds, which are opaque under the diaphanoscope. If the seeds with glumes removed are placed in a drop of water on a slide the elongated hyaline macrospores will float from the caryopses and can be identified under a binocular microscope. In the field, the severity of the disease and whether it is profitable to harvest the crop can be determined at the honey dew or conidial stage, which is characterized by a pink slime found between the young ovules and the glumes.

Pycnidia.—Pycnidia of *Septoria apii*, causing late blight of celery, can be detected under a binocular or stereoscopic microscope. These pycnidia are small, black, globose structures on the ribs of the celery seeds.

Covered smut of cereals and grasses.—Bunted grains of wheat and covered smut grains of barley and oats in which the so-called grains are full of spores are indicative of their respective diseases. Samples of seed may also be infected when bunted or smutted grains are not present, in which case the smut spores are present on the exterior of the seeds. The disease may be identified by shaking 100 seeds in a test tube of water and evaporating the liquid and then examining the concentrate under a compound microscope. Loose smuts in wheat, *Ustilago tritici* (Pers.) Rostr., and barley, *Ustilago nuda* (Jens.) Rostr., are present in seeds as deep-seated mycelia and therefore cannot be detected by microscopic examination.

DISEASES FOR WHICH EXAMINATION SHOULD BE MADE AT THE END OF THE GERMINATION TEST

Anthracnose of bean produces brownish-gray spots with a light center on the seeds. The spots can readily be seen on light-colored dry seed but not on dark seeds. The spots of *Ascochyta* spp. on peas are not easily seen when the seeds are dry. *Diplodia* spp. produce badly rotted seeds of corn. *Fusarium* spp. and *Gibberella* spp. produce discolored seeds of wheat and barley. These symptoms are not usually sufficient for the determination of the disease; therefore, moist germinating conditions are provided in order that the growth of the fungus may be resumed to produce fruiting structures, including spores, for identification.

Peas.—Ascochyta blight is probably the most serious of the diseases occurring on peas and is due to three different pathogens: *Ascochyta pisi* Lib., *A. pinodella* Jones, and *Mycosphaerella pinodes* (Berk. and Blax.) Stone. The fungus consists of a dense white or gray mycelium and develops from the diseased seed within 4 to 7 days; the light-brown pycnidia develop within about 10 days. The spores within the dark-brown pycnidia are one- or two-celled and are not curved. They vary in color from pink to salmon or carrot red and rarely exceed 15 by 4.5 microns in size (Crosier (*14*)).

Fusarium wilt is caused by the fungus *Fusarium orthoceras* Appel. and Wr. var. *pisi* Linford. Other species of *Fusarium* are also present on germinating seeds. The mycelium of the genus *Fusarium* is a fluffy white to pink or red as contrasted with the dense white or gray mycelium of *Ascochyta*. The spores are 0 to 5 septate, elliptical or slightly curved, and range from 27 to 45 by 4.5 to 5.5 microns in size.

Beans.—Anthracnose caused by the fungus *Colletotrichum lindemuthianum* (Sacc. Magn.) Briosi Cav. is one of the important bean diseases. It penetrates the seed coat, enters the cotyledons, and produces brown to yellowish sunken lesions on the seeds. Fruiting structures bearing single-celled conidia are differentiated within the lesions. The individual conidia are hyaline nonseptate, oval to oblong, straight or slightly curved, range from 13 by 4.4 to 22 by 5.3 microns in size, and are held together by a mucilaginous pink-colored excretion. Seedlings developing from infected seed may be stunted or decayed and are classified as abnormal. Anthracnose occurs on practically

all varieties of garden bean and on most of the dry-shelled field varieties (Harter and Zaumeyer (*26*)).

Discolored bean seed may be due to bacterial blight which is caused by three organisms as follows: Common blight, *Xanthomonas phaseoli;* halo blight, *Pseudomonas medicaginis* var. *phaseolicola;* and wilt, *Corynebacterium flaccumfaciens.* The first two frequently appear together and cannot readily be distinguished. The bacteria are present under the seed coat. Infected seeds appear shrunken, wrinkled, rotted, or discolored. They may be discolored only at the hilum. The discoloration can readily be detected on light-colored seeds but not on dark-colored seeds. When the seeds germinate, the bacteria invade the cotyledons. Frequently lesions are formed on the cotyledons, cotyledonary nodes, or the primary leaves, and these lesions enlarge and coalesce with similar infected areas. The dry, wilt-infected seeds of white-seeded varieties of beans are conspicuously yellow owing to bright yellow masses of bacteria which are clearly visible through the seed coat but the bacteria are not easily recognized in the dark-seeded varieties. Wilt is primarily a vascular parasite in which the vascular bundles become plugged, thus cutting off the supply of water and causing the seedlings to wilt and die if attacked when only 2 or 3 inches high. The color of the exudate from the common blight organism is yellow and from the halo blight organism is light cream or silver (Harter and Zaumeyer (*26*)).

Corn.—Diplodia spp. and *Gibberella* spp. are two of several fungi producing seed-borne diseases in corn. The fungi *Diplodia* spp., produce dry rot of the ear and stalk and root rot of the corn plant. The infected kernels are grayish brown in color with small black pycnidia, each containing two-celled spores. The two-celled spores are 25 to 30 by 6 microns in size and are olive in color. White or grayish mycelia emerge from the kernel on moist substratum at the designated temperatures for germinating seeds of corn (Koehler and Holbert (*31*)). *Gibberella zeae* Petch produces seedling blight, pink ear rot, and stalk rot of corn. It is characterized on the moist seed bed in the germinators by reddish coloration of the seed coats of the kernel. The conidial stage is *Fusarium graminearum* Schw. The mycelium is white or pink in mass. The hyaline, sickle-shaped spores (macroconidia) are three to five septate and measure 41 to 60 by 4.3 to 5.5 microns in size (Koehler and Holbert (*31*)).

Wheat, barley, rye, and oats.—Fusarium spp. cause root rot or seedling blight of the cereal seedlings. *Helminthosporium* spp. cause stripe disease (*H. gramineum*) and spot blotch (*H. sativum*). The latter also causes seedling blight or a browning of the coleoptile and roots which later become soft and watery resulting in death of the seedlings. In the laboratory the symptoms of these diseases can be detected more readily at warmer temperatures of 25° C. or higher than at the usual germination temperatures of 20° or lower, at which cereal seeds are usually tested. It takes 10 or 14 days before spores of *Helminthosporium* spp. are formed whereas the regular germination test of wheat, barley, and rye is terminated within 7 days, and oats within 10 days. The mycelium which emerges from the kernels infected with *Fusarium* spp. is white or pink and the spores (conidia) are hyaline, curved, and have three to five septa. The spores are similar to those described for the conidial stage of *Gibberella zeae*

Petch under the heading corn. *Helminthosporium sativum* causes "black point," in which the embryo ends of the kernels of wheat and barley are blackened, and spot blotch disease which appears later in the field. The conidiophores of this species may bear 2, but usually 4 or 5, spores. The spores are curved, being widest in the middle, have 1 to 10 transverse septa, are reddish to dark olive-brown in color, and vary in size, depending upon the environment. Stripe disease due to *H. gramineum* Rabenh. is a systemic disease. The mycelium is carried in the embryo of the seed. On moist blotters the mycelium emerges abundantly and is gray through olive to black. The conidia are hyaline to yellowish-brown, straight, subcylindrical to slightly tapering with rounded ends. They are 1 to 7 septate without constrictions at the septa and average 105 by 20 microns in size. *Helminthosporium victoriae* infects derivatives of the Victoria variety of oats. *H. avenae* causes injury to seedlings of various lines of oats. The symptoms of these diseases on the seedlings in moist germinators at 25° C. or higher are browning of the coleoptiles and roots. The spores form within 10 to 14 days and arise in groups of 2 to 12 at the ends of conidiophores. The spores are cigar-shaped or cylindrical bodies.

Doyer (*18*) describes the Hiltner method for detecting *Fusarium* spp. and *Helminthosporium* spp. that attack cereal seedlings. The Hiltner method is also used in differentiating between *H. gramineum* and *H. sativum* that attack cereal seedlings. The cereal seeds are sown in ground brick particles about 3 cm. below the surface. The test is terminated after 14 days. The heavily infected seedlings are apically curled and not able to penetrate the brick dust. The less heavily infected seedlings are straight with brown-discolored coleoptiles and roots. Those seedlings infected with *Fusarium* spp. twist from the bottom upward whereas those infected with *Helminthosporium* spp. begin the twisting or winding farther up on the seedling. Also the concave side of the *Helminthosporium*-infected seedlings are discolored black and contain the fungus. Stripe disease, caused by *H. gramineum*, is characterized by long brown stripes along the stem. Muskett (*39*) reported that irradiation of cereal seeds with white light is beneficial in producing spores (conidia) in *Helminthosporium avenae*. Replicates of 15 oat seeds are sown in 100-mm. Petri dishes on moist filter paper at 22° C. On the fourth day the lids are removed from the Petri dishes and the dishes are placed under a Hanovia sun lamp, at a distance of 1 foot, for 20 minutes. After 9 days the material is examined for the presence of conidia of *H. avenae*.

Crucifers.—One of the most important diseases of cabbage and of other cruciferous species is due to *Alternaria brassicae* (Berk.) Sacc. and *Alternaria circinans* (Berk. and Curt.) Bolle. The symptoms are a dark discoloration at the base of the stem extending down the hypocotyl. The cotyledons may be entirely rotted if the seed coats persist. When the seed coats do not persist, the cotyledons may have numerous to few black spots or necrotic areas on the cotyledons. Discoloration is often evident on the dorsal side of the cotyledons when no abnormalities are present on the axial side. The mycelium is dark to black. The conidia of *A. brassicae* are obclavate, light olive brown, and long-beaked, and have 5 to 12 transverse septa and a few longitudinal septa. They are 100 to 238 by 16 to 35 microns in size (Crosier (*15*)).

Pod spot on radish is due to 3 pathogenic species of *Alternaria: A. raphani*, *A. brassicae*, and *A. oleraceae*. The saprophytic form *A. tenuis* may also be present. However, *A. raphani* is the most common form and is extremely pathogenic. The usual symptoms of the disease on the seedlings are olive to gray or black, round, raised areas on the cotyledons and at the base of the cotyledons. There are also lesions on the hypocotyl and the roots of the seedlings. When the seed coat adheres to the base of the hypocotyl, this area becomes soft and decayed. The conidia of *A. raphani* are borne in chains. They are olive brown and muriform, and have three to nine transverse septa and numerous longitudinal septa. They are 55 to 135 by 14 to 25 microns in size (McLean (*36*); Groves and Skolko (*25*)). The *Alternaria* species have been studied in detail by Neergaard (*40*) who has transferred *Alternaria radicina* which attacks carrot seed to *Stemphylium radicinum*. *Phoma lingam* producing black leg of cabbage and other cruciferous plants is a disease of major importance. It is characterized by dark sunken stripes on the hypocotyl of the seedlings. The dark-colored pycnidia produce small, oval spores which ooze out of the pycnidia and in mass are pink. Individual spores are hyaline, nonseptate, and 1 to 2.5 by 3 to 6 microns in size (Walker (*49*)).

Beet.—One of the most important diseases of beets is the result of the fungus *Phoma betae* Frank, which causes root rot. At the end of the 14-day germination test dark pycnidia with small, oval, one-celled spores oozing out can be observed under a binocular. The roots of the diseased seedlings are dark brown in color. This condition must not be confused with the discoloration of the radicles caused by toxic nitrogenous substances in the seed balls.

Flax.—The seed-borne organisms attacking flax seed are *Colletotrichum linicola* (seedling blight), *Polyspora lini* (stem break and browning), *Botrytis cinerea* (gray mold), *Phoma* sp. (foot-rot), and *Fusarium lini* (wilt). Muskett (*39*) reports that the best medium for the detection of these diseases is a 2-percent malt extract agar. The seeds are planted on the agar solution in Petri dishes and incubated at 22° C. for a period of 5 days. The fungi are identified by the type of colonies produced on the agar solution. When tested in moist germinators, identification of the spores is usually necessary.

Cotton.—One of the most important diseases of cotton is Anthracnose due to the fungus *Glomerella gossypii* Edg. The infection is usually from external spores on the seed. Damping off of the seedlings may occur. The symptoms are lesions on the cotyledons, stems, and leaves, and rotting. Small reddish to light-colored spots or necrosis of the marginal tissues is common on the cotyledons. Similar oblong brown cankers occur on the hypocotyl and young stem. Girdling of the stem occurs under high humidity. The conidia develop on the mycelium or in acervuli. The conidia are cylindrical, generally straight, hyaline, one-celled, 3.5 to 7 by 12 to 25 microns in size, and are held in a mucilaginous mass.

Fusarium wilt of cotton is due to the fungus *Fusarium oxysporum* f. *vasinfectum* (Atk.) Snyder and Hansen which causes wilting of the leaves and premature death in some varieties. The sickle-shaped, macroconidia are hyaline, three, four, or five septate, and 3 to 4.5 by 40 to 50 microns in size. Microconidia are unicellular and ellipsoidal. They are 2 to 3.5 by 5 to 12 microns in size (Dickson (*17*)).

Clover and Alfalfa.—The fungus *Botrytis anthophila* has been found to cause a mold on seeds of red and Ladino clovers in Oregon. Infected seeds are usually shriveled and dull brown to gray pink in color. Most infected seeds fail to germinate. *Sclerotinia spermophila*, described on seed of white clover in Great Britain, is possibly another stage of the same fungus. Diseased seeds kept moist in a germinator for 5 days produce sclerotia. Sclerotia which overwinter in the field produce stromatal heads that give rise to perethecia and ascospores. The "blackpatch" disease, caused by an unidentified fungus is carried on the surface of and within the seeds of red clover. This disease can materially reduce seed yield and cause seedling blight. During germination the large mycelia can destroy seedlings and spread to adjacent ones before germination is complete.

Celery.—A common seed-borne disease of celery is late blight. It is due to the fungi *Septoria apii* (Briosi and Cav.) Chester and *S. apii-graveolentis* Dorogen. Late blight produces necrotic spots on the leaves and lesions on the petioles. It has been mentioned earlier that the pycnidia which are present on the ribs of the seed can be detected under a binocular microscope. When the seeds have lain in water for a short time the numerous, long, slender, filiform, septate, spores emerge. The conidia have several septations and are straight to slightly curved. The conidia of the first-named *Septoria* are 22.5 to 58.5 by 1.5 to 3.0 microns in size, whereas those of the latter are somewhat shorter, 13.5 to 34.2 by 1 to 2.5 microns.

Rice.—Seedling blights and culm rot are diseases of major importance affecting rice. Gibberella blight or "Bakanae disease" is due to *Gibberella fujikuroi* (Saw.) Wr. and *G. zeae* Schw. Petch. The conidial stage of the former fungus is *Fusarium moniliforme* (Sheld.) and of the latter, *Fusarium graminearum* Schw. Another seedling blight disease, Helminthosporium blight, is caused by *Cochliobolus* (*Ophiobolus*) *miyabeanus* Ito and Kuribay. Symptoms of these seedling blights include reduction of germination, and browning of the roots and the coleoptiles of the shoots which results in reduced vigor or killing of the seedlings. These diseases also produce kernel blight. The Gibberella blight has been isolated from yellow and pink discolored seeds and the Helminthosporium blight from brown necrotic areas on seeds.

The culm disease due to the fungus *Leptosphaeria salvinii* Catt. causes lodging and lightweight grain. Black discolored areas appear on the culms and black sclerotia develop inside the leaf sheath and later in the culm. The black sclerotia are carried with the seed. The spherical sclerotia are black and 230 to 270 microns in diameter. The conidial stage is *Helminthosporium sigmoideum* Cav. The conidia are wide in the center, taper toward each end, slightly curved, and typically triseptate.

The Committee on the Determination of Seed-Borne Organisms of the International Seed Testing Association has proposed methods for determining the presence of certain seed-borne diseases and injury conditions. A report by Crosier (*16*) includes a list of "infectious entities" (seed-borne fungi, bacteria, insects, and eelworms) for each of several kinds or groups of seed. This report which was prepared primarily by Dr. W. C. Crosier, New York Agricultural Experiment Station, Geneva, N. Y., and the late Dr. L. C. Doyer, Waginengen,

The Netherlands, was accepted by the International Seed Testing Congress held at Washington, D. C., May 1950, and is being incorporated into the International Rules for Seed Testing by the Rules Committee. These methods, with minor modifications, and the list of infectious entities are given in the following pages.

METHODS

In general, the procedure shall consist of macroscopic examination of the seed sample, microscopic examination of the seed sample, and examination of the seeds and seedlings during or at the end of the germination test.

I. Upon receipt the whole sample or, in case the sample may be too large, a portion of it, should be inspected for the presence of bunt kernels, ergots, fragments of smutted seeds, sclerotia and discolorations due to pathogenic organisms. Fungi also may be present in chaff, straw, or other inert matter carried with the seed. Attention should also be paid to the fact that the seeds may show round holes out of which insects such as *Bruchus* spp. may have emerged, in which case larvae or weevils still in a living state may be found in the sample. Furthermore, the presence of storage pests such as granary moths (larval or adult stage) and moths, or mites, should also be determined. Specifically the sample shall be examined for the presence of:

   A. Ergots, sclerotia, smut-kernels, etc.

   B. Discolorations and blemishes indicative of bacteria or fungi (*Diplodia zeae* in corn, *Xanthomonas phaseoli* in beans, etc.).

   C. Damage and invasion by insects and other animal life (*Bruchus* spp., *Tylenchus* spp., etc.).

   D. Stored seed pests (granary weevils, mites, etc.).

II. The seed sample shall be examined microscopically for the presence of pests and conditions as indicated below.

   A. Spores adhering to the seeds (*Polyspora lini*, *Tilletia* spp., etc.). Fungus spores, intermingled with the seeds or adhering to them, may be identified by vigorously shaking 100 seeds or more in a test tube with a little water plus a detergent or alcohol. The washings should be either centrifuged or evaporated to a few drops before being examined microscopically for the presence of fungus spores. This is particularly applicable in the case of *Tilletia* spp. In the case of other spores such as *Fusarium* spp. these pathogens will be more easily detected in the germination test, during which the fungi present usually develop their own characteristic fructifications on the invaded tissues.

   B. Disease fungi with distinctly recognizable forms (acervuli of *Colletotrichum* spp., pycnidia of *Septoria petroselini*, etc.). In order to identify the presence of acervuli, pycnidia, perithecia, or any other typical stage of fungus infection present on the seed, about 50 or 100 seeds should be examined by means of a stereoscopic microscope. In this way the percentage of such infections may be determined.

III. The sample shall be examined *during, or at the end of, the germination test for the following pests and conditions:*

   A. Pathogenic bacteria and fungi in, or growing out of, the seeds (Examples: *Alternaria brassicae*, *Xanthomonas campestris*, etc.). With regard to fungi which develop in a characteristic manner in moist surroundings, it is desirable to arrange the seeds in the germination medium in such a way that they are not in contact with each other; in the case of cereals a substratum of folded blotting paper is satisfactory. Beans and peas which are more inclined to roll, should be arranged on substrata consisting of a sheet of moist

blotting paper, laid in a tray with perforated bottom (sizes about 27 by 10 cm.). On this blotting paper about 50 beans or peas are evenly distributed and covered with another sheet of moist blotting paper. Should any symptoms of metallic poisoning appear as a result of using metal trays, it would be advisable to use bakelite or plastic trays. The bottom of the trays must be perforated so as to avoid the collection of water.

Beet and flax seeds should be tested in trays similar to those just described, but in the case of beet seeds the trays should remain uncovered. One hundred seeds of beet and flax should be used. In the determination of pests the seeds should not be soaked beforehand. An exception in this respect is made for beans (*Phaseolus* spp.) in that half of the seeds are soaked prior to testing. In this way the degree of resistance against unfavorable conditions of each lot can be stated. Beans of high quality are not injured by soaking whereas dead or decadent seeds often disintegrate or become mucilaginous through bacterial action. Broad or fava beans (*Vicia faba*) must always be soaked in advance, otherwise germination is seriously delayed. Temperature and moisture conditions similar to those used for ordinary germination tests should be maintained except that temperatures of 25° or 28° C. should be used for cereal. The sanitary tests for beans, flax, and pea seed may be terminated after 5 or 6 days; for *Phoma*-infected beet seed it is desirable to leave the seeds in the germinator for about 12 days; and for cereals, 10 to 14 days.

Although infection by *Ascochyta*, *Botrytis*, *Colletotrichum lindemuthianum*, *Fusarium*, and *Stemphylium* may be identified with the naked eye, a stereoscopic microscope (× 20) is required for the determination of *Colletotrichum* and *Polyspora* on flax, *Colletotrichum* on spinach, and *Phoma betae* on beet seeds. A compound microscope is necessary for identifying the spores.

Disinfection or disinfestation studies may be undertaken in conjunction with the examination for pests. The seeds are treated either with a dust or a suspension. The sanitary test with this treated seed is made as previously described. Insofar as the microorganisms are superficial, they will be eliminated for the greater part by efficient treatment, but in cases in which these infections are more deep-seated, such as *Ascochyta* spp. in peas, or *Colletotrichum lindemuthianum* in beans, disinfection will not, as a rule, be complete.

B. Insects inside the seeds including the larval stage, and evidence of those that may have emerged.

At the end of the test the seeds may be cut so as to reveal any abnormalities that may be present in their interiors. In this way insects in the larval or adult stage may be found inside the seeds. When Chalcididae are found in conifer or other tree seeds, the germination power is always completely lost in consequence of their activities. Beans and peas, invaded by *Bruchus* spp., may still germinate if the germ has escaped injury by the insect.

C. Physiological disturbances (marsh spot in peas).

The symptoms of "marsh spot" may be found by cutting peas transversely to the cotyledons; if typical spots occur special attention should be paid to the plumules to determine whether these also show brown discolorations of a serious nature.

PARTIAL LIST OF PESTS AND INJURY CONDITIONS

As each seed species may carry its own particular type of infectious entities short lists of the most characteristic of these entities are given below. The Roman numerals and capital letters preceding the names indicate the methods that are applicable for determining their presence as given in the paragraphs under "Methods."

Bean (Phaseolus spp.)

I B. *Colletotrichum lindemuthianum* (Sacc. & Magn.) Briosi & Cav., *Pseudomonas phaseolicola* (Burk.) Stapp & Cotte, and *Xanthomonas* spp.
I C. *Acanthoscelides obtectus* Say.
III A. *Ascochyta boltshauseri* Sacc., *A. phaseolorum* Sacc., *Botrytis cinerea* Fr., *Cercospora cruenta* Sacc., *Colletotrichum lindemuthianum* (Sacc. & Magn.) Briosi & Cav., *C. truncatum* (Schw.) Andrus & Moore, *Corynebacterium flaccumfaciens* (Hedges) Dowson, *Diaporthe phaseolorum* (Cke. & Ell.) Sacc., *Fusarium* spp., *Macrophomina phaseoli* (Maubl.) Ashby, *Pleospora herbarum* Rab., *Pseudomonas viridiflava* (Burk.) Dowson, *Rhizoctonia solani* Kuehn, and *Sclerotinia sclerotiorum* (Lib.) DBy.

Beet

II A. *Uromyces betae* (Pers.) Lév.
III A. *Coprinus lagopus* Fr. and *Phoma betae* Frank.

Broad or fava bean

I C. *Bruchus atomarius* (granarius) L., and *B. rufimanus* Boh.
III A. *Ascochyta pisi* Lib., *Fusarium* spp., and *Ascochyta fabae* Spegazzini.
III B. *Bruchus atomarius* (granarius) L., and *B. rufimanus* Boh.

Cabbage and other Cruciferae

I A. *Sclerotinia sclerotiorum* (Lib.) Dby.
III A. *Alternaria brassicae* (Berk.) Sacc., *A. brassicicola* (Schw.) Wilts., *Phoma lingam* Desm., *Mycosphaerella brassicicola* (Duby) Oudem., and *Xanthomonas campestris* (Pammel) Dowson.

Carnation and other Caryophyllaceae

II A. *Puccinia dianthi* DC. or *P. arenariae* (Schum.) Wint.
III A. *Alternaria dianthi* F. L. Stevens & Hall, *A. dianthicola* Neerg., *A. gysophilae* Neerg., *Botrytis cinerea* Fr., and *Rhizoctonia solani* Kuehn.

Carrot

III A. *Alternaria porri* (Ell.) Neerg. f. sp. *dauci*, *Septoria daucina* Brun., and *Stemphylium radicinum* (Meier, Drechs. & Eddy) Neerg.

Celery

II B. *Septoria apii* (Briosi & Cav.) Chester and *S. apii-graveolentis* Dorogin.
III A. *Stemphylium radicinum* (Meier, Drechs. & Eddy) Neerg.

Cereal or small grains

I A. *Claviceps purpurea* (Fr.) Tul., *Tilletia caries* (DC.) Tul., *T. foetida* (Wallr.) Liro, *Ustilago crameri* Koern., *U. hordei* (Pers.) Lagh. and *U. kolleri* Wille.
I B. *Gibberella zeae* (Schw.) Petch and *Helminthosporium sativum* Pam., King & Bakke.
I C. *Tylenchus tritici* (Stein.) Bast.
I D. Granary weevils, moths (both larvae and adults), and mites.
II A. *Sclerospora graminicola* (Sacc.) Schroet., *Tilletia* spp., *Urocystis occulta* (Wallr.) Rab., and *Ustilago* spp.
III A. *Dilophospora alopecuri* Fr. in wheat, *Fusarium* spp. *Helminthosporium avenae* Eidam, *H. victoriae* Murphy and Meehan, and *Pseudomonas coronafaciens* Elliott in oats, *Helminthosporium gramineum* Rab. and *H. teres* Sacc. in barley, *Fusarium* spp. and *Helminthosporium sativum* in barley and wheat, and *Xanthomonas* spp. in barley, oats, rye, and wheat.

China aster

III A. *Alternaria zinniae* Pape, *Ascochyta asteris* (Bres.) Gloyer, *Botrytis cinerea* Fr., *Cladosporium* spp., *Fusarium conglutinans* var. *callistephi* Beach, *Phoma glomerata* (Corda) Woll. and H., *Rhizoctonia solani* Kuehn, and *Septoria callistephi* Gloyer.

Clover and alfalfa

I A. *Botrytis cinerea* Fr., *Sclerotinia sclerotiorum* (Lib.) DBy., *S. trifoliorum* Erikss. and *Typhula trifolii* Rostr.
I B. *Sclerotinia spermophila* Noble.
I C. *Bruchophagus gibbus* Boh. and *Dasyneura leguminicola* Lint.
III A. *Ascochyta caulicola* Laub., *A. imperfecta* Pk., *A. lethalis* Ell. & C. Barth., *Botrytis antophila* A. Bond, *Cercospora medicaginis* E. and *C. zebrina* Pass., *Colletotrichum trifolii* Bain. and Essary, *Fusarium* spp., *Gloeosporium caulivorum* Kirch., *Sphaerulina trifolii* E. Rostr., and *Stemphylium botryosum* Wallr.

Corn (maize)

I B. *Diplodia frumenti* Ell. & Ev., *D. zeae* (Schw.) Lév.
I D. *Ahasverus adventa* Waltl., *Sitophilus oryza* L., *Sitotroga cerealella* Oliv., *Tribolium* spp. et al., *Tenebroides mauritanicus* L.
II A. *Nigrospora sphaerica* (Sacc.) Mason and *Bacterium stewartii* E. F. Sm.
III A. *Diplodia* spp., *Fusarium* spp., *Gibberella zeae* (Schw.) Petch., and *Penicillium* spp.

Cotton

I A. *Nematospora* spp.
III A. *Ascochyta gossypii* Syd., *Diplodia gossypiana* Cooke, *Fusarium* spp. *Fusarium oxysporum* f. *vasinfectum* (Atk.) Snyder and Hansen, *Glomerella gossypii* Edg., and *Xanthomonas malvacerum* (E. F. Sm.) Dows.

Flax

II B. *Ascochyta linicola* Naoum. and Vass., *Polyspora lini* Lafferty, and *Mycosphaerella linorum* (Wr.) Garcia Rada.
III A. *Alternaria linicola* Groves and Skolko, *Ascochyta linicola* Naoum. & Vass., *Botrytis cinerea* Fr., *Colletotrichum linicolum* Pethy. and Lafferty, *Fusarium lini* Bolley, and *Melampsora lini* DC.

Grass

I A. *Claviceps paspali* F. L. Stevens & Hall, and *C. purpurea* Fr.
I B. *Corynebacterium rathayi* (E. F. Sm.) Dows., and *C. microcephala* (Wallr.) Tul.
I C. *Tylenchus* sp.
II A. *Phialea temulenta* Prill. & Delacr., *Ustilago striiformis* (West.) Niesst. and other *Ustilago* spp.
III A. *Curvularia* spp., *Fusarium* spp., *Helminthosporium* spp., *Phialea temulenta* Prill. and Delacr., and *Phoma glomerata* (Corda) Woll. and H.

Parsley

II B. *Septoria petroselini* Desm.
III A. *Stemphylium radicinum* (Meier, Drehs. & Eddy) Neerg.

Pea

I C. *Apion vorax* Hbst., *Bruchus pisorum* L., and *Grapholitha* spp.
III A. *Ascochyta pinodella* L. K. Jones, *A. pisi* Lib., *Botrytis cinerea* Fr., *Cladosporium pisicola* Snyder, *Colletotrichum pisi* Pat., *Fusarium* spp., *Mycosphaerella pinodes* (Berk. & Blox.) Vest., *Pleospora herbarum* Rab., *Pseudomonas pisi* Sackett, *Rhizoctonia solani* Kuehn, *Septoria pisi* West., *Sclerotinia sclerotiorum* (Lib.) DBy., and *Stemphylium botryosum* Wallr.
III B. *Apion vorax* Hbst. and *Bruchus pisorum* L.
III C. Marsh spot.

Peanut

I A. *Sclerotinia minor* Jagger, and *Sclerotium rolfsii*.
III A. *Cercospora personata*.

Pepper and tomato

II A. *Phytophthora capsici* Leonian, *P. infestans* (Mont.) DBy., *P. omnivora* DBy., and *Rhizoctonia solani* Kuehn.

III A. *Alternaria solani* (Ell. and G. Martin) Sor., *Colletotrichum phomoides* (Sacc.) Ches., *Cladosporium fulvum* Cooke, *Corynebacterium michiganese* (E. F. Sm.) Jens., *Didymella lycopersici* Kleb., *Fusarium lycopersici* (Sacc.) Wr., *Gloeosporium piperatum* Ell. and Ev., *Phoma destructivora* Plowr., *Phytophthora* spp., *Pseudomonas punctulans* Bryan, *P. tomato* (Okabe) Burkh., *Vermicularia capsici* Syd., and *Xanthomonas vesicatoria* (Doidge) Dowson.

Rice

I A. *Leptosphaeria salvinii* Catt., *Sclerotium* sp., and *Ustilaginoidea virens.*

II A. *Neovissa horrida* (Takahashi).

III A. *Alternaria* sp., *Cercospora oryzae* Miyake, *Cochiliobolus miyabeanus* Ito and Kuribay, *Gibberella fujikuroi* (Sow.) Wr., *G. zeae* (Schw.) Petch., and *Piricularia oryzae.*

Soybean

I A. *Sclerotinia sclerotiorum* (Lib.) DBy.

I B. *Pseudomonas glycinea* (Coerper) Stapp and *Xanthomonas phaseoli* var. *sojense* (Hedges) Starr & Burkh.

II B. *Glomerella glycines* (Hori) Lehm. & Wolf and *Phomopsis sojae* Lehm.

III A. *Cercospora diazu* Miura, *Cercosporina kikychii* Mats. & Tom., *Diaporthe sojae* Lehm., *Peronospora manchurica* (Naoum.) Syd., *Phomopsis sojae* Lehm., *Sclerotinia sclerotiorum* (Lib.) DBy., and *Septoria glycines* Hemmi.

Tree

I C. Several species of Chalcididae.

III B. Chalcididae spp., *Megastigmus* spp. in conifers, *M. aculeatus* Swed. in rose, *Syntomaspis druparium* Boh. in apple and pear, and *Endothia parasitica* (Murr.) A. & A. in chestnut.

Vetch

I C. *Bruchus brachialis* Fahr.

III A. *Ascochyta pinodella* L. K. Jones, *A. pisi* Lib., *Colletotrichum villosum* Weimer, and *Protocoronospora nigricans* Atk. & Edg.

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AVAILABLE PUBLICATIONS ON SEED TESTING

The following publications are available upon request from the Seed Act Division, Grain Branch, Production and Marketing Administration, U. S. Department of Agriculture, Washington 25, D. C. (In requesting these publications refer to each by title) :

Specifications for (*a*) Air-conditioned Germination Cabinets, (*b*) Water-cooled Germination Cabinets, (*c*) Fluorescent Light Grids. These specifications include descriptions, photostatic copies of diagrams, and photographs.

A Selected List of Books and Other Publications for Seed Testing Laboratories. This list includes books useful in seed testing, from various fields of the plant sciences.

List of Photographs Showing Normal and Abnormal Seedlings. Approximately 150 photographs are listed by negative number, kind of seed, and nature of seedlings illustrated. These photographs are available through purchase.

A Partial List of Firms Handling Seed-Testing Equipment and Supplies. Names and addresses of firms are given for each kind of laboratory apparatus and various supplies ordinarily used in seed testing.

List of Publications on the Identification of Seeds. This is a list of photographs of seeds and descriptive material. These photographs are available by purchase.

Diagram for Constructing Purity Workboard.

Testing Sweet Sudan Grass Seed for Purity and Germination. This circular describes the detailed procedure adopted by the Seed Act Division, and includes instructions for ordering color transparencies and a standard color chart used in making tests.

Service and Regulatory Announcements No. 156. This publication contains the text of the Federal Seed Act and the Rules and Regulations Thereunder. The rules for seed testing are included.

Requirements for Labeling Agricultural Seeds and Vegetable Seeds, and Suggested Forms of Labels.

State Noxious-weed Seed Requirements Recognized in the Administration of the Federal Seed Act.

Seed List—A List of Agricultural and Vegetable Seeds and the Incidental Seeds Commonly Found With Them.

A Partial List of Rapid Moisture-Testing Devices for Grain and Related Commodities.

GLOSSARY

Acervuli.—A cushionlike mass of hyphae having conidiophores, conidia, and sometimes setae.

Achene.—A small, dry, hard, one-chambered, one-seeded indehiscent fruit, as in buckwheat, lettuce, and spinach; commonly referred to as a seed.

Acuminate.—Gradually tapering to a sharp point.

Acute.—Sharp-pointed but less tapering than acuminate.

Adnate.—United, as an inferior ovary with the calyx tube.

Adventitious (roots).—Those that arise from any structure other than a root.

After-ripening.—A period following maturity during which certain species of seeds undergo specific physiological changes before germination is possible.

Aleurone cells.—Cells forming outermost layer of endosperm.

Amino acid.—An acid obtained from proteins by hydrolysis.

Amphitropous (ovule).—Having the ovule inverted, but with the attachment near the middle of one side; half anatropous.

Anastamosing.—Connecting so as to form a well-defined network.

Anatropous (ovule).—Referring to an ovule in which the nucellus is inverted and straight, with the micropyle adjacent to the hilum.

Antipodal (cells).—Referring to those cells or nuclei which occupy the chalazal end of the megagametophyte or embryo sac.

Anther.—The portion of the stamen containing the pollen, usually bilocular.

Ascospore.—A spore produced in an ascus or saclike cell.

Bifid.—Two-cleft.

Bruchid.—One of the weevils (*Bruchis brachialis* Fahr.) which attack vetch seed.

Bulblet.—A small bulb, usually axillary, especially one borne upon the stem.

Callus.—A hard protuberance or calloused area. In the grass family it is a hard swollen area at the base or point of insertion of the lemma or palea, often with hairs.

Calyx.—The outermost cycle of floral parts; the sepals considered collectively.

Cambium.—Meristematic tissue which gives rise to secondary phloem and xylem.

Canker.—Result of a disease in which there is sharply limited necrosis of the cortical tissue.

Carbohydrates.—A class of food substance containing carbon, hydrogen, and oxygen including starches and sugars.

Carpel.—A simple pistil, or a member of a compound pistil.

Caryopsis.—A fruit developed from a single carpel with pericarp united to the seed; the fruit of cereals and grasses.

Campylotropous (ovule).—An ovule in which the nucellus is curved and the chalaza and micropyle are in a plane at right angles to the funiculus.

Cellulose.—Material of which cell walls are mainly composed.

Chalaza.—That part of an ovule or seed where the nucellus is not separated from the integuments; it is the base of the nucellus and is always opposite the upper end of the cotyledons; it is evident on the surface of seeds of many legumes as a distinct spot or elevation.

Chalcid fly.—An insect, *Bruchophagus gibbus* Boh., which in the larval or pupal stage causes much damage in clover or alfalfa seed.

Chlamydospore.—A thick-walled intercalary or terminal spore formed by the rounding up of a cell or cells.

Chlorophyll.—The green coloring matter of plants.

Chromosome.—One of the small bodies, ordinarily definite in number in the cells of a given species and often more or less characteristic in shape, into which the chromatin of the cell nucleus resolves itself previous to mitotic division of the cell.

Ciliate.—Fringed with hairs on the margin, like eyelashes.

Cleistogene.—Flowers or florets that have been fertilized without opening.

Cold test.—A germination test in which seeds are planted for a period in cool, moist, unsterilized soil before transfer to a higher temperature, designed to approximate possible unfavorable planting conditions in order to determine seedling vigor.

Coleorhiza.—The sheath which surrounds the primary root in the embryo of grasses.

Coleoptile (in Gramineae).—The first leaf above the cotyledon which encloses the stem tip and other leaves; sheath.

Composite sample.—A seed sample composed by mixing different subsamples taken from various parts of a seed lot.

Conidia.—An asexual spore which when mature comes away from its conidiophore.

Conidiophore.—A simple or branched hypha on which conidia are produced.

Convolute.—Having one part wholly rolled up longitudinally within another.

Corolla.—The inner cycle of the perianth; the petals considered collectively.

Cotyledon.—The first leaves of the embryo, one in monocotyledons, two or more in dicotyledons.

Culm.—The stem of grasses.

Cutin.—A waxlike substance in the epidermal cells of plant parts which repels liquids from passing through cell walls.

Damping-off.—The collapse of seedlings, ascribed to the attacks of such fungus organisms as *Botrytis vulgaris* and *Pythium* spp.

Dead seed.—Seeds incapable of germinating.

Dehiscent.—Fruits which split open regularly along certain lines to discharge the seeds.

Diaphanoscope.—A dark box, or purity work board, having a small opening in its top, through which a beam of light passes from below; used principally for determining the presence or absence of caryopses within the glumes in certain grass seed samples.

Diastase.—A collective enzyme which changes starches into sugars and sugars into starches.

Dicotyledon.—Having two cotyledons.

Diploid.—Having a double number of chromosomes (2N).

Dormant seed.—A viable seed which is inactive because it has not been given the usual conditions for germination; as used in this manual it refers to a seed which resists germination when given the usual conditions for germination.

Dormancy.—Delayed germination or growth; a condition of inactivity.

Elliptic.—Oblong with flowing lines, the two ends pointed and approximately alike in width.

Elliptic, narrowly.—About twice as long as broad.

Elliptic, broadly.—Length only slightly more than width.

Embryo.—The rudimentary plant formed in a seed; germ.

Endosperm.—The reserve, stored food of seeds, outside the embryo; referred to as "albumen" by older writers.

Enzyme.—A complex substance probably protein in nature produced by living cells and active as catalysts accelerating or retarding chemical reactions.

Epicotyl.—That portion of an embryo or seedling above the cotyledons or cotyledonary node; plumule.

Epigeal.—Plants in which the cotyledons appear above the surface of the soil.

Epithelium.—A cellular tissue serving as an epidermis.

Ergot.—A substance produced by a fungus which takes the place of the grain in rye and other grasses.

Filament.—The part of the stamen supporting the anther.

Filiform.—Threadlike, slender.

Floret.—In grasses, the lemma and palea with included flower (stamens and pistil).

Fluorescence.—The property of substances of becoming luminous when exposed to ultraviolet and other forms of radiant energy.

Foreign seeds.—Seeds of weeds and crops other than the kind under consideration or being tested.

Free-flowing seeds.—Nonchaffy, smooth seeds which will travel easily through sampling or mixing devices.

Funiculus.—The stalk by which the ovule or seed is attached to the placenta of the ovary.

Fruit.—The mature ovary and any associated parts.

Gall.—Swelling or excrescence of the tissue of plants resulting from the attacks of certain parasites; or seed structures in which the contents have been replaced by nematodes or eelworms.

Gametophyte.—The generation in the life history of a plant which usually comes from a spore; characterized by haploid chromosome number; ultimately produces gametes.

Geniculate.—Bent abruptly, like a knee.

Genotype.—Alike in genetic characters.

Germ plasm.—The assumed reproductive substance contained in the body of the parent from which new individuals arise; nucleus of the zygote.

Germinable.—Possibility of germination.

Germination.—Resumption of active growth by the embryo in a seed. In seed testing: The emergence and development from the seed embryo of those essential structures which, for the kind of seed in question, are indicative of its ability to produce a normal plant under favorable conditions.

Germination percentage.—The percentage of the pure seed of the kind under consideration which produces normal seedlings.

Glabrous.—Devoid of hairs.

Globose.—Spherical or nearly so.

Glumes.—The pair of bracts at the base of a spikelet in grasses.

Granular.—Surface roughened by minute granules.

Haploid.—Having the basic chromosome number for the species.

Hard seed.—Seeds which remain hard at the end of the prescribed test because they have not absorbed water, owing to an impermeable seed coat.

Hemitropous (ovule).—An ovule which is inverted with a straight nucellus and the micropyle and chalaza are at right angles to the funiculus.

Hilum.—A scar left where the seed stalk or funiculus breaks away, or where the seed was attached directly to the placenta when there is no seed-stalk.

Hirsute.—Pubescent with straight, rather stiff hairs.

Hispid.—Pubescent with stiff or rigid hairs.

Histogen.—Regions or layers of meristematic tissue from which primary tissues are derived.

Hyaline.—Having no color; thin and transparent.

Hydrolysis.—A decomposition reaction caused by water.

Hypha.—One of the threads of a fungus mycelium.

Hypocotyl.—The part of the embryo or seedling below the cotyledonary node and above the root; the transition region connecting the stem and root.

Hypogeal.—Plants in which the cotyledons remain below the surface of the soil.

Imbibition.—Absorption of moisture by a colloidal substance such as seed coats which is accompanied by swelling of the tissue.

Immature (seeds).—Not fully developed; not having parts developed.

Inhibit.—To hold back; to check; to restrain; hinder.

Indehiscent.—Fruits which do not open at maturity.

Inert matter.—As used in seed testing: Refers to all foreign matter not seeds, such as stones, sticks, sterile florets, chaff, fungus bodies, and pieces of seeds not more than one-half the original seed.

Integument.—The envelope of an ovule, later becoming a part of the seed coat.

Interpretation (germination).—A seed shall be considered to have germinated when it has developed into a normal seedling. Broken seedlings and weak, malformed, and obviously abnormal seedlings shall not be considered to have germinated.

Involucre.—A ring of bracts surrounding several flowers or their supports, as in the heads of Compositae or the umbels of Umbelliferae.

Involute.—Having edges of leaves rolled inwards.
Keel.—A sharp longitudinal fold, like the ridge of a boat.
Lance-shaped.—Longer than wide and tapering to both ends, but broader at the base.
Lanceolate.—Narrowly lance-shaped.
Lax.—Soft, drooping.
Lemma.—The outer bract of the flower of grasses, sometimes referred to as the flowering glume.
Lesion.—A wound; a well-marked but limited diseased area.
Lignin.—A substance related to cellulose which with it constitutes the essential part of woody tissue.
Lipase.—An enzyme which brings about hydrolysis of fats to glycerol and fatty acids.
Macroconidia.—The larger conidia, when there are conidia of two sizes.
Malpighian cells.—A protective layer of close packed, heavy-walled columnar cells found in most seed coats of legumes.
Manometer.—An instrument for measuring the pressure of gases and vapors. It is used in measuring air pressure in conjunction with certain seed blowers.
Megagamete.—The larger of two uniting cells or gametes; the egg.
Megaspore.—A tetraspore from which the megagametophyte develops.
Megaspore mother cell.—A specialized cell in the nucellus giving rise to four megaspores.
Meristem.—A group of embryonic cells whose derivatives may differentiate into various cell types and tissues.
Mericarp.—One of the two carpels of the fruit of an umbelliferous plant.
Micropyle.—The opening from outside the seed leading through the integuments to the nucellus; it marks the position of the radicle.
Microspore mother cell.—Special cells in the anther which give rise to the pollen grain.
Monocotyledon.—Having one cotyledon.
Morphology (seed).—The study of the form and structure of seed parts.
Muriform.—Having cross and longitudinal septa.
Mycelium.—A mass of hyphae.
Necrotic.—Death of plant cells, especially when resulting in the tissues becoming dark in color.
Nematodes.—Threadlike roundworms that live in soil and water and belong to the Nemathelminthes.
Noxious-weed seed.—Seeds from any plant considered to be extremely destructive or harmful to agriculture. These seeds are designated by law for State and Federal law enforcement.
Noxious-weed seed, primary.—Seed from noxious-weed plants restricted by law from being present in any quantity in agricultural seeds.
Noxious-weed seed, prohibited.—See noxious-weed seed, primary.
Noxious-weed seed, secondary.—Seed from noxious-weed plants permitted by law to be present in limited numbers in agricultural seeds.
Nucellus.—The body of the ovule containing the embryo sac.

Nucleus.—A clearly differentiated portion of the protoplasm which carries hereditary material and is essential to many of the activities of the cell.
Obclavate.—Inversely club-shaped (widest at the base).
Oblong.—About twice as long as broad, sides nearly parallel or somewhat curving, ends obtusely pointed.
Obovate.—Egg-shape inverted, the broader end at the top.
Obtuse.—Broad and rounded at the apex, or terminating in a short, blunt point in contrast to acute.
Optimum conditions.—The environmental factors, such as temperatures, light, and moisture, which are most conducive to the vital activities of a given organism.
Orbicular.—Length and width approximately equal, and scarcely tapering at the ends.
Origin (seed).—State or country where seed is grown.
Orthotropous (ovule).—Referring to an ovule in which the nucellus is erect with the micropyle farthest from the hilum, in a straight line with it and the chalaza; also called atropous.
Osteosclerid cells.—A layer of cells beneath the Malpighian cells (palisade cells) in the outer integument of legume seeds.
Other crop seeds.—Seeds which are grown as crops other than the kind of seed on which the test is being made.
Oval.—Length only slightly more than width.
Ovary.—The part of the pistil that contains the ovule or ovules.
Ovate.—Egg-shaped, the broader end at the base.
Ovule.—The nucellus enclosed in its integuments; the structure which after fertilization develops into a seed.
Ovule (types).—See Anatropous, Amphitropous, Campylotropous, and Orthotropous.
Oxidase.—General name for a class of enzymes which catalyze oxidative reactions within the cell, such as in the process of respiration.
Palea.—The tiny upper bract which with the lemma encloses the flower in grasses.
Palisade cells.—Outermost layer of cells in the outer integument or seed coat in legumes.
Parasite (fungi).—Fungi which obtain nutrients from living tissue of their hosts.
Parenchyma.—Simple nonspecialized cellular tissue of plants.
Pectin.—A chemical constituent of the cell walls of plants.
Pedicel.—The stalk of a spikelet.
Perianth.—The floral envelope comprised of the calyx and corolla (if present) regardless of their form.
Pericarp.—The mature ovary wall.
Perithecium.—A flask-shaped structure with an ostiole or opening containing asci and paraphyses or sterile hyphae.
Petal.—One of the members of the corolla.
Phenotype.—Alike in obvious physical characters.
Phloem.—Complex vascular tissue in plants which includes sieve tubes and conducts food materials.
Physiology (seed).—The study of the functions and activities of seeds.

Pistil.—A carpel or group of undiverged carpels, commonly subdivided into stigma, style, and ovary.

Pitted.—Marked with small depressions or pits.

Pollen.—The fertilizing powder contained in the anther.

Pollination.—The transference of pollen from the anthers to the stigmas of flowers.

Prechill.—To place seeds on a moist substratum and hold at a low temperature, usually 10° C., for a definite period of time before transferring them to a higher germination temperature.

Propagate.—To multiply or increase.

Protease.—A collective enzyme which brings about hydrolysis of proteins to amino acids.

Protein.—Complex organic compounds which contain oxygen, hydrogen, carbon, nitrogen, and generally sulfur; essential for production of new protoplasm.

Pubescent.—Covered with soft, short hairs.

Pure-live seed.—Percentage of pure germinating seed; determined by multiplying the pure seed percentage by its own germination percentage and dividing the product by 100.

Pure seed.—The principal named kind, variety, or type of seed in a seed lot.

Pycnidia.—A globose structure with an opening or pore termed ostiole, containing pycnospores.

Rachilla.—The axis of a grass spikelet; the small stem on which the flower or floret is borne as opposed to the central axis or rachis.

Radial.—Pertaining to or resembling a ray or radius.

Radicle.—The rudimentary root of the embryo.

Raphe.—A line or ridge of the ovule which runs from the hilum to the chalaza in anatropous and amphitropous seeds.

Receptacle.—The portion of the axis from which the floral parts arise; the torus.

Rudimentary (embryo).—An embryo which is imperfectly developed and functionally useless.

Saprophyte (fungi).—Fungi which obtain nutrients from dead material or nonliving tissues of their hosts.

Scabrous.—Rough to the touch, covered with minute points or very short stiff hairs.

Scarify.—To scratch or roughen the hard seed coat (generally of legumes) in order to aid germination.

Schizocarp.—A fruit derived from a compound pistil in which the one-seeded carpels separate from one another at maturity, as in the Umbelliferae.

Sclerotia.—A firm frequently rounded mass of hyphae with or without the addition of host tissue normally having no spores in or on it.

Scutellum.—The cotyledon of an embryo of a grass; a food absorbing structure.

Seed.—An embryo or embryos with or without an external food reserve surrounded by one or two integuments.

Seed (kind).—One or more related species or subspecies which singly or collectively is known by one common name.

Seed lot.—A uniformly blended quantity of seed designated by a proper number or mark.

Seed, other crop.—Seeds of plants grown as crops other than the kind, variety, or type included in the pure seed.
Seed stocks.—A marked variety which may be perpetuated from seed.
Seed technology.—Science of seed testing.
Seeds, agricultural.—Includes all grass, forage, and field crop seeds.
Seeds, vegetable—Seeds generally grown in gardens or on truck farms.
Seedling.—The embryo or young plant from the time it emerges from the seed until it is entirely dependent on food manufactured by itself. It consists of an epicotyl, one or two cotyledons, hypocotyl, and root; the single cotyledon is usually held within the seed coat in monocots.
Seedling, abnormal.—Having weak or malformed parts, such as stubby roots, split hypocotyls, absence of primary leaves, and absence of terminal bud; not potentially capable of producing a normal plant under favorable growing conditions.
Seedling, normal.—Having healthy, well-formed structures, such as epicotyl, one or two cotyledons, hypocotyl, and root; potentially capable of producing a healthy plant under favorable growing conditions.
Sepal.—One of the members of the calyx.
Sessile.—With or without a pedicel or stalk.
Sinus.—The space between the margin of lemma above the point of attachment to the rachilla.
Smooth.—Not rough to the touch.
Spatulate.—Broad and rounded at the apex, narrowed toward the base.
Spikelet.—The unit of influorescence in grasses, consisting of two glumes and one or more florets.
Sporophyte.—The plant as it is commonly known, having the diploid chromosome number.
Stamen.—A pollen-bearing organ.
Stellate.—Star-shaped.
Stereoscopic microscope.—A microscope having two oculars which give depth to the object being viewed, or the appearance of solidity.
Stigma.—The receptive portion of the pistil.
Striate.—Marked with slender longitudinal grooves or lines.
Strophiole.—A swollen appendage at the hilum of some seeds.
Style.—The usually elongated portion of the pistil connecting the stigma and ovary.
Stroma.—A mass of vegetative hyphae with or without tissue of the host or substratum, sometimes sclerotiumlike in form, in or on which spores are produced.
Suberin.—A fatty substance found between cell walls which renders cells almost or entirely impermeable to water.
Substratum.—The material upon which seeds are placed for a germination test.
Suture.—A line of splitting or dehiscence.
Swollen seed.—Seeds which have imbibed water and although healthy in appearance, have not germinated during the prescribed test period.
Synergids.—The nuclei or cells adjacent to the egg cell at the micropylar end of the embryo sac.

Tangential.—At right angles to the radius or radial rays.
Temperature, alternating.—In germination testing, specific temperatures with seeds being held at both the lower and higher temperatures for a designated time each day.
Temperature, constant.—In germination testing, a specific temperature which should not vary by more than 1° C.
Testa.—Hard outer seed coat or seed coats.
Tolerance.—A specified or calculated allowance for sampling variation and sometimes experimental error.
Toxic.—Acting, or likely to act as a poison.
Transversely.—Across, horizontal.
Tubercle.—A small projection.
Truncate.—Ending abruptly, as if cut off horizontally.
Undulate.—With a wavy surface.
Viability.—Ability to live, grow, and develop.
Villous.—Bearing long and soft hairs.
Vigor.—Strength or force of seedling and plant growth; as, a plant grows with vigor.
Web, basal.—A tuft of long hairs attached at one point just above the callus in certain bluegrasses.
Weed seed.—Seed of any troublesome plant which occurs without intentional cultivation.
Woolly.—Clothed with long and entangled soft hairs.
Working sample.—A specified weight of seed on which a purity analysis is made.
Xylem.—A complex vascular tissue in plants including tracheids and vessels in which water is conducted.
Zygote.—The product of the union of two gametes; a fertilized egg.

APPENDIX

RULES FOR TESTING SEEDS

SAMPLING

Ordinarily, it is not the duty of the analyst nor does he have the opportunity to take samples, but he should be prepared to suggest the best sampling procedure. No matter how accurately an analysis is made, it can show only the quality of the sample submitted; therefore, every effort should be made to insure that the sample furnished represents the bulk of the seed to be tested.

General Procedure

(*a*) In order to secure a representative sample, equal portions shall be taken from evenly distributed parts of the quantity of seed to be sampled. Access shall be had to all parts of that quantity.

(*b*) For free-flowing seeds in bags or bulk, a probe or trier shall be used. For small free-flowing seeds in bags a probe or trier long enough to sample all portions of the bag shall be used.

(*c*) Non-free-flowing seeds, such as certain grass seed, uncleaned seed, or screenings, difficult to sample with a probe or trier, shall be sampled by thrusting the hand into the bulk and withdrawing representative portions.

(*d*) Composite samples shall be obtained to determine the quality of a lot of seed (that is, percentages of pure seed, other crop seed, weed seed, inert matter, and germination). Individual-bag samples may be obtained to determine whether the lot of seed is uniform.

(1) To determine whether there is an obvious lack of uniformity of seed from which a composite sample is being obtained, each portion shall be examined and the portions shall then be combined to form a composite sample or samples.

(2) If the lot is found not to be uniform when obtaining a composite sample to determine its quality then additional individual-bag samples shall be taken for the purpose of testing for uniformity. Such individual-bag samples may also be taken for the purpose of testing for uniformity even though a composite sample has not previously been obtained. The identity of each individual-bag sample must be maintained.

Bulk

Bulk seeds shall be sampled by inserting a long probe or by thrusting the hand into the bulk, as circumstances require, in at least seven uniformly distributed parts of the quantity being sampled.

Bags

(*a*) To obtain a composite sample:

(1) In quantities of five bags or less, each bag shall be sampled.

(2) In quantities of more than five bags, at least every fifth bag, but not less than five bags, shall be sampled.

(3) For inspection purposes unopened bags shall be sampled except under circumstances where the identity of the seed has been preserved.

(*b*) To obtain individual-bag samples:

In obtaining samples to test for uniformity at least four bags shall be sampled if there are less than 100 bags in the lot; seven bags if there are from 100 to 400 bags in the lot, and 10 bags if there are over 400 bags in the lot.

Packets

In sampling seeds in packets, entire unopened packets shall be taken.

Size of Sample

(*a*) For composite samples to test for quality, the following are minimum weights for samples of seed to be submitted for analysis, test, or examination:

(1) Two ounces (approximately 55 grams) of grass seed not otherwise mentioned, white or alsike clover, or seeds not larger than these.

(2) Five ounces (approximately 150 grams) of red or crimson clover, alfalfa, lespedezas, ryegrasses, bromegrasses, millet, flax, rape, or seeds of similar size.

(3) One pound of Sudan grass, sorghum, proso, hemp seed, or seeds of similar size.

(4) Two pounds (approximately 1,000 grams) of cereals, vetches, or seeds of similar or larger size.

(5) Vegetable seed samples shall consist of at least 400 seeds.

(*b*) For individual-bag samples to test for uniformity:

The size of any individual-bag sample to determine uniformity in a lot of seed shall be not less than the quantities set out in the column "Minimum weight for noxious-weed seed examination" for the respective kinds of seed listed in table 3.

If the sample drawn is larger than desired it shall be thoroughly mixed before it is divided to the desired size.

Forwarding and Receipt of Official Samples

Before being forwarded for analysis, test, or examination the containers of official samples shall be properly sealed and identified. The containers of official samples shall be initialed and dated, and the sample shall be weighed by the person who breaks the seals.

ANALYSIS OF THE SEED

The standard analysis and test for germination for law enforcement, labeling, and general information as to seed quality, should determine for the sample analyzed: (1) The purity composition, including an identification to determine the kind of seed, and, if possible from appearance, the varietal composition; (2) the rate of occurrence of noxious-weed seeds per unit weight; and (3) the percentage germination of the pure seed under consideration.

Obtaining the Working Sample

The working sample on which the actual analysis is made shall be taken from the submitted sample in such a manner that it will be

representative. The sample shall be repeatedly divided to obtain the weight to be used for the working sample. With free-flowing seed, some form of efficient mechanical divider shall be used. With non-free-flowing seed of a character that a mechanical divider cannot be used, the sample shall be thoroughly mixed and placed in a pile, and the pile shall be repeatedly divided into halves until a sample of the desired weight remains.

Weight of Working Sample

For the detailed purity analysis, the working samples of agricultural and vegetable seeds shall be at least the weights set forth in table 3. For those seeds not listed approximately 3,000 seeds shall be used.

TABLE 3.—*Minimum weights and approximate numbers of seeds in working samples for purity analyses*

Name of seed	Minimum weight for purity analysis	Minimum weight for noxious-weed seed examination	Approximate number of seeds per gram	Approximate number of seeds per ounce
AGRICULTURAL SEED	*Grams*	*Grams*	*Number*	*Number*
Alfalfa—*Medicago sativa*	5	50	500	14, 175
Alfilaria—*Erodium cicutarium*	5	50	441	15, 364
Bahia grass—*Paspalum notatum*	10	50	366	10, 376
Barley—*Hordeum vulgare*	100	500	30	851
Bean:				
Adzuki—*Phaseolus angularis*	500	500	11	312
Field—*Phaseolus vulgaris*	500	500	4	113
Mung—*Phaseolus aureus*	100	500	24	680
Velvet—*Stizolobium deeringianum*	500	500	2	57
Beet, field and sugar—*Beta vulgaris*	50	300	54	1, 531
Beggarweed, Florida—*Desmodium tortuosum*	5	50	442	12, 541
Bentgrass:				
Astoria—*Agrostis tenuis*	½	25	12, 048	341, 560
Creeping—*Agrostis palustris*	½	25	17, 196	487, 521
Colonial—*Agrostis tenuis*	½	25	19, 231	545, 199
Highland—*Agrostis tenuis*	½	25	20, 000	567, 000
Velvet—*Agrostis canina*	½	25	23, 810	675, 014
Bermuda grass—*Cynodon dactylon*	1	25	3, 940	111, 699
Bluegrass:				
Annual—*Poa annua*	1	25	2, 636	74, 731
Bulbous—*Poa bulbosa*	2	50	1, 020	28, 968
Canada—*Poa compressa*	1	25	5, 500	155, 925
Kentucky—*Poa pratensis*	1	25	4, 800	136, 080
Nevada—*Poa nevadensis*	1	25	2, 304	65, 434
Rough—*Poa trivialis*	1	25	5, 600	158, 760
Texas—*Poa arachnifera*	1	25	2, 500	71, 000
Wood—*Poa nemoralis*	1	25	7, 097	201, 200

TABLE 3.—*Minimum weights and approximate numbers of seeds in working samples for purity analyses*—Continued

Name of seed	Minimum weight for purity analysis	Minimum weight for noxious-weed seed examination	Approximate number of seeds per gram	Approximate number of seeds per ounce
AGRICULTURAL SEED—continued				
Bluestem:	*Grams*	*Grams*	*Number*	*Number*
Big—*Andropogon furcatus* [1]	10	50	336	9,542
Little—*Andropogon scoparius* [1]	5	50	560	15,904
Sand—*Andropogon hallii* [1]	10	50	233	6,617
Brome, mountain—*Bromus marginatus*	25	150	141	4,004
Brome, smooth—*Bromus inermis*	5	50	300	8,505
Broomcorn—*Sorghum vulgare* var. *technicum*	50	300	60	1,704
Buckwheat—*Fagopyrum esculentum*	50	300	45	1,276
Buffalo grass—*Buchloë dactyloides:* [2]				
Burs	50	300	110	3,124
Caryopses	2	50	738	20,959
Canary grass—*Phalaris canariensis*	25	150	150	4,254
Canary grass, reed—*Phalaris arundinacea*	2	50	1,200	34,020
Carpet grass—*Axonopus affinis*	1	25	2,475	70,166
Chickpea—*Cicer arietinum*	500	500	2	57
Clover:				
Alsike—*Trifolium hybridum*	2	50	1,500	42,525
Alyce—*Alysicarpus vaginalis*	5	50	664	18,824
Berseem—*Trifolium alexandrinum*	5	50	456	12,928
Bur—*Medicago hispida* (in bur)	50	300		
Bur—*Medicago hispida* (out of bur)	10	50	375	10,650
Bur, spotted—*Medicago arabica* (in bur)	50	300	49	1,389
Bur, spotted—*Medicago arabica* (out of bur)	10	50	550	15,620
Button—*Medicago orbicularis*	10	50	337	9,554
Cluster—*Trifolium glomeratum*	1	25	2,924	82,895
Crimson—*Trifolium incarnatum*	10	50	330	9,356
Ladino—*Trifolium repens*	2	50	1,937	55,010
Lappa—*Trifolium lappaceum*	2	50	1,500	42,525
Large hop—*Trifolium procumbens*	1	25	5,434	154,326
Persian—*Trifolium resupinatum*	2	50	1,416	40,144
Red—*Trifolium pratense*	5	50	600	17,010
Sour—*Melilotus indica*	5	50	662	18,768
Strawberry—*Trifolium fragiferum*	5	50	635	18,002
Sub—*Trifolium subterraneum*	25	150	119	3,374
Suckling or small hop—*Trifolium dubium*	2	50	1,948	55,226
Sweet:				
White—*Melilotus alba*	5	50	570	16,160
Yellow—*Melilotus officinalis*	5	50	570	16,160
White—*Trifolium repens*	2	50	1,500	42,525
Corn:				
Field—*Zea mays*	500	500	3	85
Pop—*Zea mays* var. *everta*	500	500		

See footnotes at end of table.

TABLE 3.—*Minimum weights and approximate numbers of seeds in working samples for purity analyses*—Continued

Name of seed	Minimum weight for purity analysis	Minimum weight for noxious-weed seed examination	Approximate number of seeds per gram	Approximate number of seeds per ounce
AGRICULTURAL SEED—continued				
	Grams	*Grams*	*Number*	*Number*
Cotton—*Gossypium* spp.	500	500	8	227
Cowpea—*Vigna sinensis*	500	500	8	227
Crested dogtail—*Cynosurus cristatus*	2	50	1, 900	53, 865
Crotalaria:				
Crotalaria intermedia	10	50	207	5, 878
Crotalaria juncea	100	500	36	1, 022
Crotalaria lanceolata	10	50	375	10, 650
Crotalaria spectabilis	25	150	80	2, 268
Crotalaria striata	10	50	215	6, 106
Dallis grass—*Paspalum dilatatum*	[3] 2	50	592	16, 795
Dropseed, sand—*Sporobolus cryptandrus*	½	25	11, 927	338, 727
Fescue:				
Chewings—*Festuca rubra* var. *commutata*	2	50	1, 200	34, 120
Hair—*Festuca capillata*	1	25	3, 200	90, 720
Meadow—*Festuca elatior*	5	50	500	14, 175
Red—*Festuca rubra*	2	50	1, 200	34, 120
Sheep—*Festuca ovina*	2	50	1, 167	33, 143
Tall—*Festuca arundinacea*	5	50	500	14, 175
Flax—*Linum usitatissimum*	10	50	178	5, 046
Grama:				
Blue—*Bouteloua gracilis* [1]	2	50	1, 977	56, 147
Side-oats—*Bouteloua curtipendula:* [4]				
Other than caryopses	5	50	422	11, 985
Caryopses	2	50	1, 607	45, 639
Guinea grass—*Panicum maximum*	5	50	2, 207	62, 540
Harding grass—*Phalaris tuberosa* var. *stenoptera*	5	50	750	21, 300
Hemp—*Cannabis sativa*	50	300	46	1, 304
Indian grass, yellow—*Sorghastrum nutans* [1]	10	50	364	10, 338
Japanese lawngrass—*Zoysia japonica*	2	50	3, 012	85, 541
Johnson grass—*Sorghum halepense*	10	50	290	8, 222
Kudzu—*Pueraria thunbergiana*	25	150	81	2, 296
Lespedeza:				
Sericea or Chinese—*Lespedeza cuneata* (*L. sericea*)	5	50	820	23, 248
Common (including Kobe)—*Lespedeza striata*	5	50	750	21, 263
Korean—*Lespedeza stipulacea*	5	50	525	14, 884
Siberian—*Lespedeza hedysaroides*	5	50	820	23, 288
Lovegrass, weeping—*Eragrostis curvula*	1	25	3, 282	93, 208
Lupine:				
Blue—*Lupinus angustifolius*	500	500	7	198
White—*Lupinus albus*	500	500	7	198
Yellow—*Lupinus luteus*	500	500	9	225
Manila grass—*Zoysia matrella*	2	50	-------	-------
Meadow foxtail—*Alopecurus pratensis*	2	50	1, 200	34, 020
Medic, black—*Medicago lupulina*	5	50	586	16, 613

See footnotes at end of table.

TABLE 3.—*Minimum weights and approximate numbers of seeds in working samples for purity analyses*—Continued

Name of seed	Minimum weight for purity analysis	Minimum weight for noxious-weed seed examination	Approximate number of seeds per gram	Approximate number of seeds per ounce
AGRICULTURAL SEED—continued				
	Grams	*Grams*	*Number*	*Number*
Millet:				
Browntop—*Panicum fasciculatum*	10	50	303	8, 590
Foxtail, German, Hungarian, Golden or Siberian—*Setaria italica*	5	50	470	13, 325
Japanese—*Echinochloa crusgalli* var. *frumentacea*	10	50	320	9, 072
Pearl—*Pennisetum glaucum*	25	150	194	5, 500
Proso—*Panicum miliaceum*	25	150	180	5, 103
Molasses grass—*Melinis minutiflora*	1	25	15, 000	425, 250
Mustard:				
Black—*Brassica nigra*	5	50	1, 256	35, 608
White—*Brassica hirta*	25	150	162	4, 593
Napier grass—*Pennisetum purpureum*	5	50	----	----
Oats—*Avena sativa* and *A. byzantina*	100	500	28	794
Oatgrass, tall meadow—*Arrhenatherum elatius*	10	50	330	9, 356
Orchard grass—*Dactylis glomerata*	2	50	1, 441	40, 852
Panic grass, blue—*Panicum antidotale*	2	50	1, 448	41, 123
Peanut—*Arachis hypogaea*	500	500	1–3	----
Peas, field—*Pisum sativum* var. *arvense*	500	500	4	113
Rape:				
Annual—*Brassica napus* var. *annua*	10	50	346	9, 809
Bird—*Brassica campestris*	10	50	425	12, 049
Turnip—*Brassica campestris* vars	10	50	536	15, 196
Winter—*Brassica napus* var. *biennis*	10	50	230	6, 521
Redtop—*Agrostis alba*	½	25	11, 000	311, 850
Rescue grass—*Bromus catharticus*	25	150	144	4, 089
Rhodes grass—*Chloris gayana*	1	25	4, 724	133, 925
Rice—*Oryza sativa*	100	500	66	1, 871
Ricegrass, Indian—*Oryzopsis hymenoides*	10	50	308	8, 747
Rough pea—*Lathyrus hirsutus*	100	500	39	1, 095
Rye—*Secale cereale*	100	500	40	1, 134
Ryegrass:				
Italian—*Lolium multiflorum*	5	50	500	14, 175
Perennial—*Lolium perenne*	5	50	500	14, 175
Sainfoin—*Onobrychis viciaefolia*	50	300	50	1, 418
Sesame—*Sesamum orientale*	10	50	360	10, 206
Sesbania—*Sesbania exaltata*	25	150	105	2, 982
Smilo—*Oryzopsis miliacea*	2	50	2, 008	57, 027
Sorghum:				
(Grain and Sweet)—*Sorghum vulgare*	50	300	50–55	{ 1, 418– 1, 559
Soybean—*Glycine max*	500	500	6–13	175–435
Sudan grass—*Sorghum vulgare* var. *sudanense*	25	150	120	3, 402
Sunflower (Cult.)—*Helianthus annuus*	100	500	----	----
Sweet vernal grass—*Anthoxanthum odoratum*	2	50	1, 600	45, 360
Switch grass—*Panicum virgatum*	5	50	814	23, 117
Timothy—*Phleum pratense*	2	50	2, 500	70, 875

957116—52——23

TABLE 3.—*Minimum weights and approximate numbers of seeds in working samples for purity analyses*—Continued

Name of seed	Minimum weight for purity analysis	Minimum weight for noxious-weed seed examination	Approximate number of seeds per gram	Approximate number of seeds per ounce
AGRICULTURAL SEED—continued	*Grams*	*Grams*	*Number*	*Number*
Tobacco—*Nicotiana tabacum*	½	25	15, 625	442, 969
Trefoil, big—*Lotus uliginosus*	2	50	1, 944	55, 209
Trefoil, birdsfoot—*Lotus corniculatus*	2	50	814	23, 117
Vasey grass—*Paspalum urvillei*	2	50	970	27, 548
Velvet-grass—*Holcus lanatus*	1	25	3, 359	95, 060
Vetch:				
Common—*Vicia sativa*	100	500	19	539
Hairy—*Vicia villosa*	100	500	36	1, 021
Hungarian—*Vicia pannonica*	100	500	24	680
Monantha—*Vicia articulata* (*V. monantha*)	100	500		
Narrowleaf—*Vicia angustifolia*	50	300	60	1, 701
Purple—*Vicia atropurpurea*	100	500	22	624
Woollypod—*Vicia dasycarpa*	100	500	25	709
Wheat: Common, spelt, emmer, durum, club, Polish—*Triticum* spp	100	500	25	709
Wheatgrass:				
Crested, fairway—*Agropyron cristatum*	5	50	714	20, 242
Crested, standard—*Agropyron cristatum*	10	50	425	12, 049
Slender—*Agropyron trachycaulum*	10	50	340	9, 639
Western—*Agropyron smithii*	10	50	235	6, 662
Wild-rye, Canada—*Elymus canadensis*	10	50	261	7, 412
VEGETABLE SEED				
Artichoke—*Cynara scolymus*	100	500	24	680
Asparagus—*Asparagus officinalis*	100	500	25	709
Bean:				
Asparagus—*Vigna sesquipedalis*	100	500	8	227
Garden—*Phaseolus vulgaris*	500	500	4	113
Horse or broad—*Vicia faba*	500	500		
Lima—*Phaseolus lunatus* var. *macrocarpus*	500	500	2	57
Runner—*Phaseolus coccineus*	500	500		
Beet, mangel—*Beta vulgaris*	50	300	58	1, 644
Broccoli—*Brassica oleracea* var. *botrytis*	10	50	315	8, 930
Brussels sprouts—*Brassica oleracea* var. *gemmifera*	10	50	315	8, 930
Cabbage—*Brassica oleracea* var. *capitata*	10	50	315	8, 930
Cardoon—*Cynara cardunculus*	100	500		
Carrot—*Daucus carota*	5	50	826	23, 417
Cauliflower—*Brassica oleracea* var. *botrytis*	10	50	315	8, 930
Celeriac—*Apium graveolens* var. *rapaceum*	1	25	2, 521	71, 470
Celery—*Apium graveolens* var. *dulce*	1	25	2, 521	71, 470
Chicory—*Cichorium intybus*	5	50	940	26, 649
Citron—*Citrullus vulgaris*	500	500	11	312
Collards—*Brassica oleracea* var. *acephala*	10	50	315	8, 930
Corn, sweet—*Zea mays*	500	500		

TABLE 3.—*Minimum weights and approximate numbers of seeds in working samples for purity analyses*—Continued

Name of seed	Minimum weight for purity analysis	Minimum weight for noxious-weed seed examination	Approximate number of seeds per gram	Approximate number of seeds per ounce
VEGETABLE SEED—continued				
	Grams	*Grams*	*Number*	*Number*
Cornsalad (Fetticus)—*Valerianella locusta* var. *olitoria*	10	50	380	10, 773
Cowpea—*Vigna sinensis*	500	500	8	227
Cress:				
Garden—*Lepidium sativum*	5	50	424	12, 020
Water—*Rorippa nasturtium-aquaticum*	1	25	5, 172	146, 626
Cucumber—*Cucumis sativus*	100	500	38	1, 077
Dandelion—*Taraxacum officinale*	2	50	1, 240	35, 154
Eggplant—*Solanum melongena* var. *esculentum*	10	50	228	6, 464
Endive—*Cichorium endivia*	5	50	940	26, 649
Kale [5]—*Brassica oleracea* var. *acephala*	10	50	315	8, 930
Kohlrabi—*Brassica oleracea* var. *gongylodes*	10	50	315	8, 930
Leek—*Allium porrum*	10	50	396	11, 227
Lettuce—*Lactuca sativa*	5	50	888	25, 175
Muskmelon—*Cucumis melo*	100	500	45	1, 276
Mustard:				
India—*Brassica juncea*	5	50	624	17, 690
Spinach—*Brassica perviridis*	5	50	536	15, 196
Okra—*Hibiscus esculentus*	100	500	19	539
Onion—*Allium cepa*	10	50	341	9, 667
Pakchoi—*Brassica chinensis*	5	50	633	17, 946
Parsley—*Petroselinum hortense*	5	50	648	18, 371
Parsnip—*Pastinaca sativa*	10	50	429	12, 162
Peas, garden—*Pisum sativum*	500	500	3	85
Pepper—*Capsicum* spp	25	150	167	4, 734
Pe-tsai (Chinese cabbage)—*Brassica pekinensis*	5	50	633	17, 946
Pumpkin—*Cucurbita pepo*	500	500	4	113
Radish—*Raphanus sativus*	50	300	75	2, 126
Rhubarb—*Rheum rhaponticum*	50	300	60	1, 701
Rutabaga—*Brassica napus* var. *napobrassica*	10	50	428	12, 134
Salsify—*Tragopogon porrifolius*	50	300	66	1, 871
Sorrel—*Rumex acetosa*	2	50	1, 079	30, 590
Soybean—*Glycine max*	500	500	6–13	175–435
Spinach:				
Common—*Spinacia oleracea*	25	150	100	2, 835
New Zealand—*Tetragonia expansa*	100	500	13	369
Squash—*Cucurbita moschata* and *C. maxima*	500	500	14	397
Swiss chard—*Beta vulgaris* var. *cicla*	50	300	58	1, 644
Tomato:				
Common—*Lycopersicon esculentum*	5	50	405	11, 482
Husk—*Physalis pubescens*	2	50	1, 240	35, 154
Turnip—*Brassica rapa*	10	50	536	15, 196
Watermelon—*Citrullus vulgaris*	500	500	11	312

See footnotes at end of table.

TABLE 3.—*Minimum weights and approximate numbers of seeds in working samples for purity analyses*—Continued

Name of seed	Minimum weight for purity analysis	Minimum weight for noxious-weed seed examination	Approximate number of seeds per gram	Approximate number of seeds per ounce
HERBS	*Grams*	*Grams*	*Number*	*Number*
Dill—*Anethum graveolens*	5	50	800	22, 720
Sage—*Salvia officinalis*	25	150	121	3, 436
Savory—*Satureja hortensis*	2	50	1, 750	49, 700
TENTATIVE METHODS				
Wheatgrass:				
Hairy intermediate—*Agropyron trichophorum*	10	50	--------	--------
Intermediate—*Agropyron intermedium*	10	50	--------	--------
Tall—*Agropyron elongatum*	10	50	--------	--------

[1] Pure seed unit consists of naked caryopsis, or spikelet or floret with at least 1 caryopsis.

[2] Pure seed unit consists of bur, floret, or caryopsis.

[3] If the purity separation of Dallis grass yields less than 400 seeds a duplicate analysis shall be made and the results shall be calculated on the basis of 4 grams.

[4] Pure seed unit consists of spike, spikelet, floret with a caryopsis, or free caryopsis.

[5] Includes the kales which are varieties of *Brassica napus*.

The weight of the working sample in mixtures shall be determined by the kind (or group of kinds of seeds of similar size) which comprises the major proportion of the sample. When there are two or more general weights of seed (based on the weight of the sample in table 3), each present to about the same extent, the analyst will use his judgment in deciding upon the kind or group which will determine the sample weight. The weight of samples for noxious-weed seed examinations in mixtures shall be that given in table 3 for the kind of seed used to determine the weight of the working sample in the mixture.

Separation

The working sample shall be weighed in grams to four significant figures, and shall then be separated into four parts, as follows: (1) Kind, variety, or type to be considered pure seed; (2) other crop seed; (3) weed seed; and (4) inert matter.

Each of these four component parts shall be weighed in grams to the same number of decimal places as the working sample, and the percentage by weight of each part (based on the sum of the weights of the component parts and not on the original weight) shall be determined, except that the pure seed need not be weighed when the minimum working sample is 500 grams; the inert matter, other crop seeds, and weed seeds shall be weighed and their percentages calculated on the basis of the original weight and the pure seed percentage shall be determined by subtracting the sum of the percentages of inert matter,

other crop seeds, and weed seeds from 100 percent. The size of the working sample for any kind of seed shall not be changed from that prescribed under the heading, "Obtaining the Working Sample." The sum of the weights of the component parts shall be compared with the original weight of the working sample as a check against loss of material or other error. In the case of other crop seed and weed seed, the seeds of each species shall be separated where possible, and the number or the weight of each kind shall be determined. The separation of the seed of the kind, variety, or type considered pure seed must be on such a basis that the separation can be made definitely by seed characteristics, except that when the sample contains two or more similar kinds of seeds the separation of which in the entire working sample would be very difficult, it is permissible to separate and weigh the similar seeds as a group. From this mixture at least 400 seeds are to be taken indiscriminately, and the separation made on this portion. The proportion of each kind is then determined by weight or if the seeds are of similar weight the proportion may be determined by count, and from this the percentage in the entire sample is calculated. With reference to classification of crop seeds or fragments thereof, applicable methods of determination may include visual examination, use of reflected light, or specific gravity. This has reference particularly to insect-damaged, broken or diseased seeds, or sterile grass glumes.

Kind, Variety, or Type Considered Pure Seed

The pure seed shall include: (*a*) All seeds of each kind, variety, or type under consideration present in excess of 5 percent of the whole, whether shriveled, cracked, or otherwise injured, and (*b*) pieces of such seeds that are larger than one-half of the original size, whether broken, insect-damaged, or diseased: *Provided*, That seeds of legumes and crucifers with the seed coat entirely removed shall be classified as inert matter and not as pure seed.

Other Crop Seed

Other crop seed shall include: (*a*) Seeds of plants grown as crops (other than the kind, variety, or type included in the pure seed) each kind, variety, or type of which is present in a proportion to the whole of 5 percent or less, whether shriveled, cracked, or otherwise injured, and (*b*) pieces of such seeds larger than one-half of the original size whether broken, insect-damaged, or diseased: *Provided*, That other crop seed shall not include (1) seeds of plants recognized as weeds or (2) seeds of legumes and crucifers with the seed coats entirely removed.

Weed Seed

Seeds, bulblets, or tubers of plants recognized as weeds by laws or official regulations or by general usage shall be considered weed seeds: *Provided*, That undeveloped or badly injured weed seeds, including noxious-weed seeds, as described under inert matter, shall be considered inert matter and not weed seeds. When seeds of *Juncus* spp., are present and would not add more than 0.1 percent to the percentage of weed seed, they need not be separated but may be included with the inert matter. However, the presence of the seed shall be recorded.

Inert Matter

Inert matter shall include seedlike structures from both crop and weed plants and other matter not seeds, as follows:

(*a*) Seedlike structures from crop plants: Pieces of seeds one-half the original size or less, whether broken, insect-damaged, or diseased; seeds of legumes and crucifers with the seed coats entirely removed; empty glumes and sterile florets of grasses; attached sterile florets of grasses (which must be removed from the fertile florets except in bluegrasses, tall meadow oatgrass, Rhodes grass, bluestems, and gramas).

(*b*) Seedlike structures from weed plants: All badly injured, undeveloped, or empty structures which resemble seeds but which by visual examination (including dissection or reflected light) can be definitely demonstrated as having no embryo or having only a rudimentary embryo or having an embryo that has been destroyed by a disease organism. Included as inert matter are structures from weed plants, as follows:

(1) Seeds of grasses with over one-half the embryo removed;

(2) "Seeds" of dodder which are fragile, ashen gray to brown in color, and somewhat enlarged;

(3 Ragweed seed with both the involucre and pericarp absent;

(4) Shriveled, blackened seeds of buckhorn;

(5) Empty seeds or fruits such as occur in the sedge, buckwheat, morning-glory, and sunflower families;

(6) Empty glumes and sterile florets of grasses;

(7) Seeds of legumes and species of *Brassica* with the seed coats entirely removed;

(8) Bulblets of wild onion and garlic with the basal or stem end portion removed;

(9) Seeds of *Juncus* spp., when not in excess of 0.1 percent.

(*c*) Other matter: Soil, sand, stones, chaff, stems, leaves, nematode galls, fungus bodies (such as ergot and other sclerotia and smut balls), and all other matter not seeds.

The above definitions shall not prohibit the separation of pure seed and inert matter of the kinds of seeds listed below by the uniform blowing method using a controlled pressure blower calibrated by means of a standard reference sample. The Subcommittee on Standardized Blowing Techniques may be expected to supply standard reference samples of the kinds of subject seeds. Kinds of subject seeds are Kentucky bluegrass (*Poa pratensis*) and Canada bluegrass (*Poa compressa*).

EXAMINATIONS

Noxious-Weed Seeds

The determination of the number of seeds, bulblets, or tubers of individual noxious weeds present per unit weight should be made on at least the minimum quantities listed in table 3 except that if 30 or more noxious-weed seeds, bulblets, or tubers of one kind are found in the pure seed analysis (or noxious-weed seed examination of a like amount), the occurrence of that species in the remainder of the bulk examined for noxious-weed seeds need not be noted.

Identification and Varietal Determination

The separation representing the kind of seed under consideration should be examined to determine whether it conforms to the name under which it was submitted, or for further information as to varietal composition. If such identification is not possible from seed characters or if it is not attempted, such fact should be recorded and clearly reported or identification may be based on the seedling, growing plant,

or mature plant characteristics according to such authentic information as is available. If a growing test for this purpose is planned, this fact should be reported.

Origin

The presence of incidental weed seeds, foreign matter, or the existence of any other circumstances shall be considered in determining the origin of seed.

Fluorescence Test on Ryegrass

A fluorescence test shall be made on all samples of ryegrass for which the proportion of perennial ryegrass (*Lolium perenne*) and Italian ryegrass (*L. multiflorum*) is to be determined. The seedlings shall be grown on filter paper and the number of fluorescent seedlings determined under the ultraviolet light at the end of the germination period. The percentages of pure seed, fluorescence, nonfluorescence, germination, and dead seed shall be determined and the results shall be subjected to the following formula to calculate the proportion of the two kinds of ryegrass present in a sample:

$$\%\ \text{perennial ryegrass} = \frac{1.0526 \times \%\ \text{nonfluorescence} \times \%\ \text{pure ryegrass}}{\%\ \text{fluorescence} + \%\ \text{nonfluorescence}}$$

Example:

Ryegrass = 98.50%; fluorescence = 16.5%; nonfluorescence = 73.5%.

Substituting, we have, $\frac{1.0526 \times 73.5\% \times 98.50\%}{90\%} = 84.67\%$.

A nomograph may be used in converting results of fluorescence tests to pure seed in lieu of calculating the results from the above formula.

USE OF NOMOGRAPH FOR DETERMINING PURE SEED OF RYEGRASS FROM FLUORESCENCE TESTS

(1) Enter % nonfluorescence on Scale 2. Read off value on Scale 1 at this point. If the % germination is equal to or less than this value on Scale 1, all the pure ryegrass is perennial.

(2) If the germination is greater than this value on Scale 1, proceed as follows:

Join % nonfluorescence on Scale 2 with % pure ryegrass on Scale 4.

Prick off intersection on Scale 3.

Join % germination on Scale 1 and prick-off point on Scale 3 and project to cut Scale 4.

Read on Scale 4 the percentage of pure perennial ryegrass.

Example I

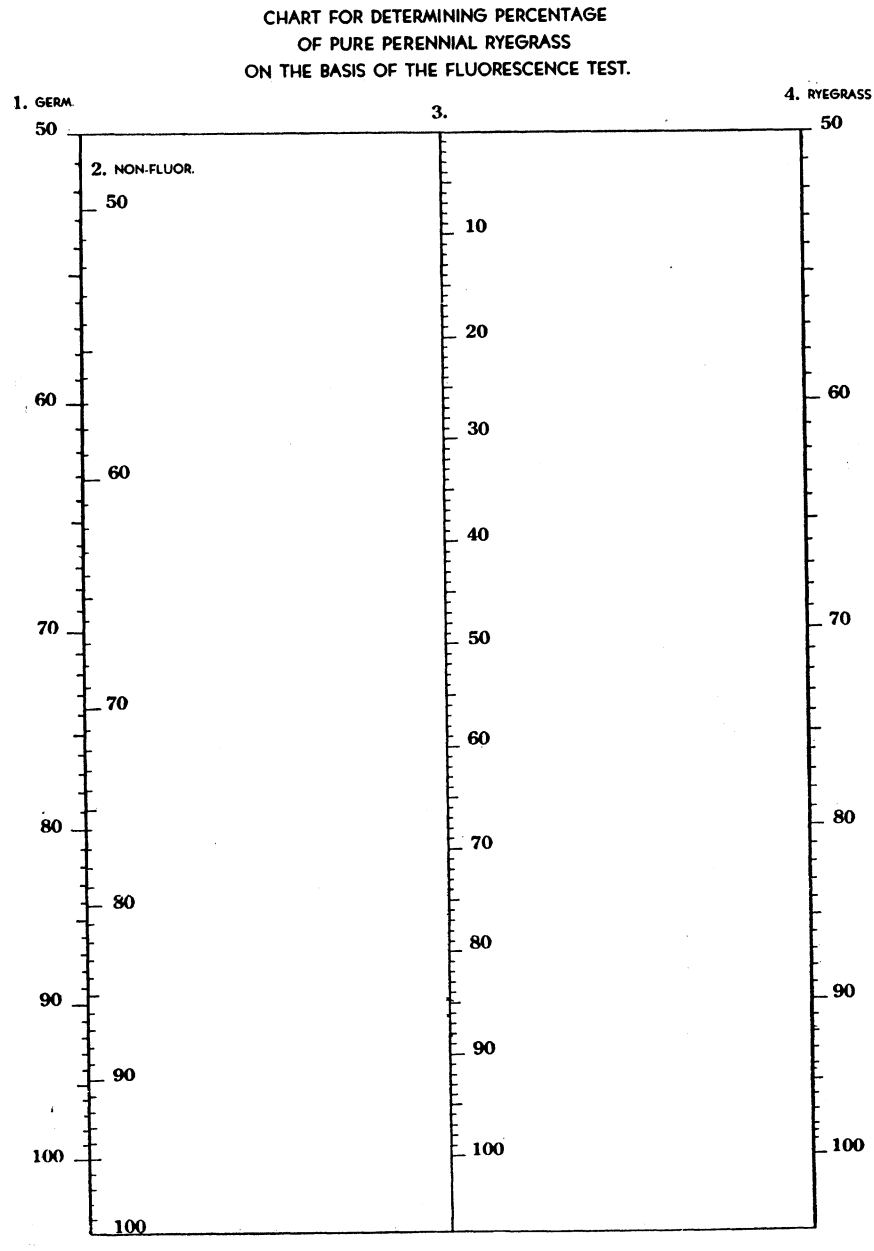
Pure ryegrass 98%; nonfluorescence 80%; germination 84%.

(1) Enter 80 on Scale 2. Corresponding value on Scale 1 is 84.2. Since germination is 84, that is, less than this value, all the pure ryegrass is perennial.

Example II

Pure ryegrass 95%; nonfluorescence 75%; germination 84%.

(1) Enter 75 on Scale 2. Corresponding value on Scale 1 is 79 (nearly). Since germination is 84, that is, greater than this value, proceed as follows:



(2) Join 75 on Scale 2 and 95 on Scale 4. Read off 79.4 on Scale 3.

(3) Join 84 on Scale 1 and 79.4 on Scale 3 and project to cut Scale 4 at 89.4.

(4) Percent pure perennial ryegrass is 89.4.

Sweetclover

In determining the percentage of yellow blossom biennial sweetclover in a mixture of yellow and white blossom biennial sweetclover, 5 grams of seed shall be examined to determine the percentage of mottled seed. The percentage of mottled seed shall be multiplied by 4 and the product shall be construed as representing the percentage of yellow blossom sweetclover.

GERMINATION TESTS

Source of Seeds for Germination

(1) *When both purity and germination tests are required:*

Seeds for germination shall be taken from the separation of the kind, variety, or type considered pure seed and shall be counted without discrimination as to size or appearance.

(2) *When only a germination test is required:*

If only a germination test is required and the pure seed is estimated or determined to be at least 98 percent, the pure seed for the germination test may be taken indiscriminately from a representative portion of the bulk.

If only a germination test is required and the pure seed is found to be less than 98 percent, the pure seed shall be taken indiscriminately from a pure seed separation made according to the provisions of these rules which govern the separation of the kind, variety, or type considered pure seed, except that the crop seeds, inert matter, and weed seeds need not be separated.

Reports of Germination

The exact pure seed percentage or the fact that it was estimated to be 98 percent or more shall be recorded and included in any report of germination.

Number of Seeds for Germination

At least 400 seeds shall be tested for germination. These seeds shall be tested in replicate tests of 100 seeds or less, except that in mixtures 200 seeds of those kinds present to the extent of 15 percent or less may be used in which case an additional 2 percent is to be added to the regular germination tolerances.

Retests

Retests shall be made if there is a difference of 10 percent between any two of the separate 100 seeds tested when the average of the tests is 80 percent or above; and if there is a difference of 15 percent when the average is below 80 percent; otherwise, the average of the tests shall be considered the result of the test.

Seed Germination

In seed laboratory practice, germination is defined as the emergence and development from the seed embryo of those essential structures which, for the kind of seed in question (table 4), are indicative of the ability to produce a normal plant under favorable conditions.

Hard Seeds

Seeds which remain hard at the end of the prescribed test because they have not absorbed water owing to an impermeable seed coat, are to be counted as "hard seed." Kinds of seed known and recognized as containing hard seed are indicated in table 4 (footnote 5).

Extension of Time on Legumes, Okra, and Asparagus for Swollen Seeds and Seeds Which Have Just Started to Germinate

If at the end of the germination period provided for in table 4 there are still present swollen seeds or seeds which have just started to germinate, all other seeds and seedlings shall be removed and the test continued for 5 additional days and the normal seedlings included in the percentage of germination.

Evaluation of Seedlings

The photographs of normal and abnormal seedlings prepared by the Federal Seed Laboratory, Beltsville, Md., as approved at present or in the future by the Association of Official Seed Analysts, shall be accepted as standard guides for classification of seedlings. The negative numbers shall be listed in the column headed "Remarks" following the respective kinds of seed. During the progress of the test, seeds which are obviously dead and moldy and which may be a source of contamination of healthy seeds should be removed at each count and the number of such dead seeds should be recorded. Soil and/or sand tests are to be used as a standard guide for the evaluation of germination tests made on approved artificial media in determining the classification of questionable seedlings. This is intended to provide a method of checking the reliability of tests made on artificial substrata when there may be doubt as to the proper evaluation of such tests and it is not intended to mean that all samples are to be tested in sand or soil.

Moisture and Aeration

The substratum must be moist enough at all times to supply the needed moisture to the seeds but there is danger that in supplying excessive moisture the aeration of seeds will be restricted. Except as provided for those kinds of seeds requiring high moisture levels of the germination media, the substrata should never be so wet that a film of water is formed around the seeds. For most kinds of seeds blotters or other paper substrata should not be so wet that, by pressing, a film of water forms around the finger. The following formula should be used as a basic guide in the preparation of sand for germination tests:

$$\frac{\text{118.29 cc. (1 gill) sand}}{\text{Its weight in grams}} \times 20.2 - 8.0 = \text{The number of cc. of water to add to each 100 grams of sand.}$$

The amount of water provided by this formula may have to be modified slightly, depending on the kind of seed being tested. For example, slightly more moisture should be added when the larger seeds are to be tested. In preparing soil tests water should be added until the consistency of the soil is such that a ball is formed by squeezing in the palm of the hand, but the ball will break freely when pressed between two fingers. After the soil has been wetted it should be rubbed through a sieve and put in the containers for the test, without packing. The addition of water subsequent to placing the seed in test will depend on the evaporation from the substrata in the germination chambers. Since the rate of evaporation will depend on the relative humidity of the air, it is desirable to keep water in the germination chambers or to provide other means of supplying a relative humidity of approximately 95 percent. Germination tests should be observed at frequent intervals to insure adequate moisture in the substrata at all times.

TABLE 4.—*Testing procedures for laboratory germination and hard seed content of specified kinds of seed samples*

Name of seed	Substrata [1]	Temperature [2]	First count [3]	Final count	Remarks [4]
AGRICULTURAL SEED		° *C.*	*Days*	*Days*	
Alfalfa—*Medicago sativa*	B, S	20	4	[5] 7	Photographs 2481, 2486.
Alfilaria—*Erodium cicutarium*	B	20–30	3	14	Clip seeds.
Bahia grass—*Paspalum notatum*	P	30–35	3	21	Light; remove all glumes with aid of sharp scalpel; fresh and dormant seed lightly scratch surface of caryopsis and use KNO_3.[6]
Barley—*Hordeum vulgare*	T, S	20	4	7	Fresh and dormant seed prechill 5 days at 5° or 10° C.[7]
Bean:					
Adzuki—*Phaseolus angularis*	R, S	20–30	4	[5] 10	
Field—*Phaseolus vulgaris*	R, S	20–30	5	[5] 8	Watch for abnormals; open the cotyledons if plumule is not visible. Abnormal seedlings include those without a terminal bud or growing point of the stem ("baldheads") and seedlings with both primary leaves absent even though the terminal bud or growing point is present ("snakeheads"). Such abnormal seedlings are not to be included in determining the percentage of germination. Photographs 1834, 1835, 1846, 1854, 1855.
Mung—*Phaseolus aureus*	R, S	20–30	3	[5] 7	
Velvet—*Stizolobium deeringianum*	R, C, S	20–30	3	[5] 14	
Beet, field, sugar—*Beta vulgaris*	B	20–30	3	14	Soak in water 2 hours before testing, using at least 250 cc. water per 100 "seeds"; wash in running water after soaking and blot surface dry. Samples producing darkened radicles should be retested in sand or soil or by washing in running water for 3 hours and testing on 0.3-inch-thick "Kimpak" containing 85 cc. water per 9″×9″ square on top of moistened blotters, keeping seed covered with slightly moist blotters.

See footnotes at end of table.

TABLE 4.—*Testing procedures for laboratory germination and hard seed content of specified kinds of seed samples*—Con.

Name of seed	Substrata [1]	Temperature [2]	First count [3]	Final count	Remarks [4]
AGRICULTURAL SEED—continued		° *C.*	*Days*	*Days*	
Beggarweed, Florida—*Desmodium tortuosum*	B	30	5	[5] 28	
Bentgrass:					
Colonial, Astoria and Highland—*Agrostis tenuis.*	P	20–30	7	28	Light, KNO_3;[6] fresh seed KNO_3,[6] 10°–30° C., and approximately 100 foot-candles of light.
Creeping (seaside)—*Agrostis palustris*	P	20–30	7	28	Light, KNO_3.[6]
Velvet—*Agrostis canina*	P	20–30	7	21	Do.
Bermuda grass—*Cynodon dactylon*	P	20–35	7	21	Light, KNO_3.[6] Photograph 2518.
Bluegrass:					
Annual—*Poa annua*	P	20–30	7	21	Light.
Bulbous—*Poa bulbosa*	P, S	10	10	35	Prechill 1 week at 5° C.,[7] KNO_3[6] or soil.
Canada—*Poa compressa*	P	15–30	10	28	Light, 0.1 percent KNO_3;[6] fresh and dormant seed KNO_3,[6] 10°–30°C., and approximately 100 foot-candles of light.
Kentucky—*Poa pratensis*	P	15–30	10	28	Light, 0.1 percent KNO_3.[6] Prechill dormant seeds at 10° C. for 5 days.[7]
Nevada—*Poa nevadensis*	P	20–30	7	21	Light, KNO_3.[6]
Rough—*Poa trivialis*	P	20–30	7	21	Light.
Texas—*Poa arachnifera*	P	20–30	7	28	Light, KNO_3;[6] prechill fresh and dormant seed at 5° C. for 2 weeks.[7]
Wood—*Poa nemoralis*	P	20–30	7	28	Light.
Bluestem:					
Big—*Andropogon furcatus*	P, TS	20–30	7	28	Light, KNO_3;[6] prechill fresh and dormant seed at 5° C. for 2 weeks.[7]
Little—*Andropogon scoparius*	P, TS	20–30	7	28	Do.
Sand—*Andropogon hallii*	P, TS	20–30	7	28	Do.
Brome:					
Mountain—*Bromus marginatus*	P	20–30	6	14	Light.
Smooth—*Bromus inermis*	P, TB	20–30	6	14	Do.
Broomcorn—*Sorghum vulgare* var. *technicum*	B, S	20–30	3	10	
Buckwheat—*Fagopyrum esculentum*	B, T	20–30	3	6	

Buffalo grass—*Buchloë dactyloides:*					
Burs	P, TB, TS	20–35	7	28	Light, KNO_3;[6] prechill fresh and dormant seed at 5°C.[7] for 6 weeks and germinate 14 additional days.
Caryopses	P	20–35	5	14	Light, KNO_3.[6]
Canary grass—*Phalaris canariensis*	B	20–30	3	7	
Canary grass reed—*Phalaris arundinacea*	P	20–30	5	21	Light; fresh and dormant seed KNO_3.[6]
Carpet grass—*Axonopus affinis*	P	20–35	10	21	Do.
Chickpea—*Cicer arietinum*	R, S	20–30	3	7	
Clover:					
Alsike—*Trifolium hybridum*	B, S	20	3	[5] 7	Dormant seed 15° C. The germination temperature should never exceed 20° C. and a temperature of 17° to 18° is most desirable.
Alyce—*Alysicarpus vaginalis*	B	35	4	[5] 21	At conclusion of 21-day test period carefully pierce seed coat of swollen seeds with needle or scalpel and continue test for 5 days.
Berseem—*Trifolium alexandrinum*	B, S	20	3	[5] 7	Dormant seed 15° C. The germination temperature should never exceed 20° C. and a temperature of 17° to 18° is most desirable.
Bur—*Medicago hispida*	B, T	20	4	[5] 14	Remove seeds from bur.
Bur, spotted—*Medicago arabica*	B, T	20	4	[5] 14	Do.
Button—*Medicago orbicularis*	B	20	4	[5] 10	Dormant seed 15° C. The germination temperature should never exceed 20° C. and a temperature of 17° to 18° is most desirable.
Cluster—*Trifolium glomeratum*	B	20	4	[5] 10	Do.
Crimson—*Trifolium incarnatum*	B, S	20	4	[5] 7	Dormant seed 15° C. The germination temperature should never exceed 20° C.; and a temperature of 17° to 18° is most desirable. Photographs 2479, 2482.
Ladino—*Trifolium repens*	B, S	20	3	[5] 7	Dormant seed 15° C. The germination temperature should never exceed 20° C. and a temperature of 17° to 18° is most desirable.
Lappa—*Trifolium lappaceum*	B	20	3	[5] 7	Do.
Large hop—*Trifolium procumbens*	B	20	4	[5] 14	Do.
Persian—*Trifolium resupinatum*	B	20	3	[5] 7	Do.
Red—*Trifolium pratense*	B, S	20	4	[5] 7	Dormant seed 15° C. The germination temperature should never exceed 20° C. and a temperature of 17° to 18° is most desirable. Photographs 2483, 2484.

See footnotes at end of table.

TABLE 4.—*Testing procedures for laboratory germination and hard seed content of specified kinds of seed samples*—Con.

Name of seed	Substrata [1]	Temperature [2]	First count [3]	Final count	Remarks [4]
AGRICULTURAL SEED—continued					
		° *C.*	*Days*	*Days*	
Clover—Continued					
Sour—*Melilotus indica*	B	20	3	[5] 14	
Strawberry—*Trifolium fragiferum*	B	20	3	[5] 7	Dormant seed 15° C. The germination temperature should never exceed 20° C. and a temperature of 17° to 18° is most desirable.
Sub—*Trifolium subterraneum*	B	20	4	[5] 14	Do.
Suckling (small hop)—*Trifolium dubium*	B	20	4	[5] 14	Do.
Sweet—*Melilotus alba and M. officinalis*	B, S	20	4	[5] 7	Photographs 2374, 2375, 2376, 2381.
White—*Trifolium repens*	B, S	20	3	[5] 7	Dormant seed 15° C. The germination temperature should never exceed 20° C. and a temperature of 17° to 18° is most desirable.
Corn:					
Field—*Zea mays*	R, S	20–30	4	7	Photographs 2510, 2511, 2512, 2514.
Pop—*Zea mays* var. *everta*	R, S	20–30	4	7	
Cotton—*Gossypium* spp	R, S	20–30	4	12	Roll towel tests in upright position. Alternate method: Shake seed in a closed container, thoroughly wetting the lint. Blot off excess moisture.
Cowpea—*Vigna sinensis*	R, S	20–30	5	[5] 8	Watch for weevil injury to plumule. Photographs 1989, 1990, 2377.
Crested dogtail—*Cynosurus cristatus*	P	20–30	10	21	Light; fresh and dormant seed prechill for 3 days at 5° or 10° C.[7]
Crotalaria—*Crotalaria intermedia, C. juncea, C. lanceolata, C. spectabilis,* and *C. striata.*	B, S	20–30	4	[5] 10	Photographs 2496, 2497.
Dallis grass—*Paspalum dilatatum*	P	20–35	7	21	Light; fresh and dormant seed KNO_3.[6]
Dropseed, sand—*Sporobolus cryptandrus*	P	15–35	5	42	Light, KNO_3;[6] dormant seed prechill at 5° C. for 4 to 8 weeks and germinate for 28 days.[7]

Fescue:					
Chewings—*Festuca rubra* var. *commutata*	P	15–25	7	21	Alternate method: 20°–30° C., light, and test for 28 days.
Hair—*Festuca capillata*	P	10–25	10	28	KNO_3.[6]
Meadow—*Festuca elatior*	P	20–30	5	14	Light.
Red—*Festuca rubra*	P	15–25	7	21	Alternate method: 20°–30° C., light, and test for 28 days.
Sheep—*Festuca ovina*	P	15–25	7	21	Do.
Tall—*Festuca arundinacea*	P	20–30	5	14	Light.
Flax—*Linum usitatissimum*	B, S	20–30	3	7	Photographs 2003, 2008, 2485, 2487.
Grama:					
Blue—*Bouteloua gracilis*	P, TB	20–30	7	28	Light; fresh and dormant seed KNO_3.[6]
Side-oats—*Bouteloua curtipendula*	P	15–30	7	28	Light, KNO_3.[6]
Guinea grass—*Panicum maximum*	P	20–30	10	28	Light.
Harding grass—*Phalaris tuberosa* var. *stenoptera*	P	10–30	7	28	Light; fresh and dormant seed KNO_3.[6]
Hemp—*Cannabis sativa*	B	20–30	3	7	
Indian grass, yellow—*Sorghastrum nutans*	P, TS	20–30	7	28	Light, KNO_3; fresh and dormant seed prechill at 5° C. for 2 weeks.[6 7]
Japanese lawngrass—*Zoysia japonica*	P	20–35	10	28	Light, KNO_3.[6]
Johnson grass—*Sorghum halepense*	P	20–35	7	35	Light; fresh and dormant seed KNO_3.[6]
Kudzu—*Pueraria thunbergiana*	T	20–30	5	[5] 14	
Lespedeza:					
Common (Kobe)—*Lespedeza striata*	B, S	20–35	7	[5] 14	
Korean—*Lespedeza stipulacea*	B	20–35	5	[5] 14	
Sericea or Chinese—*Lespedeza cuneata* (*L. sericea*).	B, S	20–35	7	[5] 28	Photograph 2494.
Siberian—*Lespedeza hedysaroides*	B, S	20–35	7	[5] 21	
Lovegrass, weeping—*Eragrostis curvula*	P	20–35	5	14	Light; fresh and dormant seed KNO_3.[6]
Lupine:					
Blue—*Lupinus angustifolius*	R, S	20	4	[5] 10	Photographs 14535 through 14542.
White—*Lupinus albus*	R, T	20	3	[5] 7	
Yellow—*Lupinus luteus*	R, T	20	7	[5] 21	
Manila grass—*Zoysia matrella*	P	20–35	10	28	Light, KNO_3.[6]
Meadow foxtail—*Alopecurus pratensis*	P	20–30	7	14	Light.
Medic, black—*Medicago lupulina*	B, S	20	4	[5] 7	

See footnotes at end of table.

TABLE 4.—*Testing procedures for laboratory germination and hard seed content of specified kinds of seed samples*—Con.

Name of seed	Substrata [1]	Temperature [2]	First count [3]	Final count	Remarks [4]
AGRICULTURAL SEED—continued					
		° C.	*Days*	*Days*	
Millet:					
Browntop—*Panicum fasciculatum*	B	20–30	4	14	
Foxtail, such as common, German, Hungarian, Siberian, or Golden—*Setaria italica.*	B	20–30	4	10	
Japanese—*Echinochloa crusgalli* var. *frumentacea.*	B	20–30	4	10	
Pearl—*Pennisetum glaucum*	B	20–30	3	7	
Proso—*Panicum miliaceum*	B	20–30	3	7	
Molasses grass—*Melinis minutiflora*	P	20–30	7	21	Light.
Mustard:					
Black—*Brassica nigra*	P	20–30	3	7	Light; fresh and dormant seed KNO_3,[6] and prechill at 10° C. for 3 days.[7]
White—*Brassica hirta*	P	20–30	3	5	Light.
Napier grass—*Pennisetum purpureum*	B	20–30	3	10	
Oats—*Avena sativa* and *A. byzantina*	T, S	20	5	10	Fresh and dormant seed prechill for 5 days at 5° C. or 10° C. and conclude test on seventh day.[7] Photographs 2407, 2408, 2524 through 2527.
Oatgrass, tall—*Arrhenatherum elatius*	P	20–30	6	14	Light.
Orchard grass—*Dactylis glomerata*	P, S	20–30	7	21	Light; germination more rapid on soil.
Panic grass, blue—*Panicum antidotale*	P, TS	20–30	7	28	Light.
Peanut—*Arachis hypogaea*	R, S	20–30	5	10	Remove shells.
Peas, field—*Pisum sativum* var. *arvense*	R, S	20	3	[5] 8	Photographs 2503, 2506, 14543 through 14547.
Rape:					
Annual—*Brassica napus* var. *annua*	B	20–30	3	7	
Bird—*Brassica campestris*	P	20–30	3	10	Light, fresh and dormant seed KNO_3.[6]
Turnip—*Brassica campestris* vars	B	20–30	3	7	
Winter—*Brassica napus* var. *biennis*	B	20–30	3	7	
Redtop—*Agrostis alba*	TB, P	20–30	5	10	Light.

Rescue grass—*Bromus catharticus*	P, S	10–30	7	28	Light; fresh and dormant seed in soil at 15° C.
Rhodes grass—*Chloris gayana*	P	20–30	6	14	Light.
Rice—*Oryza sativa*	B, T	20–30	5	14	
Ricegrass, Indian—*Oryzopsis hymenoides*	P	15	7	42	Prechill fresh and dormant seed at 3° C. for 4 weeks and test for 21 additional days.[7]
Rough pea—*Lathyrus hirsutus*	T	20	7	[5] 14	
Rye—*Secale cereale*	T, S	20	4	7	Prechill fresh and dormant seed at 5° or 10° C. for 5 days.[7] Photographs 2403, 2406, 2528 through 2531.
Ryegrass:					
Italian—*Lolium multiflorum*	P, TB	20–30	5	14	KNO_3;[6] light; for fluorescence test the seed should be germinated on filter paper; fresh and dormant seed KNO_3,[6] 10°–30° C. and approximately 100 foot-candles of light.
Perennial—*Lolium perenne*	P, TB	20–30	5	14	Light; for fluorescence test the seed should be germinated on filter paper.
Sainfoin—*Onobrychis viciaefolia*	B	20–30	4	[5] 14	
Sesame—*Sesamum orientale*	P	20–30	3	6	
Sesbania—*Sesbania exaltata*	T	20–30	5	[5] 7	
Smilo—*Oryzopsis miliacea*	P	20–30	7	42	Light; fresh and dormant seed prechill at 5° C. for 2 weeks.[7]
Sorghum:					
Grain and Sweet (sorgo)—*Sorghum vulgare*	B, S	20–30	4	10	Fresh and dormant seed prechill at 5° or 10° C. for 5 days.[7] Photographs 2413 through 2416.
Soybean—*Glycine max*	R, S	20–30	5	[5] 8	Photographs 2371, 2372, 2378.
Sudan grass—*Sorghum vulgare* var. *sudanense*	B, S	20–30	4	10	Photographs 2449 through 2452.
Sunflower (Cult.)—*Helianthus annuus*	T, B	20–30	3	7	
Sweet vernalgrass—*Anthoxanthum odoratum*	P	20–30	6	14	Light.
Switch grass—*Panicum virgatum*	P, TS	15–30	7	28	Light, KNO_3;[6] fresh and dormant seed prechill at 5° C. for 2 weeks.[7]
Timothy—*Phleum pratense*	P, TB	20–30	5	10	Light; fresh and dormant seed KNO_3.[6] Photograph 2399.
Tobacco—*Nicotiana tabacum*	P, TB	20–30	7	14	Light.
Trefoil:					
Big—*Lotus uliginosus*	B	20	3	[5] 7	
Birdsfoot—*L. corniculatus*	B	20	3	[5] 7	
Vasey grass—*Paspalum urvillei*	P	20–35	7	21	Light; fresh and dormant seed KNO_3.[6]
Velvetgrass—*Holcus lanatus*	P	20–30	6	14	Light.

See footnotes at end of table.

367116—52—24

TABLE 4.—*Testing procedures for laboratory germination and hard seed content of specified kinds of seed samples*—Con.

Name of seed	Substrata [1]	Temperature [2]	First count [3]	Final count	Remarks [4]
AGRICULTURAL SEED—continued					
		° *C.*	*Days*	*Days*	
Vetch:					
Common—*Vicia sativa*	T	20	5	[5] 10	Test questionable samples with stubby roots in soil.
Hairy—*Vicia villosa*	T	20	5	[5] 14	Photographs 2453 through 2457.
Hungarian—*Vicia pannonica*	T	20	5	[5] 10	
Monantha—*Vicia articulata* (*V. monantha*)	T	20	5	[5] 10	
Narrowleaf—*Vicia angustifolia*	T	20	5	[5] 14	
Purple—*Vicia atropurpurea*	T	20	5	[5] 10	
Woollypod—*Vicia dasycarpa*	T	20	5	[5] 14	
Wheat:					
Common, club, Polish (including spelt and emmer)—*Triticum* spp.	T, S	20	4	7	Fresh and dormant seed prechill at 5° or 10°C. for 5 days.[7] Photographs 2507, 2520 through 2522.
Durum—*Triticum durum*	T, S	20	4	10	Fresh and dormant seed prechill at 5° or 10° C. for 5 days.[7]
Wheatgrass:					
Crested (Fairway and Standard)— *Agropyron cristatum.*	P, TB	20–30	5	14	Light; fresh and dormant seed KNO_3,[6] and 5° or 10° C. for 7 days.[7]
Slender—*Agropyron trachycaulum*	P, TB	20–30	5	14	Light.
Western—*Agropyron smithii*	P	20–30	7	35	Light; fresh and dormant seed KNO_3,[6] or soil and 15°–30° C.
Wild-rye, Canada—*Elymus canadensis*	P	15–30	7	21	Light; fresh and dormant seed prechill at 5° C. for 2 weeks.[7]
VEGETABLE SEED					
Artichoke—*Cynara scolymus*	T	20–30	7	21	
Asparagus—*Asparagus officinalis*	T	20–30	7	[5] 21	
Bean:					
Asparagus—*Vigna sesquipedalis*	R, S	20–30	5	[5] 8	Watch for weevil injury to plumule.

Garden—*Phaseolus vulgaris*	R, S	20–30	5	[5] 8	Watch for abnormals; open the cotyledons if plumule is not visible. Abnormal seedlings in beans include seedlings without a terminal bud or growing point of the stem ("baldheads") and seedlings with both primary leaves absent even though the terminal bud or growing point is present ("snakeheads"). Such abnormal seedlings are not to be included in determining the percentage of germination. Photographs 1834, 1835, 1846, 1854, 1855.
Horse or broad—*Vicia faba*	S, C	20	4	14	Prechill fresh and dormant seed 3 days at 10° C.[7] The germination temperature should never exceed 20° C. and a temperature of 17° to 18° C. is most desirable.
Lima—*Phaseolus lunatus* var. *macrocarpus*	R, S, C	20–30	5	[5] 9	Watch for abnormals; open the cotyledons if plumule is not visible. Abnormal seedlings in beans include seedlings without a terminal bud or growing point of the stem ("baldheads") and seedlings with both primary leaves absent even though the terminal bud or growing point is present ("snakeheads"). Such abnormal seedlings are not to be included in determining the percentage of germination. Photographs 2380, 2400, 2401.
Runner—*Phaseolus coccineus*	R, S	20–30	5	[5] 9	
Beet—*Beta vulgaris*	B	20–30	3	14	Soak in water 2 hours before testing, using at least 250 cc. water per 100 "seeds"; wash in running water after soaking and blot surface dry. Samples producing darkened radicles should be retested in sand or soil or by washing in running water for 3 hours and testing on 0.3-inch-thick "Kimpak" keeping seed covered with slightly moist blotters.
Broccoli—*Brassica oleracea* var. *botrytis*	B, P	20–30	3	10	Dormant seed light, KNO_3,[6] prechill at 5° or 10° C. for 3 days.[7]
Brussels sprouts—*Brassica oleracea* var. *gemmifera.*	B, P	20–30	3	10	Do.
Cabbage—*Brassica oleracea* var. *capitata*	B, P	20–30	3	10	Do.
Cardoon—*Cynara cardunculus*	T	20–30	7	21	
Carrot—*Daucus carota*	B	20–30	6	28	

See footnotes at end of table.

TABLE 4.—*Testing procedures for laboratory germination and hard seed content of specified kinds of seed samples*—Con.

Name of seed	Substrata [1]	Temperature [2]	First count [3]	Final count	Remarks [4]
VEGETABLE SEED—continued		° *C.*	*Days*	*Days*	
Cauliflower—*Brassica oleracea* var. *botrytis*	B, P	20–30	3	10	Dormant seed light, KNO_3,[6] prechill at 5° or 10° C. for 3 days.[7]
Celeriac—*Apium graveolens* var. *rapaceum*	P, TB	20–30	10	21	Light. If injury to roots is apparent use Whatman's No. 2 filter paper or equivalent as substratum.
Celery—*Apium graveolens* var. *dulce*	P, TB	20–30	10	21	Light; fresh and dormant seed KNO_3,[6] and prechill at 10° C. for 3 days.[7] If injury to roots is apparent use Whatman's No. 2 filter paper or equivalent as substratum.
Chicory—*Cichorium intybus*	P, TS	20–30	5	14	Light; KNO_3[6] or soil. If injury to roots is apparent use Whatman's No. 2 filter paper or equivalent as substratum. Photograph 2504.
Citron—*Citrullus vulgaris*	T	20–30	7	14	Soak 6 hours; test dormant seed at 30° C.
Collards—*Brassica oleracea* var. *acephala*	B, P	20–30	3	10	Dormant seed light, KNO_3,[6] prechill at 5° or 10° C. for 3 days.[7]
Corn, sweet—*Zea mays*	R, S	20–30	4	7	Photographs 2510, 2511, 2512, 2514.
Cornsalad (Fetticus)—*Valerianella locusta* var. *olitoria.*	B	20	7	28	Fresh and dormant seed 10° or 15° C.
Cowpea—*Vigna sinensis*	R, S	20–30	5	[5]8	Watch for weevil injury to plumule. Photographs 1989, 1990, 2377.
Cress:					
Garden—*Lepidium sativum*	B, P	20	4	10	Dormant seed 15° C. and light.
Water—*Rorippa nasturtium-aquaticum*	P	20–30	4	14	Light.
Cucumber—*Cucumis sativus*	T, S, B	20–30	3	7	Keep substrata somewhat drier than they are maintained for the average kind of seed.
Dandelion—*Taraxacum officinale*	P, TB	20–30	7	21	Light. If injury to roots is apparent use Whatman's No. 2 filter paper or equivalent as substratum.
Eggplant—*Solanum melongena* var. *esculentum*	TB	20–30	7	14	Alternate method: Test between blotters with raised covers by folding up edges of bottom to form a good support for top or cover, so top will not make contact with seed.

Endive—*Cichorium endivia*	P, TS	20–30	5	14	Light, KNO_3,[6] or soil; dormant seed add about ⅛ inch of tap water at beginning of test; remove the excess water after 24 hours. If injury to roots is apparent use Whatman's No. 2 filter paper or equivalent as substratum.
Kale—*Brassica oleracea* var. *acephala*	B, P	20–30	3	10	Dormant seed light, KNO_3,[6] prechill at 5° or 10° C. for 3 days.[7]
Kohlrabi—*Brassica oleracea* var. *gongylodes*	B, P	20–30	3	10	Do.
Leek—*Allium porrum*	B	20	6	14	
Lettuce—*Lactuca sativa*	P	20	None	7	Light for at least ½ hour; fresh and dormant seed prechill at 10° or 15° C. 3 days; watch for sprouts with both spotted cotyledons and stubby radicles.[7] Photographs 2417, 2418.
Muskmelon—*Cucumis melo*	B, T, S	20–30	4	10	Keep substrata somewhat drier than they are maintained for the average kind of seed.
Mustard:					
India—*Brassica juncea*	P	20–30	3	7	Light; fresh and dormant seed KNO_3,[6] and prechill at 10° C. for 3 days.[7]
Spinach—*Brassica perviridis*	B	20–30	3	7	
Okra—*Hibiscus esculentus*	R	20–30	4	[5] 21	
Onion—*Allium cepa*	B, S	20	6	10	In sand and soil tests extend final count to 12 days. Photographs 1962, 2253, 2254, 2328, 2330, 2340, 2341, 2469.
Pakchoi—*Brassica chinensis*	B	20–30	3	7	
Parsley—*Petroselinum hortense*	B	20–30	11	28	
Parsnip—*Pastinaca sativa*	B	20–30	6	28	
Peas, garden—*Pisum sativum*	R, S	20	5	[5] 8	Photographs 2492, 2498, 2499, 2500.
Pepper—*Capsicum* spp	TB	20–30	6	14	Alternate method: Test between blotters with raised covers by folding up edges of bottom to form a good support for top or cover, so top will not make contact with seed.
Pe-tsai (Chinese cabbage)—*Brassica pekinensis*	B	20–30	3	7	
Pumpkin—*Cucurbita pepo*	T, S	20–30	4	7	Keep substrata somewhat drier than they are maintained for the average kind of seed.
Radish—*Raphanus sativus*	B	20	4	6	Classify as abnormal all seedlings with 50 percent or more of the area of the cotyledons covered with spots or darkened areas.
Rhubarb—*Rheum rhaponticum*	TS	20–30	7	21	Light.
Rutabaga—*Brassica napus* var. *napobrassica*	B	20–30	3	14	

See footnotes at end of table.

TABLE 4.—*Testing procedures for laboratory germination and hard seed content of specified kinds of seed samples*—Con.

Name of seed	Substrata [1]	Temperature [2]	First count [3]	Final count	Remarks [4]
VEGETABLE SEED—continued		° C.	*Days*	*Days*	
Salsify—*Tragopogon porrifolius*	T	20	5	10	Prechill fresh and dormant seed at 10° C. for 3 days.[7]
Sorrel—*Rumex acetosa*	TS, P	20–30	3	14	Light. Test dormant seed at 15° C.
Soybean (vegetable)—*Glycine max*	R, S	20–30	5	[5] 8	Photographs 2371, 2372, 2378.
Spinach:					
Common—*Spinacia oleracea*	TB	10	7	21	Keep substrata somewhat drier than they are maintained for the average kind of seed.
New Zealand—*Tetragonia expansa*	TS, B	10–30	5	28	Keep substrata somewhat drier than they are maintained for the average kind of seed. Alternate method: Remove pulp and test at 15° C. between blotters.
Squash—*Cucurbita moschata* and *C. maxima*	T, S	20–30	4	7	Keep substrata somewhat drier than they are maintained for the average kind of seed.
Swiss chard—*Beta vulgaris* var. *cicla*	B	20–30	3	14	Soak in water 2 hours before testing, using at least 250 cc. water per 100 "seeds"; wash in running water after soaking and blot surface dry. Samples producing darkened radicles should be retested in sand or soil or by washing in running water for 3 hours and testing on 0.3-inch-thick "Kimpak", keeping seed covered with slightly moist blotters.
Tomato:					
Common—*Lycopersicon esculentum*	B	20–30	5	14	Dormant seed light and KNO_3.[6] Alternate method: Test between blotters with raised covers by folding up edges of bottom to form a good support for top or cover, so top will not make contact with seed. Photograph 2513.
Husk—*Physalis pubescens*	P, TB	20–30	7	28	Light.
Turnip—*Brassica rapa*	B	20–30	3	7	
Watermelon—*Citrullus vulgaris*	T, S	20–30	4	14	Keep substrata somewhat drier than they are maintained for the average kind of seed.
HERBS					
Dill—*Anethum graveolens*	B	20–30	7	21	
Sage—*Salvia officinalis*	B, S	20–30	5	14	
Savory—*Satureja hortensis*	B	20–30	5	21	

TENTATIVE METHODS

Wheatgrass:					
Hairy intermediate—*Agropyron tricophorum*	P	20–30	5	28	Light.
Intermediate—*Agropyron intermedium*	P	20–30	5	21	Light.
Tall—*Agropyron elongatum*	P	20–30	5	21	Light; prechill fresh and dormant seed at 5° C. for 7 days.[7]

ALTERNATE METHODS

Barley—*Hordeum vulgare*	T, S	15	4	7	
Oats—*Avena* spp.	T, S	15	5	10	
Rye—*Secale cereale*	T, S	15	4	7	
Wheat—*Triticum* spp.	T, S	15	4	7	
Redtop—*Agrostis alba*	TB, P	20–30	5	10	Light; prechill fresh and dormant seed at 10° C. for 5 days.[7]
Timothy—*Phleum pratense*	TB, P	20–30	5	10	Do.

[1] Substrata: B=between blotters; TB=top of blotters; T=between folded paper toweling; R=rolled towels; S=soil or sand; TS=top of soil; P=covered petri dishes with (a) 2 layers of blotters; or (b) 1 layer of absorbent cotton; or (c) 5 layers of paper toweling; or (d) filter paper; or (e) ⅜-inch layer of sand or soil; C=creped cellulose paper wadding (0.3-inch-thick Kimpak or equivalent) covered with a single thickness of blotter through which holes are punched for the seeds which are pressed for about ½ their distance into the creped paper wadding.

[2] Temperature: A single numeral indicates a constant temperature. Two numerals separated by a dash indicate an alternation of temperature; the test is held at the first temperature for approximately 16 hours and at the second temperature for approximately 8 hours per day. If tests are not subjected to alternating temperatures over week ends and on holidays they are to be held at the lower temperature during such time.

[3] The number of days stated for the first count is approximate and a deviation of 1 to 3 days is permitted.

[4] Photograph numbers identify photographs of some types of normal and abnormal seedlings. These photographs may be purchased from The Press Service, Office of Information, U. S. Dept. of Agriculture, Washington 25, D. C.

[5] Hard seeds are often present. If at the end of the germination period there are still present swollen seeds or seeds which have just started to germinate all other seeds or seedlings shall be removed and the test continued for 5 additional days; the normal seedlings produced in this period should be included in the percentage of germination.

[6] A two-tenths percent solution of potassium nitrate (KNO_3) is used in moistening the substratum in all instances except for Canada and Kentucky bluegrass. This solution is prepared by dissolving 2 grams of KNO_3 in 1,000 cc. of distilled water. A one-tenth percent solution is prepared by dissolving 1 gram of KNO_3 in 1,000 cc. of distilled water.

[7] The prechilling period is not included in the germination period given in this table unless otherwise specified.

TOLERANCES

Application

The following tolerances shall be recognized between the percentages or rates of occurrence found by analysis, test, or examination and percentages or rates of occurrence required or stated. Unless otherwise provided, the tolerances shall be applied to the percentages or rates of occurrence found. These tolerances shall be applicable to Tentative Rules as well as to the established rules. The tolerance tables included herein are a part of these rules. The values shown in these tables were obtained by application of the indicated formula.

Purity Percentage

In the determination of the tolerance for the percentage of the distinguishable kind, type, or variety (pure seed), weed seeds, other crops seeds, and inert matter, the sample shall be first considered as made up of two parts: (*a*) The percentage of the component (pure seed, weed seed, crop seed, or inert matter, as the case may be) being considered, and (*b*) the difference between that percentage and 100. The number represented by (*a*) is then multiplied by the number represented by (*b*), and the product is divided by 100. The resulting number is then multiplied by 0.2, and the resulting product added to 0.2 or 0.6 as indicated in the following formula:

$$\text{Pure seed tolerance} = 0.6 + \left(\frac{0.2 \times a \times b}{100}\right)$$

Weed seeds, other crop seeds, and inert matter tolerance

$$= 0.2 + \left(\frac{0.2 \times a \times b}{100}\right)$$

For *Poa* spp., *Agrostis* spp., *Festuca* spp., *Andropogon* spp., *Bouteloua* spp., bromegrass, crested wheatgrass, western wheatgrass, molasses grass, Guinea grass, Vasey grass, orchard grass, velvet grass, tall oatgrass, meadow foxtail, sweet vernal grass, Rhodes grass, Dallis grass, carpet grass, Indian ricegrass, Bermuda grass, and wild-rye grass, and mixtures containing these seeds singly or combined in excess of 50 percent, an additional tolerance shall be allowed. This is to be obtained by multiplying the regular tolerance by the lesser of *a* and *b* divided by 100.

To find the amount of tolerance (T) to be allowed on any value given in tables 5, 6, 7, and 8 for percentage of pure seed, inert matter, weed seed, or crop seed variation, first find the value in whole numbers in the left column, then any fractional part in the horizontal column at the top of the page. The tolerance (T) to be allowed on that value will then be found at the intersection of the columns opposite the value in whole numbers and below the fractional value.

The tolerance for pure seed of purity less than 50 percent is the same as the tolerance for the larger part of the difference between the purity and 100 percent. Example: The tolerance for a purity of 30 percent would be the same as for 100 percent − 30 percent = 70 percent, or tolerance on 70 percent of 4.80 percent.

TABLE 5.—*Tolerances for pure seed variations for other than certain chaffy grasses*

[Computed on the basis of Tolerance (T)=0.6 plus 20% of the formula $a \times b$ divided by 100]

Value, percent	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	Value, percent
100	0. 60										100
99	0. 79	0. 77	0. 75	0. 73	0. 71	0. 69	0. 67	0. 65	0. 63	0. 61	99
98	1. 00	0. 98	0. 96	0. 94	0. 92	0. 90	0. 88	0. 86	0. 83	0. 81	98
97	1. 18	1. 16	1. 14	1. 12	1. 10	1. 08	1. 06	1. 05	1. 04	1. 01	97
96	1. 36	1. 34	1. 33	1. 31	1. 29	1. 27	1. 25	1. 23	1. 21	1. 20	96
95	1. 55	1. 52	1. 50	1. 48	1. 46	1. 45	1. 44	1. 42	1. 40	1. 38	95
94	1. 72	1. 71	1. 69	1. 67	1. 65	1. 63	1. 62	1. 60	1. 58	1. 56	94
93	1. 90	1. 88	1. 86	1. 85	1. 83	1. 81	1. 79	1. 78	1. 76	1. 74	93
92	2. 07	2. 05	2. 03	2. 02	2. 00	1. 98	1. 96	1. 95	1. 93	1. 91	92
91	2. 23	2. 22	2. 20	2. 18	2. 17	2. 15	2. 13	2. 12	2. 10	2. 08	91
90	2. 40	2. 38	2. 36	2. 35	2. 33	2. 31	2. 30	2. 28	2. 27	2. 25	90
89	2. 55	2. 54	2. 52	2. 51	2. 49	2. 47	2. 46	2. 44	2. 43	2. 41	89
88	2. 71	2. 68	2. 67	2. 66	2. 65	2. 63	2. 62	2. 60	2. 58	2. 57	88
87	2. 86	2. 84	2. 83	2. 81	2. 80	2. 78	2. 77	2. 75	2. 74	2. 72	87
86	3. 00	2. 99	2. 97	2. 96	2. 95	2. 93	2. 92	2. 90	2. 89	2. 87	86
85	3. 15	3. 13	3. 12	3. 10	3. 09	3. 07	3. 06	3. 05	3. 03	3. 02	85
84	3. 28	3. 27	3. 26	3. 24	3. 23	3. 21	3. 20	3. 19	3. 17	3. 16	84
83	3. 42	3. 40	3. 39	3. 38	3. 36	3. 35	3. 34	3. 32	3. 31	3. 30	83
82	3. 55	3. 53	3. 52	3. 51	3. 50	3. 48	3. 47	3. 46	3. 44	3. 43	82
81	3. 67	3. 66	3. 65	3. 64	3. 62	3. 61	3. 60	3. 59	3. 57	3. 56	81
80	3. 80	3. 78	3. 77	3. 76	3. 75	3. 73	3. 72	3. 71	3. 70	3. 68	80
79	3. 91	3. 90	3. 89	3. 88	3. 87	3. 85	3. 84	3. 83	3. 82	3. 81	79
78	4. 03	4. 02	4. 00	3. 99	3. 98	3. 97	3. 96	3. 95	3. 94	3. 92	78
77	4. 14	4. 13	4. 12	4. 10	4. 09	4. 08	4. 07	4. 06	4. 05	4. 04	77
76	4. 24	4. 23	4. 22	4. 21	4. 20	4. 19	4. 18	4. 17	4. 16	4. 15	76
75	4. 35	4. 33	4. 32	4. 31	4. 30	4. 29	4. 28	4. 27	4. 26	4. 25	75
74	4. 44	4. 43	4. 42	4. 41	4. 40	4. 39	4. 38	4. 37	4. 36	4. 35	74
73	4. 54	4. 53	4. 52	4. 51	4. 50	4. 49	4. 48	4. 47	4. 46	4. 45	73
72	4. 63	4. 62	4. 61	4. 60	4. 59	4. 58	4. 57	4. 56	4. 56	4. 55	72
71	4. 71	4. 70	4. 70	4. 69	4. 68	4. 67	4. 66	4. 65	4. 64	4. 64	71
70	4. 80	4. 79	4. 78	4. 77	4. 76	4. 75	4. 75	4. 74	4. 73	4. 72	70
69	4. 87	4. 87	4. 86	4. 85	4. 84	4. 83	4. 83	4. 82	4. 81	4. 80	69
68	4. 95	4. 94	4. 93	4. 93	4. 92	4. 91	4. 90	4. 90	4. 89	4. 88	68
67	5. 02	5. 01	5. 00	5. 00	4. 99	4. 98	4. 98	4. 97	4. 96	4. 95	67
66	5. 08	5. 08	5. 07	5. 06	5. 06	5. 05	5. 04	5. 04	5. 03	5. 02	66
65	5. 15	5. 14	5. 13	5. 13	5. 12	5. 11	5. 11	5. 10	5. 10	5. 09	65
64	5. 20	5. 20	5. 19	5. 19	5. 18	5. 17	5. 17	5. 16	5. 16	5. 15	64
63	5. 26	5. 25	5. 25	5. 24	5. 24	5. 23	5. 23	5. 22	5. 21	5. 21	63
62	5. 31	5. 30	5. 30	5. 29	5. 29	5. 28	5. 28	5. 27	5. 27	5. 26	62
61	5. 35	5. 35	5. 34	5. 34	5. 34	5. 33	5. 33	5. 32	5. 32	5. 31	61
60	5. 40	5. 39	5. 39	5. 38	5. 38	5. 37	5. 37	5. 37	5. 36	5. 36	60
59	5. 43	5. 43	5. 43	5. 42	5. 42	5. 41	5. 41	5. 41	5. 40	5. 40	59
58	5. 47	5. 46	5. 46	5. 46	5. 45	5. 45	5. 45	5. 44	5. 44	5. 44	58
57	5. 50	5. 49	5. 49	5. 49	5. 49	5. 48	5. 48	5. 48	5. 47	5. 47	57
56	5. 52	5. 52	5. 52	5. 51	5. 51	5. 51	5. 51	5. 51	5. 50	5. 50	56
55	5. 55	5. 54	5. 54	5. 54	5. 54	5. 53	5. 53	5. 53	5. 53	5. 53	55
54	5. 56	5. 56	5. 56	5. 56	5. 56	5. 55	5. 55	5. 55	5. 55	5. 55	54
53	5. 58	5. 58	5. 57	5. 57	5. 57	5. 57	5. 57	5. 57	5. 57	5. 56	53
52	5. 59	5. 59	5. 59	5. 58	5. 58	5. 58	5. 58	5. 58	5. 58	5. 58	52
51	5. 59	5. 59	5. 59	5. 59	5. 59	5. 59	5. 59	5. 59	5. 59	5. 59	51
50	5. 60	5. 59	5. 59	5. 59	5. 59	5. 59	5. 59	5. 59	5. 59	5. 59	50

TABLE 6.—*Tolerances for pure seed variations for the following chaffy grasses:* Poa *spp.*, Agrostis *spp.*, Festuca *spp.*, *bromegrass, crested wheatgrass, orchard grass, velvet grass, tall oatgrass, meadow foxtail, sweet vernal grass, Rhodes grass, Dallis grass, carpet grass, Bermuda grass, Guinea grass, molasses grass, Vasey grass,* Andropogon *spp.*, Bouteloua *spp.*, *Indian ricegrass and wild-rye, and mixtures containing these seeds singly or combined in excess of 50 percent*

[The tolerance is obtained by adding to the regular tolerance the product obtained by multiplying the regular tolerance by the lesser of *a* and *b* divided by 100]

Value, percent	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	Value, percent
100	0. 60										100
99	. 79	0. 77	0. 75	0. 73	0. 71	0. 69	0. 67	0. 65	0. 63	0. 61	99
98	1. 00	. 98	. 96	. 94	. 92	. 90	. 88	. 86	. 83	. 81	98
97	1. 21	1. 19	1. 17	1. 15	1. 12	1. 10	1. 08	1. 07	1. 06	1. 03	97
96	1. 41	1. 39	1. 38	1. 35	1. 33	1. 31	1. 29	1. 27	1. 24	1. 23	96
95	1. 62	1. 59	1. 57	1. 54	1. 52	1. 51	1. 50	1. 48	1. 45	1. 43	95
94	1. 82	1. 81	1. 78	1. 76	1. 74	1. 71	1. 70	1. 68	1. 66	1. 63	94
93	2. 03	2. 00	1. 98	1. 97	1. 95	1. 92	1. 90	1. 87	1. 86	1. 84	93
92	2. 23	2. 21	2. 18	2. 17	2. 15	2. 12	2. 10	2. 09	2. 06	2. 04	92
91	2. 43	2. 41	2. 39	2. 36	2. 35	2. 33	2. 30	2. 28	2. 27	2. 24	91
90	2. 64	2. 61	2. 59	2. 57	2. 55	2. 52	2. 51	2. 49	2. 47	2. 45	90
89	2. 83	2. 81	2. 79	2. 77	2. 75	2. 72	2. 71	2. 69	2. 67	2. 65	89
88	3. 03	3. 01	2. 99	2. 97	2. 95	2. 93	2. 91	2. 89	2. 86	2. 85	88
87	3. 23	3. 20	3. 19	3. 16	3. 15	3. 12	3. 11	3. 08	3. 07	3. 04	87
86	3. 42	3. 40	3. 37	3. 36	3. 35	3. 32	3. 31	3. 28	3. 27	3. 24	86
85	3. 62	3. 59	3. 58	3. 55	3. 54	3. 51	3. 50	3. 48	3. 46	3. 44	85
84	3. 80	3. 78	3. 77	3. 74	3. 73	3. 70	3. 69	3. 67	3. 65	3. 63	84
83	4. 00	3. 97	3. 95	3. 94	3. 91	3. 90	3. 88	3. 86	3. 84	3. 83	83
82	4. 18	4. 16	4. 14	4. 13	4. 11	4. 08	4. 07	4. 05	4. 03	4. 01	82
81	4. 36	4. 35	4. 33	4. 32	4. 29	4. 27	4. 26	4. 24	4. 21	4. 20	81
80	4. 56	4. 53	4. 51	4. 49	4. 48	4. 46	4. 44	4. 42	4. 41	4. 38	80
79	4. 73	4. 71	4. 69	4. 68	4. 66	4. 63	4. 62	4. 60	4. 59	4. 57	79
78	4. 92	4. 90	4. 87	4. 85	4. 83	4. 82	4. 80	4. 79	4. 77	4. 74	78
77	5. 09	5. 07	5. 05	5. 03	5. 01	4. 99	4. 98	4. 96	4. 94	4. 93	77
76	5. 25	5. 24	5. 22	5. 20	5. 19	5. 17	5. 15	5. 14	5. 12	5. 10	76
75	5. 43	5. 40	5. 39	5. 37	5. 35	5. 34	5. 32	5. 30	5. 29	5. 27	75
74	5. 59	5. 57	5. 56	5. 54	5. 52	5. 50	5. 49	5. 47	5. 45	5. 44	74
73	5. 76	5. 74	5. 73	5. 71	5. 69	5. 67	5. 66	5. 64	5. 63	5. 61	73
72	5. 92	5. 90	5. 89	5. 87	5. 85	5. 83	5. 82	5. 80	5. 80	5. 78	72
71	6. 07	6. 05	6. 05	6. 03	6. 01	6. 00	5. 98	5. 96	5. 94	5. 94	71
70	6. 24	6. 22	6. 20	6. 18	6. 16	6. 15	6. 14	6. 12	6. 11	6. 09	70
69	6. 37	6. 37	6. 35	6. 33	6. 32	6. 30	6. 29	6. 28	6. 26	6. 24	69
68	6. 53	6. 51	6. 49	6. 49	6. 47	6. 45	6. 43	6. 43	6. 41	6. 39	68
67	6. 67	6. 65	6. 64	6. 63	6. 61	6. 59	6. 59	6. 57	6. 55	6. 53	67
66	6. 80	6. 80	6. 78	6. 76	6. 76	6. 74	6. 72	6. 71	6. 71	6. 68	66
65	6. 95	6. 93	6. 91	6. 91	6. 89	6. 87	6. 86	6. 84	6. 84	6. 82	65
64	7. 07	7. 06	7. 04	7. 04	7. 02	7. 00	7. 00	6. 98	6. 97	6. 95	64
63	7. 20	7. 18	7. 18	7. 16	7. 15	7. 13	7. 13	7. 11	7. 09	7. 09	63
62	7. 32	7. 30	7. 30	7. 28	7. 27	7. 26	7. 25	7. 23	7. 23	7. 21	62
61	7. 43	7. 43	7. 41	7. 40	7. 40	7. 38	7. 36	7. 35	7. 35	7. 33	61
60	7. 56	7. 54	7. 53	7. 51	7. 51	7. 49	7. 48	7. 48	7. 46	7. 45	60

TABLE 6.—*Tolerances for pure seed variations for the following chaffy grasses, etc.*—Continued

Value, percent	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	Value, percent
59	7. 65	7. 65	7. 64	7. 62	7. 62	7. 60	7. 59	7. 59	7. 57	7. 56	59
58	7. 76	7. 74	7. 74	7. 73	7. 71	7. 71	7. 70	7. 68	7. 68	7. 67	58
57	7. 86	7. 84	7. 83	7. 83	7. 82	7. 80	7. 80	7. 79	7. 77	7. 77	57
56	7. 94	7. 94	7. 93	7. 93	7. 91	7. 90	7. 90	7. 89	7. 87	7. 87	56
55	8. 04	8. 02	8. 02	8. 01	8. 01	7. 99	7. 98	7. 97	7. 97	7. 96	55
54	8. 11	8. 11	8. 10	8. 10	8. 09	8. 07	8. 06	8. 06	8. 05	8. 05	54
53	8. 20	8. 19	8. 17	8. 17	8. 16	8. 16	8. 15	8. 14	8. 14	8. 12	53
52	8. 27	8. 26	8. 26	8. 24	8. 23	8. 23	8. 22	8. 21	8. 21	8. 20	52
51	8. 32	8. 32	8. 31	8. 31	8. 30	8. 30	8. 29	8. 28	8. 28	8. 27	51
50	8. 40	8. 37	8. 37	8. 36	8. 36	8. 35	8. 35	8. 34	8. 34	8. 33	50

$$\text{Regular Tolerance} + \frac{\text{Regular Tolerance} \times (100 - \text{value})}{100}$$

Example: Tolerance for 91.40 percent.

Regular Tolerance 2.17 percent.

$$2.17 + \frac{2.17 \times (100 - 91.40)}{100}$$

$$2.17 + \frac{2.17 \times 8.60}{100}$$

$$2.17 + \frac{18.5620}{100}$$

$$2.17 + 0.18$$

Tolerance 2.35 percent.

TABLE 7.—*Tolerances for weed seeds, other crop seed, and inert matter for other than certain chaffy grasses*

[Computed on the basis of Tolerance (T) = 0.2 plus 20% of the formula $a \times b$ divided by 100]

Value, percent	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	Value, percent
0	0. 20	0. 21	0. 23	0. 25	0. 27	0. 29	0. 31	0. 33	0. 35	0. 37	0
1	. 39	. 41	. 43	. 45	. 47	. 49	. 51	. 53	. 55	. 57	1
2	. 59	. 61	. 63	. 65	. 66	. 68	. 70	. 72	. 74	. 76	2
3	. 78	. 80	. 81	. 83	. 85	. 87	. 89	. 91	. 93	. 94	3
4	. 96	. 98	1. 00	1. 02	1. 04	1. 05	1. 06	1. 08	1. 10	1. 12	4
5	1. 15	1. 16	1. 18	1. 20	1. 22	1. 23	1. 25	1. 27	1. 29	1. 31	5
6	1. 32	1. 34	1. 36	1. 38	1. 39	1. 41	1. 43	1. 45	1. 46	1. 48	6
7	1. 50	1. 51	1. 53	1. 55	1. 56	1. 58	1. 60	1. 62	1. 63	1. 65	7
8	1. 67	1. 68	1. 70	1. 72	1. 73	1. 75	1. 77	1. 78	1. 80	1. 82	8
9	1. 83	1. 85	1. 87	1. 88	1. 90	1. 91	1. 93	1. 95	1. 96	1. 98	9
10	2. 00	2. 01	2. 03	2. 04	2. 06	2. 07	2. 09	2. 11	2. 12	2. 14	10
11	2. 15	2. 17	2. 18	2. 20	2. 22	2. 23	2. 25	2. 26	2. 28	2. 29	11
12	2. 31	2. 32	2. 34	2. 35	2. 37	2. 38	2. 40	2. 41	2. 43	2. 44	12
13	2. 46	2. 47	2. 49	2. 50	2. 52	2. 53	2. 55	2. 56	2. 57	2. 59	13
14	2. 60	2. 62	2. 63	2. 65	2. 66	2. 67	2. 69	2. 70	2. 72	2. 73	14

TABLE 7.—*Tolerances for weed seeds, other crop seed, and inert matter for other than certain chaffy grasses*—Continued

Value, percent	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	Value, percent
15	2. 75	2. 76	2. 77	2. 79	2. 80	2. 81	2. 83	2. 84	2. 86	2. 87	15
16	2. 88	2. 90	2. 91	2. 92	2. 94	2. 95	2. 96	2. 98	2. 99	3. 00	16
17	3. 02	3. 03	3. 04	3. 06	3. 07	3. 08	3. 10	3. 11	3. 12	3. 13	17
18	3. 15	3. 16	3. 17	3. 19	3. 20	3. 21	3. 22	3. 24	3. 25	3. 26	18
19	3. 27	3. 28	3. 30	3. 31	3. 32	3. 33	3. 35	3. 36	3. 37	3. 38	19
20	3. 40	3. 41	3. 42	3. 43	3. 44	3. 45	3. 47	3. 48	3. 49	3. 50	20
21	3. 51	3. 52	3. 54	3. 55	3. 56	3. 57	3. 58	3. 59	3. 60	3. 62	21
22	3. 63	3. 64	3. 65	3. 66	3. 67	3. 68	3. 69	3. 70	3. 72	3. 73	22
23	3. 74	3. 75	3. 76	3. 77	3. 78	3. 79	3. 80	3. 81	3. 82	3. 83	23
24	3. 84	3. 85	3. 86	3. 87	3. 88	3. 89	3. 90	3. 91	3. 92	3. 93	24
25	3. 95	3. 95	3. 96	3. 97	3. 98	3. 99	4. 00	4. 01	4. 02	4. 03	25
26	4. 04	4. 05	4. 06	4. 07	4. 08	4. 09	4. 10	4. 11	4. 12	4. 13	26
27	4. 14	4. 15	4. 16	4. 16	4. 17	4. 18	4. 19	4. 20	4. 21	4. 22	27
28	4. 23	4. 24	4. 24	4. 25	4. 26	4. 27	4. 28	4. 29	4. 30	4. 30	28
29	4. 31	4. 32	4. 33	4. 34	4. 35	4. 35	4. 36	4. 37	4. 38	4. 39	29
30	4. 40	4. 40	4. 41	4. 42	4. 43	4. 43	4. 44	4. 45	4. 46	4. 47	30
31	4. 47	4. 48	4. 49	4. 50	4. 50	4. 51	4. 52	4. 53	4. 53	4. 54	31
32	4. 55	4. 55	4. 56	4. 57	4. 58	4. 58	4. 59	4. 60	4. 60	4. 61	32
33	4. 62	4. 62	4. 63	4. 64	4. 64	4. 65	4. 66	4. 66	4. 67	4. 68	33
34	4. 68	4. 69	4. 70	4. 70	4. 71	4. 71	4. 72	4. 73	4. 73	4. 74	34
35	4. 75	4. 75	4. 76	4. 76	4. 77	4. 77	4. 78	4. 79	4. 79	4. 80	35
36	4. 80	4. 81	4. 81	4. 82	4. 83	4. 83	4. 84	4. 84	4. 85	4. 85	36
37	4. 86	4. 86	4. 87	4. 87	4. 88	4. 88	4. 89	4. 89	4. 90	4. 90	37
38	4. 91	4. 91	4. 92	4. 92	4. 93	4. 93	4. 94	4. 94	4. 94	4. 95	38
39	4. 95	4. 96	4. 96	4. 97	4. 97	4. 97	4. 98	4. 98	4. 99	4. 99	39
40	5. 00	5. 00	5. 00	5. 00	5. 01	5. 01	5. 02	5. 02	5. 03	5. 03	40

TABLE 8.—*Tolerances for inert matter, weed seed, and crop seed for chaffy grasses, as follows:* Poa *spp.*, Agrostis *spp.*, Festuca *spp.*, *bromegrass, crested wheatgrass, orchard grass, velvet grass, tall oatgrass, meadow foxtail, sweet vernal grass, Rhodes grass, Dallis grass, carpet grass, Bermuda grass, Guinea grass, molasses grass, Vasey grass,* Andropogon *spp.*, Bouteloua *spp.*, *Indian ricegrass and wild-rye, and mixtures containing these seeds singly or combined in excess of 50 percent*

[The tolerance is obtained by adding to the regular tolerance the product obtained by multiplying the regular tolerance by the lesser of *a* and *b* divided by 100]

Value, percent	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	Value, percent
0	0. 20	0. 21	0. 23	0. 25	0. 27	0. 29	0. 31	0. 33	0. 35	0. 37	0
1	. 39	. 41	. 43	. 45	. 47	. 49	. 51	. 53	. 55	. 58	1
2	. 60	. 62	. 64	. 66	. 67	. 69	. 71	. 73	. 76	. 78	2
3	. 80	. 82	. 83	. 85	. 87	. 90	. 92	. 94	. 96	. 97	3
4	. 99	1. 02	1. 04	1. 06	1. 08	1. 09	1. 10	1. 13	1. 15	1. 17	4

TABLE 8.—*Tolerances for inert matter, weed seed, and crop seed for chaffy grasses, etc.*—Continued

Value, percent	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	Value, percent
5	1. 20	1. 21	1. 24	1. 26	1. 28	1. 29	1. 31	1. 33	1. 35	1. 37	5
6	1. 39	1. 42	1. 44	1. 46	1. 47	1. 50	1. 52	1. 54	1. 55	1. 58	6
7	1. 60	1. 61	1. 64	1. 66	1. 67	1. 69	1. 72	1. 74	1. 75	1. 78	7
8	1. 80	1. 81	1. 83	1. 86	1. 87	1. 89	1. 92	1. 93	1. 95	1. 98	8
9	1. 99	2. 01	2. 04	2. 06	2. 07	2. 09	2. 11	2. 13	2. 15	2. 17	9
10	2. 20	2. 21	2. 23	2. 25	2. 27	2. 28	2. 31	2. 33	2. 34	2. 37	10
11	2. 38	2. 41	2. 42	2. 44	2. 47	2. 48	2. 51	2. 52	2. 54	2. 56	11
12	2. 58	2. 60	2. 62	2. 63	2. 66	2. 67	2. 70	2. 71	2. 74	2. 75	12
13	2. 77	2. 79	2. 81	2. 83	2. 85	2. 87	2. 89	2. 91	2. 92	2. 95	13
14	2. 96	2. 98	3. 00	3. 03	3. 04	3. 05	3. 07	3. 09	3. 12	3. 13	14
15	3. 16	3. 17	3. 19	3. 21	3. 23	3. 24	3. 26	3. 28	3. 29	3. 32	15
16	3. 34	3. 36	3. 38	3. 39	3. 42	3. 43	3. 45	3. 47	3. 49	3. 50	16
17	3. 53	3. 54	3. 56	3. 58	3. 60	3. 61	3. 64	3. 66	3. 67	3. 69	17
18	3. 71	3. 73	3. 74	3. 77	3. 78	3. 80	3. 81	3. 84	3. 86	3. 87	18
19	3. 89	3. 90	3. 93	3. 94	3. 96	3. 97	4. 00	4. 02	4. 03	4. 05	19
20	4. 08	4. 09	4. 11	4. 12	4. 14	4. 15	4. 18	4. 20	4. 21	4. 23	20
21	4. 24	4. 26	4. 29	4. 30	4. 32	4. 33	4. 35	4. 36	4. 38	4. 41	21
22	4. 42	4. 44	4. 46	4. 47	4. 49	4. 50	4. 52	4. 53	4. 56	4. 58	22
23	4. 60	4. 61	4. 63	4. 64	4. 66	4. 68	4. 69	4. 71	4. 72	4. 74	23
24	4. 76	4. 77	4. 79	4. 81	4. 82	4. 84	4. 85	4. 87	4. 89	4. 90	24
25	4. 93	4. 94	4. 95	4. 97	4. 99	5. 00	5. 02	5. 04	5. 05	5. 07	25
26	5. 09	5. 10	5. 12	5. 14	5. 15	5. 17	5. 19	5. 20	5. 22	5. 24	26
27	5. 25	5. 27	5. 29	5. 29	5. 31	5. 32	5. 34	5. 36	5. 38	5. 39	27
28	5. 41	5. 43	5. 43	5. 45	5. 46	5. 48	5. 50	5. 53	5. 53	5. 54	28
29	5. 55	5. 57	5. 59	5. 61	5. 62	5. 63	5. 65	5. 66	5. 68	5. 70	29
30	5. 72	5. 72	5. 74	5. 75	5. 77	5. 78	5. 79	5. 81	5. 83	5. 85	30
31	5. 85	5. 87	5. 89	5. 90	5. 91	5. 93	5. 94	5. 96	5. 97	5. 98	31
32	6. 00	6. 01	6. 02	6. 04	6. 06	6. 06	6. 08	6. 10	6. 10	6. 12	32
33	6. 14	6. 14	6. 16	6. 18	6. 18	6. 20	6. 22	6. 23	6. 24	6. 26	33
34	6. 27	6. 28	6. 30	6. 31	6. 33	6. 33	6. 35	6. 37	6. 37	6. 39	34
35	6. 41	6. 41	6. 43	6. 44	6. 45	6. 46	6. 48	6. 50	6. 50	6. 52	35
36	6. 52	6. 54	6. 55	6. 55	6. 58	6. 59	6. 61	6. 61	6. 63	6. 63	36
37	6. 65	6. 66	6. 68	6. 68	6. 70	6. 71	6. 72	6. 73	6. 75	6. 75	37
38	6. 77	6. 78	6. 79	6. 80	6. 82	6. 82	6. 84	6. 85	6. 85	6. 87	38
39	6. 88	6. 89	6. 90	6. 92	6. 92	6. 93	6. 95	6. 95	6. 97	6. 98	39
40	7. 00	7. 00	7. 01	7. 01	7. 03	7. 03	7. 05	7. 06	7. 08	7. 08	40

$$\text{Regular Tolerance} + \frac{(\text{Regular Tolerance} \times \text{value})}{100}$$

Example: Tolerance for 9.10 percent

$$1.85 + \frac{(1.85 \times 9.10)}{100}$$

$$1.85 + \frac{16.8350}{100}$$

$$1.85 + 0.16$$

Tolerance 2.01 percent.

Noxious-Weed Seeds

The tolerances (table 9) for rates of occurrence of noxious-weed seeds shall be recognized and shall be applied to the number of noxious-weed seeds found by analysis in the quantity of seed specified for noxious-weed seed determinations. Representations showing the rate of occurrence indicated in table 9, columns 2, 4, and 6 will be considered within the tolerance if no more than the accompanying numbers in columns 1, 3, and 5 are found by analysis. For rates of occurrence higher than those shown in table 9 and in case of additional or more extensive analyses, a tolerance based on a degree of certainty of 5 percent (P=0.05) will be recognized.

TABLE 9.—*Tolerances for noxious-weed seeds*

[Based on the Poisson distribution and calculated from the formula $Y=X+\sqrt{3.841\ X}+1$; Y=the number in the first column and X=the number in the second column]

Number found by analysis	The following are within the tolerance	Number found by analysis	The following are within the tolerance	Number found by analysis	The following are within the tolerance
2	0	56	42	103	84
4	1	57	43	104	85
6	2	58	44	105	86
8	3	59	45	106	87
9	4	60	46	107	88
11	5	61	47	108	89
12	6	63	48	110	90
13	7	64	49	111	91
14	8	65	50	112	92
16	9	66	51	113	93
17	10	67	52	114	94
18	11	68	53	115	95
20	12	69	54	116	96
21	13	71	55	117	97
22	14	72	56	118	98
23	15	73	57	120	99
24	16	74	58	121	100
25	17	75	59	122	101
27	18	76	60	123	102
28	19	77	61	124	103
29	20	78	62	125	104
30	21	80	63	126	105
32	22	81	64	127	106
33	23	82	65	128	107
34	24	83	66	129	108
35	25	84	67	130	109
37	26	85	68	132	110
38	27	86	69	133	111
39	28	87	70	134	112
41	29	89	71	135	113
42	30	90	72	136	114
43	31	91	73	137	115
44	32	92	74	138	116
45	33	93	75	139	117
46	34	94	76	140	118
48	35	95	77	141	119
49	36	96	78	142	120
50	37	97	79	144	121
51	38	99	80	145	122
52	39	100	81	146	123
53	40	101	82	147	124
55	41	102	83	148	125

TABLE 9.—*Tolerances for noxious-weed seeds*—Continued

Number found by analysis	The following are within the tolerance	Number found by analysis	The following are within the tolerance	Number found by analysis	The following are within the tolerance
149	126	213	185	276	244
150	127	214	186	277	245
151	128	215	187	278	246
152	129	216	188	279	247
153	130	217	179	280	248
154	131	218	190	281	249
156	132	219	191	282	250
157	133	220	192	283	251
158	134	221	193	284	252
159	135	222	194	285	253
160	136	223	195	286	254
161	137	224	196	287	255
162	138	226	197	288	256
163	139	227	198	289	257
164	140	228	199	290	258
165	141	229	200	292	259
166	142	230	201	293	260
167	143	231	202	294	261
169	144	232	203	295	262
170	145	233	204	296	263
171	146	234	205	297	264
172	147	235	206	298	265
173	148	236	207	299	266
174	149	237	208	300	267
175	150	238	209	301	268
176	151	239	210	302	269
177	152	240	211	303	270
178	153	242	212	304	271
179	154	243	213	305	272
180	155	244	214	306	273
181	156	245	215	307	274
183	157	246	216	309	275
184	158	247	217	310	276
185	159	248	218	311	277
186	160	249	219	312	278
187	161	250	220	313	279
188	162	251	221	314	280
189	163	252	222	315	281
190	164	253	223	316	282
191	165	254	224	317	283
192	166	255	225	318	284
193	167	256	226	319	285
194	168	258	227	320	286
195	169	259	228	321	287
197	170	260	229	322	288
198	171	261	230	323	289
199	172	262	231	324	290
200	173	263	232	325	291
201	174	264	233	326	292
202	175	265	234	328	293
203	176	266	235	329	294
204	177	267	236	330	295
205	178	268	237	331	296
206	179	269	238	332	297
207	180	270	239	333	298
208	181	271	240	334	299
209	182	272	241	335	300
211	183	273	242		
212	184	275	243		

FLUORESCENCE TEST AND 400- TO 1,000-SEED SEPARATIONS

Tolerances shall be recognized and applied to fluorescence test results of *Lolium* spp. and 400-seed separations (or a larger number of seeds) in purity analyses. These tolerances recognize the sampling error introduced by the small number of seeds used and are to be applied in determining the variations for those factors affected by the use of a small number of seeds. If the results of fluorescence tests or 400- to 1,000-seed separations are used in computing the percentages of pure seed of a sample, one-half the regular pure seed tolerance shall be added to the tolerance for the fluorescence test or 400- to 1,000-seed separations. The tolerances to be used shall be determined from the formula published by Leggatt in Bot. Rev. 5 (9): 505–529, 1939, and in the Association of Official Seed Analysts Proceedings, pages 101–107, 1935, computed to a certainty of 5 percent (P=0.05). The formula is complicated and is not given as a part of table 10.

TABLE 10.—*Tolerances for fluorescence tests and 400- to 1,000-seed separations in purity analysis* [1]

[Based on the requirement that when 2 independent trials or tests have been made on the same properly mixed bulk lot, the chances of divergence between the 2 trials exceeding the tolerance will not be greater than 1 in 20]

Number of seeds in test to which tolerance is to be applied	400	400	800	800	400	800	1,000	1,000	1,000
Number of seeds used in other test	400	800	400	800	1,000	1,000	1,000	800	400
100 percent									
99 percent	1.0	0.8	0.9	0.8	0.7	0.7	0.7	0.8	0.9
98 percent	1.6	1.3	1.4	1.2	1.2	1.0	1.0	1.2	1.4
97 percent	2.0	1.7	1.8	1.4	1.5	1.3	1.3	1.4	1.8
96 percent	2.3	1.9	2.2	1.7	1.8	1.6	1.5	1.7	2.1
95 percent	2.6	2.2	2.4	1.9	2.1	1.8	1.7	1.8	2.4
94 percent	2.9	2.4	2.7	2.1	2.3	2.0	1.9	2.0	2.6
93 percent	3.2	2.7	2.9	2.3	2.5	2.1	2.0	2.2	2.8
92 percent	3.4	2.8	3.1	2.4	2.7	2.3	2.2	2.3	3.0
91 percent	3.6	3.1	3.3	2.6	2.9	2.4	2.3	2.5	3.2
90 percent	3.8	3.2	3.4	2.8	3.0	2.6	2.4	2.7	3.3
89 percent	4.0	3.4	3.6	2.9	3.1	2.7	2.5	2.8	3.4
88 percent	4.1	3.5	3.7	3.0	3.2	2.8	2.7	2.9	3.6
87 percent	4.3	3.7	3.9	3.1	3.4	2.9	2.8	2.9	3.8
86 percent	4.5	3.8	3.9	3.2	3.6	3.0	2.9	3.1	3.9
85 percent	4.7	3.9	4.1	3.3	3.7	3.1	2.9	3.2	4.0
84 percent	4.8	4.1	4.2	3.4	3.9	3.2	3.0	3.3	4.1
83 percent	4.9	4.2	4.3	3.5	4.0	3.3	3.1	3.3	4.2
82 percent	5.0	4.3	4.4	3.6	4.1	3.4	3.2	3.4	4.3
81 percent	5.2	4.4	4.5	3.7	4.2	3.5	3.3	3.5	4.4

See footnote at end of table.

TABLE 10.—*Tolerances for fluorescence tests and 400- to 1,000-seed separations in purity analysis* [1]—Continued

Number of seeds in test to which tolerance is to be applied	400	400	800	800	400	800	1,000	1,000	1,000
Number of seeds used in other test	400	800	400	800	1,000	1,000	1,000	800	400
80 percent	5.3	4.5	4.7	3.8	4.3	3.5	3.3	3.6	4.5
79 percent	5.4	4.6	4.7	3.8	4.4	3.6	3.4	3.7	4.6
78 percent	5.5	4.7	4.8	3.9	4.5	3.7	3.5	3.7	4.7
77 percent	5.6	4.8	4.9	4.0	4.6	3.7	3.5	3.8	4.8
76 percent	5.7	4.9	5.0	4.1	4.6	3.8	3.6	3.8	4.8
75 percent	5.8	5.0	5.1	4.1	4.7	3.9	3.7	3.9	4.9
74 percent	5.8	5.0	5.1	4.2	4.8	3.9	3.7	3.9	5.0
73 percent	5.9	5.1	5.2	4.2	4.9	4.0	3.8	4.0	5.1
72 percent	6.0	5.2	5.3	4.3	4.9	4.0	3.8	4.1	5.1
71 percent	6.1	5.2	5.3	4.3	5.0	4.1	3.9	4.1	5.2
70 percent	6.2	5.3	5.4	4.4	5.1	4.1	3.9	4.2	5.2
69 percent	6.2	5.4	5.5	4.4	5.1	4.2	3.9	4.2	5.3
68 percent	6.3	5.4	5.5	4.5	5.2	4.2	4.0	4.3	5.3
67 percent	6.3	5.5	5.6	4.5	5.2	4.2	4.0	4.3	5.4
66 percent	6.4	5.5	5.6	4.6	5.3	4.3	4.0	4.3	5.4
65 percent	6.5	5.6	5.7	4.6	5.3	4.3	4.1	4.3	5.4
64 percent	6.5	5.6	5.7	4.6	5.4	4.3	4.1	4.4	5.5
63 percent	6.5	5.7	5.7	4.7	5.4	4.4	4.1	4.4	5.6
62 percent	6.6	5.7	5.8	4.7	5.4	4.4	4.2	4.4	5.6
61 percent	6.6	5.7	5.8	4.7	5.5	4.4	4.2	4.4	5.6
60 percent	6.7	5.8	5.8	4.8	5.5	4.5	4.2	4.5	5.6
59 percent	6.7	5.8	5.9	4.8	5.5	4.5	4.2	4.5	5.7
58 percent	6.8	5.8	5.9	4.8	5.6	4.5	4.2	4.6	5.7
57 percent	6.8	5.9	5.9	4.8	5.6	4.5	4.3	4.6	5.7
56 percent	6.8	5.9	5.9	4.8	5.6	4.5	4.3	4.6	5.7
55 percent	6.8	5.9	5.9	4.9	5.7	4.6	4.3	4.6	5.8
54 percent	6.9	5.9	6.0	4.9	5.7	4.6	4.3	4.6	5.8
53 percent	6.9	5.9	6.0	4.9	5.7	4.6	4.3	4.6	5.8
52 percent	6.9	6.0	6.0	4.9	5.7	4.6	4.3	4.7	5.8
51 percent	6.9	6.0	6.0	4.9	5.7	4.6	4.3	4.7	5.8
50 percent	6.9	6.0	6.0	4.9	5.7	4.6	4.3	4.7	5.8
49 percent	6.9	6.0	6.0	4.9	5.7	4.6	4.3	4.7	5.8
48 percent	6.9	6.0	6.0	4.9	5.7	4.6	4.3	4.7	5.8
47 percent	6.9	6.0	6.0	4.9	5.7	4.6	4.3	4.7	5.8
46 percent	6.9	6.0	6.0	4.9	5.7	4.6	4.3	4.7	5.8
45 percent	6.9	6.0	6.0	4.9	5.7	4.6	4.3	4.7	5.8
44 percent	6.9	6.0	6.0	4.9	5.7	4.6	4.3	4.7	5.8
43 percent	6.9	6.0	6.0	4.9	5.7	4.6	4.3	4.6	5.8
42 percent	6.9	6.0	6.0	4.9	5.7	4.6	4.3	4.6	5.8
41 percent	6.9	6.0	5.9	4.9	5.7	4.6	4.3	4.6	5.7
40 percent	6.9	6.0	5.9	4.8	5.7	4.6	4.3	4.6	5.7
39 percent	6.8	5.9	5.9	4.8	5.7	4.5	4.3	4.6	5.7
38 percent	6.8	5.9	5.9	4.8	5.7	4.5	4.3	4.5	5.7
37 percent	6.8	5.9	5.9	4.8	5.7	4.5	4.2	4.5	5.6
36 percent	6.8	5.9	5.8	4.8	5.6	4.5	4.2	4.5	5.6

See footnote at end of table.

957116—52——25

TABLE 10.—*Tolerances for fluorescence tests and 400- to 1,000-seed separations in purity analysis* [1]—Continued

Number of seeds in test to which tolerance is to be applied	400	400	800	800	400	800	1,000	1,000	1,000
Number of seeds used in other test	400	800	400	800	1,000	1,000	1,000	800	400
35 percent	6.7	5.9	5.8	4.7	5.6	4.5	4.2	4.4	5.6
34 percent	6.7	5.8	5.8	4.7	5.6	4.4	4.2	4.4	5.6
33 percent	6.7	5.8	5.7	4.7	5.5	4.4	4.1	4.4	5.5
32 percent	6.6	5.8	5.7	4.7	5.5	4.4	4.1	4.4	5.4
31 percent	6.6	5.7	5.6	4.6	5.5	4.3	4.1	4.3	5.4
30 percent	6.5	5.7	5.6	4.6	5.4	4.3	4.0	4.3	5.4
29 percent	6.5	5.6	5.6	4.6	5.4	4.3	4.0	4.3	5.3
28 percent	6.4	5.6	5.5	4.5	5.4	4.2	4.0	4.3	5.3
27 percent	6.4	5.5	5.4	4.5	5.3	4.2	3.9	4.2	5.2
26 percent	6.3	5.5	5.4	4.4	5.3	4.1	3.9	4.2	5.2
25 percent	6.2	5.4	5.3	4.4	5.2	4.1	3.8	4.1	5.1
24 percent	6.2	5.4	5.2	4.3	5.1	4.0	3.8	4.1	5.0
23 percent	6.1	5.3	5.2	4.3	5.1	4.0	3.7	4.0	4.9
22 percent	6.0	5.2	5.1	4.2	5.0	3.9	3.7	3.9	4.9
21 percent	5.9	5.2	5.0	4.1	4.9	3.9	3.6	3.9	4.8
20 percent	5.9	5.1	4.9	4.1	4.9	3.8	3.6	3.8	4.8
19 percent	5.7	5.0	4.9	4.0	4.8	3.8	3.5	3.8	4.7
18 percent	5.6	4.9	4.8	3.9	4.7	3.7	3.4	3.7	4.6
17 percent	5.5	4.8	4.7	3.8	4.6	3.6	3.4	3.6	4.4
16 percent	5.4	4.7	4.6	3.8	4.5	3.5	3.3	3.5	4.4
15 percent	5.3	4.6	4.5	3.7	4.4	3.4	3.2	3.4	4.3
14 percent	5.2	4.5	4.3	3.6	4.3	3.4	3.1	3.3	4.2
13 percent	5.0	4.4	4.2	3.5	4.2	3.3	3.0	3.3	4.0
12 percent	4.9	4.3	4.1	3.4	4.1	3.2	2.9	3.2	3.9
11 percent	4.7	4.1	3.9	3.3	4.0	3.0	2.8	3.1	3.8
10 percent	4.6	4.0	3.8	3.1	3.8	2.9	2.7	2.9	3.6
9 percent	4.4	3.8	3.6	3.0	3.7	2.8	2.6	2.8	3.4
8 percent	4.2	3.7	3.5	2.9	3.5	2.7	2.5	2.7	3.3
7 percent	4.0	3.5	3.3	2.7	3.3	2.5	2.4	2.5	3.1
6 percent	3.7	3.3	3.1	2.5	3.1	2.4	2.2	2.4	2.9
5 percent	3.5	3.1	2.9	2.4	2.9	2.2	2.0	2.2	2.7
4 percent	3.2	2.8	2.6	2.2	2.7	2.0	1.9	2.0	2.4
3 percent	2.8	2.5	2.3	1.9	2.4	1.8	1.6	1.8	2.2
2 percent	2.4	2.2	1.9	1.6	2.1	1.5	1.4	1.5	1.8
1 percent	1.8	1.7	1.4	1.3	1.7	1.1	1.0	1.2	1.4
0 percent	1.0	1.0	.5	.5	.4	.4	.3	.4	.4

[1] Method of using table: Enter the percentage to which the tolerance is to be applied in the left-hand column. Next, find in the top horizontal row the number of seeds used in your test and to which the tolerance is to be applied; then, find in the second row the number of seeds used in the test with which your results are to be compared. (If the number of seeds is not known assume that 400 seeds were used.) The corresponding tolerance will be found in the appropriate column and should be added to the percentage for which the tolerance is required.

Examples

1. Laboratory A reported 97.80 percent perennial ryegrass seed by applying the results of a 400-seed fluorescence test to the formula for determining percentage of ryegrass. Upon testing a sample of this seed, laboratory B found 94.6 percent perennial ryegrass based on 98.60 percent ryegrass and a 400-seed fluorescence test which gave 8 percent fluorescence and 82 percent nonfluorescence. Does the result of laboratory B confirm the report of laboratory A?

(*a*) Perennial ryegrass found by laboratory B=

$$\frac{1.0526 \times 82.00 \times 98.60}{90} = 94.56\%$$

(*b*) One-half pure seed tolerance for 98.60% ryegrass=0.44%

(*c*) Fluorescence tolerance for 91.1% in the

$$\frac{400 \text{ (laboratory B)}}{400 \text{ (laboratory A)}} \text{seed column} = 3.6\%$$

Total tolerance=4.04%

(*d*) Laboratory B found 94.6 percent ryegrass plus 4.04 percent tolerance=98.64 percent and thus confirmed the report of laboratory A. Note that the 91.1 percent used in determining the fluorescence tolerance (operation No. 3 above) is the product:

$$\frac{\text{Number of nonfluorescent seeds}}{\text{Number of seeds germinating}} \text{ or } \frac{328}{360} = 91.1\%$$

It is necessary to use the tolerance applicable to the nonfluorescence value since the total tolerance should finally be applied to the perennial ryegrass value.

2. Laboratory A reported a pure seed percentage of 87.65 for Kentucky bluegrass. Upon testing a sample of this seed, laboratory B found a pure seed content of 80.08 percent for Kentucky bluegrass. In making its test laboratory B found 86.57 percent *Poa* spp. in a 1-gram working sample; upon examination of 1,000 seeds of the *Poa* spp. 92.5 percent of these seeds was found to be Kentucky bluegrass and 7.5 percent Canada bluegrass. Did Laboratory B confirm the report of laboratory A with respect to pure seed for Kentucky bluegrass?

(*a*) Pure seed found by laboratory B=86.57×92.5=80.08%

(*b*) ½ pure seed tolerance for *Poa* species (chaffy grasses) for 86.57%=1.66%

(*c*) Tolerance for 1,000-seed examination in the 92.5% line and the

$$\frac{1{,}000 \text{ (laboratory B)}}{400 \text{ (laboratory A)}} \text{seed column} = 2.9\%$$

(*d*) Total tolerance=4.56 percent.

Laboratory B found 80.08 percent pure seed plus 4.56 percent tolerance=84.64% which does not confirm the report of Laboratory A. Since we do not know the size of the sample used by laboratory A, we must assume that this laboratory followed the rules and used at least 400 seeds in separating the two kinds of seeds having similar characteristics.

Germination

The following tolerances are applicable to the percentages of germination and also to the sum of the germination plus the hard seed when 400 or more seeds are tested:

Found by test	*Tolerance*	*Found by test*	*Tolerance*
96 or over	5	70 or over but less than 80	8
90 or over but less than 96	6	60 or over but less than 70	9
80 or over but less than 90	7	Less than 60	10

In table 11 these tolerances have been added to germination values ranging from 50 to 99 percent for tests based on 400 or more seeds. When only 200 seeds of mixtures are tested 2 percent shall be added to the above germination tolerances.

TABLE 11.—*Tolerances for germination tests*

Percent found by test	The following are within tolerance	Percent found by test	The following are within tolerance
99	100	74	82
98	100	73	81
97	100	72	80
96	100	71	79
95	100	70	78
94	100	69	78
93	99	68	77
92	98	67	76
91	97	66	75
90	96	65	74
89	96	64	73
88	95	63	72
87	94	62	71
86	93	61	70
85	92	60	69
84	91	59	69
83	90	58	68
82	89	57	67
81	88	56	66
80	87	55	65
79	87	54	64
78	86	53	63
77	85	52	62
76	84	51	61
75	83	50	60

SAMPLE RECORD AND REPORT FORMS

SAMPLE PURITY RECORD CARD

Lab. No. _____ Kind _____ Sender's mark _____

Received _____ Kind of test _____

Test made by _____ Date _____

Sent by _____

Address _____

Remarks _____

Time of test _____ Checked by _____

	Weight	*Percent*
Pure		
Crop		
Inert		
Weed		
Weight of sample	*Final*	*Original*
Date reported		

Character of inert _____

Noxious-weed seed according to law; based on examination of _____ gm.

Weed seeds	Crop seeds

SAMPLE GERMINATION RECORD CARD

Lab. No. _____ Kind _____

Germination test begun														
Special treatment														
Temperature °C														
Substratum														
Number of seeds tested														
Number seeds germinating each day	3													
	10													
	14													
	21													
	28													
Normal	Total													
	Average percent													
Hard seed	Total													
	Average percent													
Abnormal														
	Total													
	Average percent													
Decayed														
Dead														

SAMPLE FORM FOR REPORTING PURITY OR PURITY AND GERMINATION TEST RESULTS

REPORT OF PURITY TEST OF SEED RECEIVED

Test No.	Sender's mark	Name of seed	Pure seed (percent)	Crop seed (percent)	Inert (percent)	Weed seed (percent)

Remarks:

Weed seeds	Percent by weight	Crop seeds	Percent by weight

Germination test			Noxious-weed seed examination	
Duration of test in days	Germination (percent)	Hard seed (percent)	Noxious-weed seed according to ____ State seed law based on examination of ____ grams	Number of seeds found

Remarks:

SAMPLE FORM FOR REPORTING GERMINATION TEST RESULTS

REPORT OF GERMINATION TEST OF SEED RECEIVED ----------

Test No.	Sender's mark	Name of seed	Duration of test in days	Germination, percent	Hard seeds, percent

LIST OF BOTANICAL NAMES

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION

Identification		Botanical name	Purity	Germination	
Plate	*Page*		*Page*	*Page*	*Figure*
XXIV, 489		*Abutilon theophrasti* Medic.			
XXIII, 479		*Acalypha virginica* L.			
XXXI, 661		*Achillea millefolium* L.			
XXXI, 662		*Achyrachaena mollis* Schauer			
XVIII, 353	237	*Adesmia muricata* (Jacq.) DC.			
XVIII, 354	238	*Aeschynomene virginica* (L.) BSP.			
XXV, 521		*Aethusa cynapium* L.			
	198	*Agropyron*			
I, 13	200	*Agropyron cristatum* (L.) Gaertn.	55	126	
	200	*Agropyron dasystachyum* (Hook.) Scribn.			
I, 14	200	*Agropyron desertorum* (Fisch.) Schult. (formerly *A. cristatum*).	55	126	
I, 12	201	*Agropyron elongatum* (Host.) Beauv.			
	201	*Agropyron inerme* (Scribn. and Smith) Rydb.			
I, 15	201	*Agropyron intermedium* (Host.) Beauv.			
		Agropyron pauciflorum (see *A. trachycaulum*).			
I, 9	201	*Agropyron repens* (L.) Beauv.			
	200	*Agropyron riparium* Scribn. and Smith.			
I, 10	201	*Agropyron smithii* Rydb.	55	126	
	200	*Agropyron smithii* var. *molle* (Scribn. and Smith) Jones.			
	200	*Agropyron subsecundum* (Link) Hitchc.			
I, 11	200	*Agropyron trachycaulum* (Link) Malte.	55	126	
I, 16	200	*Agropyron trichophorum* (Link) Richt.			
XV, 273		*Agrostemma githago* L.			
	196	*Agrostis*			
I, 1	197	*Agrostis alba* L.	55	126	
I, 5	198	*Agrostis canina* L.	55	126	
I, 6	198	*Agrostis elliottiana* Schult.			
I, 3–4	198	*Agrostis exarata* Trin.			
I, 7	198	*Agrostis hiemalis* (Walt.) BSP.			
	198	*Agrostis palustris* Huds.	55	126	
I, 8	198	*Agrostis scabra* Willd.			
I, 2	196	*Agrostis tenuis* Sibth.	55	126	
	198	Hort. vars.: Colonial bent			
	198	Astoria			
	197	Highland			
	201	*Aira*			
		Aira capillaris (see *A. elegans*).			
I, 18	201	*Aira caryophyllea* L.			
I, 17	201	*Aira elegans* Willd. ex Gaudin			
		Aira spp. (see *Deschampsia* spp.)			
XV, 271		Aizoaceae			

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Botanical name	Purity	Germination	
Plate	*Page*		*Page*	*Page*	*Figure*
XXVIII, 586		*Ajuga chamaepitys* (L.) Schreb.			
		Alhagi camelorum Fisch. (see *A. pseudalhagi*).			
XVIII, 355	238	*Alhagi pseudalhagi* (Bieb.) Desv.			
		Allionia nyctaginea (see *Mirabilis nyctaginea*).			
		Allium spp	82		
		Allium cepa L	82	160	57
		Allium porrum L	82	160	
XIII, 220		*Allium vineale* L			
XXVII, 569		*Allocarya* sp			
	202	*Alopecurus*			
I, 19	202	*Alopecurus aequalis* Sobol			
I, 20	202	*Alopecurus carolinianus* Walt			
I, 21	202	*Alopecurus geniculatus* L			
I, 23	202	*Alopecurus myosuroides* Huds			
I, 22	202	*Alopecurus pratensis* L	66	126	
		Alsine graminea (see *Stellaria graminea*).			
		Alsine media (see *Stellaria media*).			
XXIV, 490		*Althaea hirsuta* L			
XVIII, 356	238	*Alysicarpus vaginalis* (L.) DC.	77	142	
XVI, 310		*Alyssum alyssoides* L			
XIV–XV, 267–268		Amaranthaceae			
XIV, 267*b*		*Amaranthus albus* L. (*A. graecizans* of Am. authors, not L.)			
		Amaranthus blitoides (see *A. graecizans*).			
XV, 268		*Amaranthus graecizans* L			
XIV, 267*a*		*Amaranthus retroflexus* L			
XXXI, 663		*Ambrosia artemisiifolia* L			
XXXI, 664		*Ambrosia psilostachya* DC			
XXXI, 665		*Ambrosia trifida* L			
XXV, 522		*Ammi majus* L			
XXV, 523		*Ammi visnaga* (L.) Lam			
XXVII, 570		*Amsinckia intermedia* Fisch. and Mey.			
XXVII, 571		*Amsinckia tesselata* Gray			
XXVI, 541		*Anagallis arvensis* L			
	202	*Andropogon*			
		Andropogon furcatus (see *A. gerardi*).			
II, 25	203	*Andropogon gerardi* Vitman	57	126	
II, 26	203	*Andropogon hallii* Hack	57	126	
II, 29	203	*Andropogon intermedius* R. Br			
II, 28	203	*Andropogon ischaemum* L			
II, 30	203	*Andropogon nodosus* (Willem.) Nash.			
II, 31	203	*Andropogon sericeus* R. Br			
II, 27	203	*Andropogon scoparius* Michx	57	126	
II, 32	203	*Andropogon virginicus* L			
XVI, 294		*Anemone canadensis* L			
XXXI, 666		*Anthemis arvensis* L			
XXXI, 667		*Anthemis cotula* L			
XXXI, 668		*Anthemis tinctoria* L			
	203	*Anthoxanthum*			
	204	*Anthoxanthum aristatum* Boiss			

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Botanical name	Purity	Germination	
Plate	*Page*		*Page*	*Page*	*Figure*
II, 33	204	*Anthoxanthum odoratum* L.	66	126	
XXV, 524		*Anthriscus sylvestris* (L.) Hoffm.			
XVIII, 357	238	*Anthyllis vulneraria* L.			
		Apargia spp. (see *Leontodon*)			
II, 34	204	*Apera spica-venti* (L.) Beauv.			
XXV, 525		*Apium ammi* (L.) Urban			
		Apium graveolens var. *dulce* (Mill.) Pers.	80	167	
		Apium graveolens var. *rapaceum* DC.	80	167	
		Apium petroselinum (see *Petroselinum crispum*).			
XXV, 526		*Apium segetum* (L.) Dumort.			
XXXI, 669		*Aplopappus ciliatus* (Nutt.) DC.			
XXVI, 542–543		Apocynaceae			
XXVI, 542		*Apocynum androsaemifolium* L.			
XXVI, 543		*Apocynum cannabinum* L.			
XVI, 311		*Arabis glabra* (L.) Benth.			
		Arachis hypogaea L.	73	142	
XXXI, 670		*Arctium lappa* L.			
XV, 276		*Arenaria serpyllifolia* L.			
I, 24	204	*Aristida dichotoma* Michx.			
XXXI, 671		*Arnoseris minima* (L.) Schweigger and Koerte.			
II, 35	205	*Arrhenatherum elatius* (L.) Presl.	66	126	
XXVI, 544–548		Asclepiadaceae			
XXVI, 545		*Asclepias galioides* HBK.			
XXVI, 544		*Asclepias mexicana* Cav.			
XXVI, 546		*Asclepias syriaca* L.			
XXVI, 547		*Asclepias tuberosa* L.			
		Asparagus officinalis L.	82	160	
XXVII, 572		*Asperugo procumbens* L.			
	238	*Astragalus*			
XVIII, 358	239	*Astragalus chinensis* L. f.			
XVIII, 359	239	*Astragalus cicer* L.			
XVIII, 360	239	*Astragalus falcatus* Lam.			
XVIII, 361	239	*Astragalus flexuosus* Dougl.			
XVIII, 362	239	*Astragalus nuttallianus* DC.			
XVIII, 363	239	*Astragalus rubyi* Greene and Morris.			
XIV, 246		*Atriplex patula* var. *hastata* (L.) Gray.			
XIV, 247		*Atriplex rosea* L.			
XIV, 248		*Atriplex truncata* Gray			
	205	*Avena*			
II, 40	207	*Avena barbata* Brot.			
II, 37	207	*Avena byzantina* E. Koch	57	126	
II, 39	207	*Avena fatua* L.			
II, 38	207	*Avena* (homozygous fatuoid)			
II, 36	207	*Avena sativa* L.	57	126	35
II, 41	208	*Avena strigosa* Schreb.			
	208	*Axonopus*			
II, 42	208	*Axonopus affinis* Chase	58	126	
II, 43	208	*Axonopus compressus* (Swartz) Beauv.			
XIV, 249		*Axyris amaranthoides* L.			

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Botanical name	Purity	Germination	
Plate	*Page*		*Page*	*Page*	*Figure*
XXVIII, 587	------	*Ballota nigra* L.	------	------	------
------	------	*Barbarea barbarea* (see *B. vulgaris*).	------	------	------
------	------	*Barbarea praecox* (see *B. verna*)	------	------	------
XVI, 312	------	*Barbarea verna* (Mill.) Aschers.	------	------	------
XVI, 313	------	*Barbarea vulgaris* R. Br.	------	------	------
------	------	*Barkhausia setosa* (see *Crepis setosa*).	------	------	------
XIV, 250	------	*Bassia hyssopifolia* (Pall.) Ktze.	------	------	------
------	------	*Beckmannia erucaeformis* (see *B. syzigachne*).	------	------	------
II, 44	208	*Beckmannia syzigachne* (Steud.) Fernald.	------	------	------
XVI, 314	------	*Berteroa incana* (L.) DC.	------	------	------
------	------	*Beta vulgaris* L.	84	107	24, 25
------	------	*Beta vulgaris* var. *cicla*	84	107	------
------	------	*Beta vulgaris* var. *saccharifera*	84	107	------
XV, 269	------	*Boerhaavia erecta* L.	------	------	------
XXV, 510	------	*Boisduvalia densiflora* (Lindl.) Wats.	------	------	------
XXV, 511	------	*Boisduvalia stricta* (Gray) Greene.	------	------	------
XXVII–XXVIII, 569–580.	------	Boraginaceae	------	------	------
------	209	*Bouteloua*	------	------	------
II, 46	209	*Bouteloua curtipendula* (Michx.) Torr.	57	126	------
II, 47	209	*Bouteloua gracilis* (HBK) Lag. ex. Steud.	57	126	------
II, 48	209	*Bouteloua hirsuta* Lag.	------	------	------
------	234	*Brassica*	------	------	------
------	------	*Brassica adpressa* (see *Hirschfeldia incana*).	------	------	------
------	------	*Brassica alba* Moench (see *B. hirta*).	------	------	------
------	------	*Brassica arvensis* (L.) Rabenh. (see *B. kaber*).	------	------	------
XVI, 315	235	*Brassica campestris* L.	83	119	------
------	234	*Brassica campestris* var. *sarson* Prain.	------	------	------
------	235	*Brassica campestris* vars.	83	119	------
------	235	*Brassica chinensis* L.	83	119	------
------	234	*Brassica hirta* Moench	83	119	------
XVII, 316	235	*Brassica juncea* (L.) Coss.	83	119	------
XVII, 317	235	*Brassica kaber* (DC.) L. C. Wheeler.	------	------	------
------	234	*Brassica napus* var. *annua* Koch.	83	119	------
XVII, 318	234	*Brassica napus* var. *biennis* (Schubl. and Mart.) Reichb.	83	119	------
------	234	*Brassica napus* var. *napobrassica* (L.) Reichb.	83	119	------
------	234	*Brassica napus* var. *pabularia* (DC.) Reichb.	------	------	------
XVII, 319	235	*Brassica nigra* (L.) Koch	83	119	------
------	234	*Brassica oleracea* L.	------	------	------
------	------	*Brassica oleracea* var. *acephala* DC.	83	119	------

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Botanical name	Purity	Germination	
Plate	*Page*		*Page*	*Page*	*Figure*
------	------	*Brassica oleracea* var. *botrytis* L.	83	119	------
------	------	*Brassica oleracea* var. *capitata* L.	83	119	31
------	------	*Brassica oleracea* var. *gemmifera* Zenker.	83	119	------
------	------	*Brassica oleracea* var. *gongylodes* L.	83	119	------
------	235	*Brassica pekinensis* (Lour.) Rupr.	83	119	------
------	235	*Brassica perviridis* Bailey	83	119	------
------	235	*Brassica rapa* L.	83	119	------
------	235	*Brassica tournefortii* Gouan	------	------	------
------	------	*Brassica* spp.	83	119	------
XXXI, 672	------	*Brauneria angustifolia* (DC.) Heller.	------	------	------
XIII, 221	------	*Brodiaea coronaria* (Salisb.) Jeps.	------	------	------
XIII, 222	------	*Brodiaea grandiflora* Lindl.	------	------	------
------	209	*Bromus*	------	------	------
------	------	*Bromus breviaristatus* Buckl.	60	------	------
------	210	*Bromus carinatus* Hook. and Arn.	------	------	------
III 56	210	*Bromus catharticus* Vahl	59	126	------
III, 52	211	*Bromus commutatus* Schrad.	------	------	------
------	210	*Bromus commutatus* var. *apricorum* Simonkai.	------	------	------
------	------	*Bromus hordeaceus* (see *B. mollis*).	------	------	------
III, 55	210	*Bromus inermis* Leyss.	59	126	------
III, 51	211	*Bromus japonicus* Thunb.	------	------	------
III, 57	210	*Bromus marginatus* Nees	59	126	------
III, 54	211	*Bromus mollis* L.	------	------	------
------	------	*Bromus polyanthus* Scribn.	60	------	------
------	211	*Bromus rigidus* Roth	------	------	------
------	210	*Bromus rubens* L.	------	------	------
III, 53	211	*Bromus secalinus* L.	------	------	------
------	210	*Bromus secalinus* var. *velutinus* (Schrad.) Koch.	------	------	------
III, 50	211	*Bromus sterilis* L.	------	------	------
III, 49	210	*Bromus tectorum* L.	------	------	------
II, 45	208	*Buchloë dactyloides* (Nutt.) Engelm.	67	126	------
XXV, 527	------	*Bunium bulbocastrum* L.	------	------	------
XXV, 528	------	*Bupleurum protractum* Hoffmgg. and Link.	------	------	------
XXV, 529	------	*Bupleurum rotundifolium* L.	------	------	------
XXV, 530	------	*Bupleurum tenuissimum* L.	------	------	------
------	------	*Bursa bursa-pastoris* (see *Capsella bursa-pastoris*).	------	------	------
XVII, 320	------	*Camelina microcarpa* Andrz.	------	------	------
XVII, 321	------	*Camelina sativa* (L.) Crantz	------	------	------
XXXI, 659	------	Campanulaceae	------	------	------
------	------	*Campe barbarea* (see *Barbarea vulgaris*).	------	------	------
------	------	*Campe verna* (see *Barbarea verna*).	------	------	------
XIII, 225	------	Cannabinaceae	84	167	------
XIII, 225	------	*Cannabis sativa* L.	84	167	------

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Botanical name	Purity	Germination	
Plate	*Page*		*Page*	*Page*	*Figure*
		Caperonia palustris (L.) St. Hil.			
XXX, 651		Caprifoliaceae			
	237	*Capsella bursa-pastoris* (L.) Medic.			
		Capsicum sp	80	167	
	235	*Cardaria*			
XVII, 322	235	*Cardaria draba* (L.) Desv			
	235	*Cardaria draba* var. *repens* (Schrenk.) O. E. Schulz.			
XVII, 323	235	*Cardaria pubescens* (C. A. Mey.) Rollins.			
XXXI, 674		*Carduus acanthoides* L			
XXXI, 673		*Carduus crispus* L			
XXXI, 675		*Carduus macrocephalus* Desf			
XXXII, 676		*Carduus pycnocephalus* L			
XII, 204		*Carex festucacea* Schkuhr			
XII, 205		*Carex trichocarpa* Muhl			
XXXII, 677		*Carthamus tinctorius* L			
		Carum bulbocastrum (see *Bunium bulbocastrum*).			
XXV, 531		*Carum carvi* L			
XV–XVI	232	Caryophyllaceae			
XIX, 364	239	*Cassia nictitans* L			
XIX, 365	239	*Cassia tora* L			
		Caucalis nodosa (see *Torilis nodosa*).			
III, 63	211	*Cenchrus pauciflorus* Benth			
XXXII, 678		*Centaurea calcitrapa* L			
XXXII, 679		*Centaurea cyanus* L			
XXXII, 680		*Centaurea iberica* Trevir			
XXXII, 681		*Centaurea jacea* L			
XXXII, 682		*Centaurea maculosa* Lam			
XXXII, 683		*Centaurea melitensis* L			
XXXII, 684		*Centaurea picris* Pall			
		Centaurea repens (see *C. picris*)			
XXXII, 685		*Centaurea scabiosa* L			
XXXII, 686		*Centaurea solstitialis* L			
XXXII, 687		*Centromadia* sp			
XXXI, 655		*Cephalaria transylvanica* (L.) Schrad.			
XV, 277		*Cerastium vulgatum* L			
XXVI, 532		*Chaerophyllum* sp			
		Chamomilla inodora (see *Matricaria inodora*).			
		Cheirinia spp. (see *Erysimum* spp.)			
XIV, 246–266		Chenopodiaceae	84	107	
XIV, 251		*Chenopodium album* L			
XIV, 252		*Chenopodium berlandieri* Moq			
XIV, 253		*Chenopodium hircinum* Schrad			
XIV, 254		*Chenopodium hybridum* L			
XIV, 255		*Chenopodium hybridum* var. *gigantospermum* (Aellen) Rouleau.			
XIV, 256		*Chenopodium leptophyllum* Nutt.			
XIV, 257		*Chenopodium murale* L			
XIV, 258		*Chenopodium rubrum* L			
	211	*Chloris*			
III, 59	212	*Chloris acicularis* Lindl			

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Botanical name	Purity	Germination	
Plate	*Page*		*Page*	*Page*	*Figure*
III, 58	212	*Chloris divaricata* R. Br.			
III, 60	212	*Chloris gayana* Kunth	66	126	
	212	*Chloris virgata* Swartz			
XXXII, 688		*Chondrilla juncea* L.			
XVII, 324	236	*Chorispora tenella* (Willd.) DC.			
XXXII, 689		*Chrysanthemum leucanthemum* L.			
XIX, 366	239	*Cicer arietinum* L.	73	142	
		Cichorium endivia L.	84	113	
XXXII, 690		*Cichorium intybus* L.	84	113	
XXVI, 533		*Cicuta maculata* L.			
XXXII, 691		*Cirsium arvense* (L.) Scop.			
		Cirsium lanceolatum Scop. (see *C. vulgare*).			
XXXII, 692		*Cirsium vulgare* (Savi) Tenore			
		Citrullus vulgaris Schrad.	82	124	
		Clinopodium (see *Satureja*)			
XXVII, 563		*Collomia gracilis* Dougl.			
XXVII, 564		*Collomia grandiflora* Dougl.			
XII, 215		*Commelina communis* L.			
XII, 215–216		Commelinaceae			
XXXI–XXXIV, 661–735.		Compositae	84	113	
XXVI, 534		*Conium maculatum* L.			
XVII, 325	236	*Conringia orientalis* (L.) Dumort.			
XXVI–XXVII, 549–562.	258	Convolvulaceae			
	258	*Convolvulus*			
XXVI, 549	258	*Convolvulus arvensis* L.			
XXVI, 550	258	*Convolvulus sepium* L.			
XIV, 259		*Corispermum hyssopifolium* L.			
XIV, 260		*Corispermum villosum* Rydb.			
XIX, 367	240	*Coronilla scorpioides* Koch			
XIX, 368	239	*Coronilla varia* L.			
	236	*Coronopus didymus* (L.) Sm.			
III, 61	212	*Corynephorus canescens* (L.) Beauv.			
XXXII, 693*a*		*Crepis capillaris* (L.) Wallr.			
XXXII, 693*b*		*Crepis setosa* Hall			
		Crepis virens (L.) (see *C. capillaris*).			
	240	*Crotalaria*			
XIX, 369	240	*Crotalaria intermedia* Kotschy	74	142	
	240	*Crotalaria juncea* L.	74	142	
XIX, 370	240	*Crotalaria lanceolata* E. Mey.	74	142	
XIX, 371	240	*Crotalaria mucronata* Desv.	74	142	
XIX, 372	240	*Crotalaria spectabilis* Roth	74	142	56
	240	*Crotalaria striata* DC. (see *C. mucronata*).			
XXIII, 480		*Croton* sp.			
XVI–XVIII, 310–344.	233	Cruciferae	83	119	
		Cucumis melo L.	82	124	
		Cucumis sativus L.	82	124	34
		Cucurbita maxima Duchesne	82	124	
		Cucurbita moschata Duchesne	82	124	

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Botanical name	Purity	Germination	
Plate	*Page*		*Page*	*Page*	*Figure*
------	------	*Cucurbita pepo* L.	82	124	------
------	------	Cucurbitaceae	82	124	------
------	259	*Cuscuta*	------	------	------
XXVII, 558	260	*Cuscuta epilinum* Weihe	------	------	------
XXVII, 557	260	*Cuscuta epithymum* Murr	------	------	------
XXVII, 562	260	*Cuscuta gronovii* Willd	------	------	------
XXVII, 559	260	*Cuscuta indecora* Choisy	------	------	------
XXVII, 560	260	*Cuscuta pentagona* Engelm	------	------	------
XXVII, 556	260	*Cuscuta planiflora* Tenore	------	------	------
XXVII, 561	260	*Cuscuta racemosa* var. *chiliana* Engelm.	------	------	------
XIX, 373	240	*Cyamopsis tetragonolobus* (L.) Taub.	------	------	------
XIV, 261	------	*Cycloloma atriplicifolium* (Spreng.) Coult.	------	------	------
------	------	*Cynara cardunculus* L.	84	113	30
------	------	*Cynara scolymus* L.	84	113	------
III, 62	------	*Cynodon dactylon* (L.) Pers.	60	126	------
------	212	*Cynosurus*	------	------	------
III, 64	213	*Cynosurus cristatus* L.	60	126	------
III, 65	213	*Cynosurus echinatus* L.	------	------	------
XII, 204–214	------	Cyperaceae	------	------	------
XII, 206	------	*Cyperus esculentus* L.	------	------	------
XII, 207	------	*Cyperus rotundus* L.	------	------	------
------	------	*Cyperus* spp.	------	------	------
III, 66	213	*Dactylis glomerata* L.	60	126	------
III, 67–68	213	*Danthonia spicata* (L.) Beauv.	------	------	------
XXIX, 612	------	*Datura stramonium* L.	------	------	------
XIX, 374	240	*Daubentonia texana* Pierce	------	------	------
XXVI, 535	------	*Daucus carota* L.	80	167	61
XVI, 295	------	*Delphinium consolida* L.	------	------	------
XVI, 296	------	*Delphinium menziesii* Hook.	------	------	------
III, 69	213	*Deschampsia caespitosa* (L.) Beauv.	------	------	------
III, 70	213	*Deschampsia flexuosa* (L.) Trin.	------	------	------
XIX, 375	241	*Desmodium tortuosum* (Sev.) DC.	74	142	------
XV, 278	------	*Dianthus armeria* L.	------	------	------
XXVI, 551	------	*Dichondra repens* Forst.	------	------	------
IV, 73	------	*Digitaria filiformis* (L.) Koel.	------	------	------
IV, 74	------	*Digitaria ischaemum* (Schreb.) Schreb. ex Muhl.	------	------	------
IV, 75	------	*Digitaria sanguinalis* (L.) Scop.	------	------	------
XXX, 645	------	*Diodia teres* Walt.	------	------	------
XXX, 646	------	*Diodia virginiana* L.	------	------	------
XXXI, 655–658	------	Dipsacaceae	------	------	------
XXXI, 656	------	*Dipsacus sylvestris* Huds.	------	------	------
------	214	*Distichlis*	------	------	------
------	------	*Distichlis dentata* (see *D. stricta*).	------	------	------
III, 72	214	*Distichlis spicata* (L.) Greene	------	------	------
III, 71	214	*Distichlis stricta* (Torr.) Rydb.	------	------	------
------	------	*Dondia depressa* (see *Suaeda depressa*).	------	------	------
------	------	*Downingia* spp. Nutt.	56	------	------
------	------	*Dracocephalum parviflorum* (see *Moldavica parviflora*).	------	------	------

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Botanical name	Purity	Germination	
Plate	*Page*		*Page*	*Page*	*Figure*
------	------	*Echinacea angustifolia* (see *Brauneria angustifolia*).	------	------	------
------	214	*Echinochloa*	------	------	------
IV, 76	214	*Echinochloa colonum* (L.) Link	------	------	------
IV, 77	214	*Echinochloa crusgalli* (L.) Beauv.	------	------	------
IV, 78	214	*Echinochloa crusgalli* var. *frumentacea* (Roxb.) W. F. Wight.	65	126	------
XXVII, 573	------	*Echium vulgare* L	------	------	------
XII, 208	------	*Eleocharis obtusa* (Willd.) Schultes.	------	------	------
XII, 209	------	*Eleocharis tenuis* (Willd.) Schultes.	------	------	------
IV, 79	------	*Eleusine coracana* (L.) Gaertn	------	------	------
IV, 80	------	*Eleusine indica* (L.) Gaertn	------	------	------
IV, 81–84	214	*Elymus*	------	------	------
IV, 81	215	*Elymus canadensis* L	55	126	------
IV, 82	215	*Elymus glaucus* Buckl	------	------	------
IV, 83	215	*Elymus junceus* Fisch	------	------	------
------	215	*Elymus riparius* Wiegand	------	------	------
------	215	*Elymus triticoides* Buckl	------	------	------
IV, 84	215	*Elymus virginicus* L	------	------	------
------	------	*Elymus* spp	55	------	------
------	215	*Eragrostis*	------	------	------
------	------	*Eragrostis abyssinica* (Jacq.) Link. (see *E. tef*).	------	------	------
IV, 85	216	*Eragrostis capillaris* (L.) Nees	------	------	------
IV, 87	216	*Eragrostis chloromelas* Steud	------	------	------
IV, 86	216	*Eragrostis cilianensis* (All.) Lutati.	------	------	------
IV, 88	216	*Eragrostis curvula* (Schrad.) Nees.	66	126	------
IV, 89	216	*Eragrostis lehmanniana* Nees	------	------	------
------	216	*Eragrostis tef* (Zuccagni) Trotter.	------	------	------
IV, 90	216	*Eragrostis trichodes* (Nutt.) Wood.	------	------	------
XXXII, 694	------	*Erechtites hieracifolia* (L.) Raf	------	------	------
XXXII, 695	------	*Erechtites prenanthoides* DC	------	------	------
XXIII, 481	------	*Eremocarpus setigerus* Benth	------	------	------
IV, 91	------	*Eremochloa ophiuroides* (Munro) Hack.	------	------	------
XXXII, 696	------	*Erigeron annuus* (L.) Pers	------	------	------
XXXII, 697	------	*Erigeron canadensis* L	------	------	------
IV, 92	------	*Eriochloa punctata* (L.) Desv	------	------	------
------	------	*Eriocoma cuspidata* (see *Oryzopsis hymenoides*).	------	------	------
XXIII, 469	------	*Erodium cicutarium* (L.) L'Her	82	167	------
XVII, 326	236	*Eruca sativa* Mill	------	------	------
XVII, 327	------	*Erysimum asperum* (Nutt.) DC.	------	------	------
XVII, 328	------	*Erysimum cheiranthoides* L	------	------	------
XVII, 329	------	*Erysimum inconspicuum* (S. Wats.) Mac M.	------	------	------
------	------	*Erysimum officinale* (see *Sisymbrium officinale*).	------	------	------
------	------	*Erysimum parviflorum* (see *E. inconspicuum*).	------	------	------

957116—52——26

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Botanical name	Purity	Germination	
Plate	*Page*		*Page*	*Page*	*Figure*
XVI, 305		*Eschscholtzia californica* Cham			
XXIII–XXIV, 479–488.		Euphorbiaceae			
XXIII, 482		*Euphorbia corollata* L			
XXIV, 484		*Euphorbia dentata* Michx			
XXIII, 483		*Euphorbia esula* L			
XXIV, 485		*Euphorbia helioscopia* L			
XXIV, 486		*Euphorbia marginata* Pursh			
XXIV, 487		*Euphorbia nutans* Lag			
		Euphorbia preslii Guss. (see *E. nutans*).			
XXIV, 488		*Euphorbia supina* Raf			
XXIX, 623		*Euphrasia* sp			
		Fagopyrum esculentum Moench	81	167	
XXVI, 536		*Falcaria rivini* Host			
		Falcatula ornithopodioides (DC.) Wilmott (see *Trifolium ornithopodioides*).			
	216	*Festuca* (fine-leaved)			
	218	*Festuca* (tall)			
IV, 94	218	*Festuca arundinacea* Schreb	61	126	
	218	Hort. vars.: Alta			
	218	Ky–31			
	217	*Festuca capillata* Lam	61	126	
IV, 93	218	*Festuca elatior* L	61	126	
	217	*Festuca megalura*			
IV, 96	217	*Festuca myuros* L			
	217	*Festuca octoflora*			
	217	*Festuca ovina* L	61	126	
IV, 95	217	*Festuca rubra* L	61	126	
	217	*Festuca rubra* var. *commutata* Gaud.	61	126	
XII, 210		*Fimbristylis autumnalis* (L.) R and S.			
XII, 211		*Fimbristylis baldwiniana* (Schulter) Torr.			
		Fimbristylis laxa (see *F. baldwiniana*).			
XXXII, 698		*Franseria discolor* Nutt			
XXXII, 699		*Franseria tenuifolia* Torr. and Gray.			
XVI, 309		*Fumaria officinalis* L			
XIX, 376	241	*Galega officinalis* L			
XXVIII, 588		*Galeopsis ladanum* L			
XXVIII, 589		*Galeopsis tetrahit* L			
XXXIII, 700		*Galinsoga parviflora* Cav			
XXX, 647		*Galium aparine* L			
XXX, 648		*Galium mollugo* L			
V, 97		*Gastridium ventricosum* (Gouan.) Schinz. and Thell.			
XXV, 512		*Gaura coccinea* Pursh			
XXV, 513		*Gaura odorata* Sesse			
XXV, 514		*Gaura sinuata* Nutt			
XXV, 515		*Gaura villosa* Torr			
XXIII, 469–474		Geraniaceae	82		
XXIII, 470		*Geranium carolinianum* L			
XXIII, 471		*Geranium columbinum* L			
XXIII, 472		*Geranium dissectum* L			
XXIII, 473		*Geranium molle* L			
XXIII, 474		*Geranium pusillum* L			
XVIII, 346		*Geum* sp			
XXVII, 565		*Gilia capitata* Hook			

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Botanical name	Purity	Germination	
Plate	*Page*		*Page*	*Page*	*Figure*
XVI, 306	------	*Glaucium corniculatum* Curt	------	------	------
V, 98	------	*Glyceria fluitans* (L.) R. Br	------	------	------
V, 99	------	*Glyceria grandis* S. Wats	------	------	------
V, 100	------	*Glyceria striata* (Lam.) Hitchc	------	------	------
XIX, 377	241	*Glycine max* (L.) Merr	73	142	50
XXV, 516	------	*Godetia tenella* (Cw.) S. Wats	------	------	------
XXVI, 548	------	*Gonolobus laevis* Michx	------	------	------
----------	------	*Gossypium* spp	81	164	59
I–XII, 1–203 (see fig. 63).	195	Gramineae	55	126	------
XXXIII, 701	------	*Grindelia squarrosa* (Pursh.) Dunal.	------	------	------
V, 101	------	*Hackelochloa granularis* (L.) Kuntze.	------	------	------
XIV, 263	------	*Halogeton glomeratus* C. A. Mey.	------	------	------
XXVIII, 590	------	*Hedeoma pulegioides* (L.) Pers	------	------	------
XIX, 378	241	*Hedysarum coronarium* L	------	------	------
XXXIII, 702	------	*Helianthus annuus* L	84	113	------
XXXIII, 703	------	*Helianthus ciliaris* DC	------	------	------
XXVII, 574	------	*Heliotropium curassavicum* L	------	------	------
XXVII, 575	------	*Heliotropium europaeum* L	------	------	------
XXXIII, 704	------	*Hemizonia luzulaefolia* DC	------	------	------
XXXIII, 705	------	*Heterotheca grandiflora* Nutt	------	------	------
----------	------	*Hibiscus esculentus* L	81	164	60
XXIV, 491	------	*Hibiscus trionum* L	------	------	------
XXXIII, 706	------	*Hieracium aurantiacum* L	------	------	------
XVII, 330	------	*Hirschfeldia incana* (L.) Lagreze-Fossat.	------	------	------
XIX, 379	241	*Hoffmannseggia* sp	------	------	------
V, 102	------	*Holcus lanatus* L	66	126	------
V, 103	------	*Holcus mollis* L	------	------	------
----------	------	*Hookera coronaria* (see *Brodiaea coronaria*).	------	------	------
----------	------	*Hookera douglasii* (see *Brodiaea grandiflora*).	------	------	------
----------	218	*Hordeum*	------	------	------
V, 106	219	*Hordeum brachyantherum* Nevski.	------	------	------
V, 107	219	*Hordeum jubatum* L	------	------	------
V, 108	219	*Hordeum leporinum* Link	------	------	------
----------	------	*Hordeum murinum* (see *H. leporinum*).	------	------	------
----------	------	*Hordeum nodosum* (see *H. brachyantherum*).	------	------	------
V, 105	219	*Hordeum pusillum* Nutt	------	------	------
V, 104	218	*Hordeum vulgare* L	62	126	------
----------	------	*Hosackia americana* (see *Lotus purshianus*).	------	------	------
XXX, 649	------	*Houstonia purpurea* L	------	------	------
XXVII, 568	------	Hydrophyllaceae	------	------	------
----------	------	*Hymenophysa pubescens* of Am. auth. (see *Cardaria pubescens*).	------	------	------
XXIX, 613	------	*Hyoscyamus niger* L	------	------	------
XXIV, 504	------	Hypericaceae	------	------	------
XXIV, 504	------	*Hypericum perforatum* L	------	------	------
XXXIII, 707	------	*Hypochaeris radicata* L	------	------	------
XIX, 380	242	*Indigofera hirsuta* L	------	------	------
----------	258	*Ipomoea*	------	------	------
XXVI, 552	259	*Ipomoea hederacea* (L.) Jacq	------	------	------
----------	259	*Ipomoea lacunosa* L	------	------	------

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Botanical name	Purity	Germination	
Plate	*Page*		*Page*	*Page*	*Figure*
XXVI, 554	258	*Ipomoea pandurata* (L.) G. F. W. Mey.			
XXVI, 553	259	*Ipomoea purpurea* (L.) Roth			
XIII, 224		Iridaceae			
XXXIII, 708		*Iva axillaris* Pursh			
XXXIII, 709		*Iva ciliata* Willd			
XXXIII, 710		*Iva xanthifolia* Nutt			
XXVI, 555	259	*Jacquemontia tamnifolia* (L.) Griseb.			
XII, 217–219		Juncaceae			
		Juncoides campestre (see *Luzula campestris*).			
		Juncoides nemorosum (see *Luzula luzuloides*).			
XII, 219		*Juncus tenuis* Willd			
		Juncus spp	56		
XXIX, 624		*Kickxia spuria* (L.) Dumort			
		Knautia arvensis (see *Scabiosa arvensis*).			
		Kochia hyssopifolia (see *Bassia hyssopifolia*).			
XIV, 264		*Kochia scoparia* (L.) Roth			
		Koellia sp. (see *Pycnanthemum* sp.).			
XII, 212		*Kyllinga* sp			
XXVIII–XXIX, 586–611.		Labiatae			
XXXIII, 711		*Lactuca canadensis* L			
XXXIII, 713		*Lactuca pulchella* (Pursh.) DC			
		Lactuca sativa L	84	113	27, 28, 29
XXXIII, 712		*Lactuca scariola* var. *integrifolia* (Bogenh.) G. Beck.			
XXVIII, 591		*Lamium amplexicaule* L			
XXVII, 576		*Lappula echinata* Gilib			
		Lappula lappula (see *L. echinata*).			
XXVII, 577		*Lappula occidentalis* (S. Wats.) Greene.			
XXXIII, 714		*Lapsana communis* L			
	242	*Lathyrus*			
	243	*Lathyrus angulatus* L			
	242	*Lathyrus annuus* L.			
XIX, 381	242	*Lathyrus aphaca* L			
XIX, 382	243	*Lathyrus hirsutus* L	74	142	
	243	*Lathyrus pusillus* Ell			
	243	*Lathyrus stipularis* Presl			
	243	*Lathyrus sphaericus* Retz			
XIX, 383	243	*Lathyrus sylvestris* L			
XIX, 384	243	*Lathyrus tingitanus* L			
XIX, 385	243	*Lathyrus tuberosus* L			
XVIII–XXIII, 353–468.	237	Leguminosae	73	142	
XXXIII, 715		*Leontodon autumnalis* L			
XXXIII, 716		*Leontodon nudicaulis* L			
XXVIII, 592		*Leonurus cardiaca* L			
		Lepidium apetalum (see *L. densiflorum*).			
XVII, 331	236	*Lepidium campestre* (L.) R. Br.			

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Botanical name	Purity	Germination	
Plate	*Page*		*Page*	*Page*	*Figure*
XVII, 332		*Lepidium densiflorum* Schrad			
		Lepidium draba (see *Cardaria draba*).			
XVII, 333	237	*Lepidium latifolium* L			
		Lepidium sativum L	83	119	
XVII, 334		*Lepidium virginicum* L			
V, 109	219	*Leptoloma cognatum* (Schult.) Chase.			
	243	*Lespedeza*			
	244	*Lespedeza bicolor* Turcz			
XX, 389	244	*Lespedeza cuneata* (Dumont) G. Don.	74	142	
	244	*Lespedeza hedysaroides* (Pallas) Ricker.	74	142	
XX, 388	244	*Lespedeza stipulacea* Maxim	74	142	
XIX, 386	244	*Lespedeza striata* (Thunb.) H. and A.	74	142	
XIX, 387	244	*Lespedeza striata* Hort. var. Kobe.	74	142	
XIII, 220–223		Liliaceae	82	160	
XXIII, 476–477		Linaceae	81	162	
		Linaria spuria (see *Kickxia spuria*).			
XXIX, 625		*Linaria vulgaris* Hill			
XXIII, 476		*Linum usitatissimum* L	81	162	58
XXIII, 477		*Linum virginianum* L			
XXVIII, 581		*Lippia nodiflora* Michx			
XXVII, 578		*Lithospermum arvense* L			
XXIV–XXV, 506–508.		Loasaceae			
XXXI, 660		Lobeliaceae			
XXXI, 660		*Lobelia inflata* L			
		Lobelia sp			
	219	*Lolium*			
V, 111	220	*Lolium multiflorum* Lam	64	126	
V, 110	220	*Lolium perenne* L	64	126	
V, 112	220	*Lolium persicum* Boiss. and Hohen.			
	220	*Lolium rigidum* Gaud			
V, 113	220	*Lolium temulentum* L			
	245	*Lotus*			
		Lotus americanus (see *L. purshianus*).			
XX, 390	245	*Lotus angustissimus*			
XX, 391	245	*Lotus corniculatus* L	75	142	54, 55
XX, 392	245	*Lotus hispidus* Desf			
		Lotus major Sm. not Scop. (see *L. uliginosus*).			
XX, 393	245	*Lotus purshianus* (Benth.) Clements and Clements.			
	245	*Lotus uliginosus* Schkuhr	75	142	
XX, 394	245	*Lotus uliginosus* var. *villosus*			
XX, 395	245	*Lotus uliginosus* var. *glabriusculus*.			
	245	*Lotus* spp			
XXV, 517		*Ludwigia alternifolia* L			
	245	*Lupinus*			
	246	*Lupinus albus* L	73	142	
XX, 396	246	*Lupinus angustifolius* L	73	142	51, 52
XX, 397	246	*Lupinus luteus* L	73	142	
XII, 217		*Luzula campestris* (L.) DC			

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Botanical name	Purity	Germination	
Plate	*Page*		*Page*	*Page*	*Figure*
XII, 218	------	*Luzula luzuloides* (Lam.) Dandy and Wilmott.	------	------	------
------	232	*Lychnis*	------	------	------
XV, 279	232	*Lychnis alba* Mill	------	------	------
XV, 280	232	*Lychnis dioica* L	------	------	------
------	------	*Lycopersicon esculentum* Mill	80	167	62
XXVIII, 593	------	*Lycopus virginicus* L	------	------	------
XXV, 509	------	Lythraceae	------	------	------
XXV, 509	------	*Lythrum hyssopifolia* L	------	------	------
XXXIII, 717	------	*Madia glomerata* Hllk	------	------	------
XXXIII, 718	------	*Madia sativa* Molina	------	------	------
XXIV, 492	------	*Malva moschata* L	------	------	------
XXIV, 493	------	*Malva parviflora* L	------	------	------
XXIV, 494	------	*Malva rotundifolia* L	------	------	------
XXIV, 495	------	*Malva sylvestris* L	------	------	------
XXIV, 489–502	------	Malvaceae	81	164	------
------	------	*Malvastrum americanum* (see *M. coromandelianum*).	------	------	------
------	------	*Malvastrum angustum* (see *Sidopsis hispida*).	------	------	------
XXIV, 496	------	*Malvastrum coromandelianum* (L.) Garcke.	------	------	------
------	------	*Malvastrum tricuspidatum* (see *M. coromandelianum*).	------	------	------
XXVIII, 594	------	*Marrubium vulgare* L	------	------	------
XXXIII, 719	------	*Matricaria inodora* L	------	------	------
------	246	*Medicago*	------	------	------
XX, 398	246	*Medicago arabica* (L.) Huds	77	142	------
XX, 399	246	*Medicago hispida* Gaertn	77	142	------
XX, 400	247	*Medicago lupulina* L	77	142	------
XX, 401	247	*Medicago orbicularis* (L.) All	------	------	------
XX, 402	247	*Medicago sativa* L	77	142	53
XX, 403	247	*Medicago tuberculata* Willd	------	------	------
------	------	*Meibomia purpurea* (see *Desmodium tortuosum*).	------	------	------
------	------	*Meibomia tortuosa* (see *Desmodium tortuosum*).	------	------	------
XXIX, 626	------	*Melampyrum arvense* L	------	------	------
------	247	*Melilotus*	------	------	------
XX, 404	247	*Melilotus alba* Desr	75	142	------
XX, 406	248	*Melilotus indica* (L.) All	75	142	------
XX, 405	247	*Melilotus officinalis* (L.) Lam	75	142	------
V, 114	------	*Melinis minutiflora* Beauv	66	126	------
XXIV, 503	------	*Melochia corchorifolia* L	------	------	------
XXVIII, 595	------	*Mentha arvensis* L	------	------	------
XXIV, 506	------	*Mentzelia albicaulis* Dougl	------	------	------
XXIV, 507	------	*Mentzelia dispersa* Wats	------	------	------
XXV, 508	------	*Mentzelia nuda* (Pursh.) Greene.	------	------	------
XV, 270	------	*Mirabilis nyctaginea* (Michx.) MacM.	------	------	------
XXVIII, 596	------	*Moldavica parviflora* Nutt	------	------	------
V, 115	------	*Molinia caerulea* (L.) Moench	------	------	------
XIII, 223	------	*Muscari comosum* Mill	------	------	------
XXVII, 579	------	*Myosotis arvensis* (L.) Hill	------	------	------
V, 116	220	*Nassella trichotoma* (Ness.) Hack.	------	------	------
XXVII, 566	------	*Navarretia intertexta* (Benth.) Hook.	------	------	------

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Botanical name	Purity	Germination	
Plate	*Page*		*Page*	*Page*	*Figure*
XXVII, 567		*Navarretia squarrosa* (Esch.) H. and A.			
XXVIII, 597		*Nepeta cataria* L.			
XVII, 335		*Neslia paniculata* (L.) Desv.			
		Nicotiana tabacum L.	334	349	
XVI, 297		*Nigella damescena* L.			
XVI, 298		*Nigella sativa* L.			
XV, 269–270		Nyctaginaceae			
XXV, 518		*Oenothera biennis* L.			
XXV, 519		*Oenothera laciniata* Hill			
XXV, 520		*Oenothera parodiana* Munz			
XXV, 510–520		Onagraceae			
XX, 407	248	*Onobrychis viciaefolia* Scop.	74	142	
XX, 408	248	*Ononis repens* L.			
XX, 409	248	*Ornithopus sativus* Link			
V, 117		*Oryza sativa* L.	62	126	38
V, 118		*Oryzopsis hymenoides* (Roem. and Schult.) Ricker.	65	126	
V, 119		*Oryzopsis miliacea* (L.) Benth. and Hook.	65	126	
XXIII, 475		Oxalidaceae			
XXIII, 475		*Oxalis stricta* L.			
		Oxybaphus nyctaginea (see *Mirabilis nyctaginea*).			
		Panicularia americana (see *Glyceria grandis*).			
		Panicularia fluitans (see *Glyceria fluitans*).			
		Panicularia nervata (see *Glyceria striata*).			
	220	*Panicum*			
VI, 121	221	*Panicum anceps* Michx.			
VI, 122	221	*Panicum antidotale* Retz.	65	126	
VI, 123	221	*Panicum bergii* Arech.			
VI, 124	221	*Panicum brachyanthum* Steud.			
VI, 125	221	*Panicum capillare* L.			
VI, 126	221	*Panicum capillare* var. *occidentale* Rydb.			
VI, 127	221	*Panicum dichotomiflorum* Michx.			
VI, 128	221	*Panicum fasciculatum* Swartz.	65	126	
VI, 129	221	*Panicum gattingeri* Nash			
VI, 130	221	*Panicum hillmani* Chase			
VI, 131	221	*Panicum huachucae* Ashe			
VI, 132	221	*Panicum maximum* Jacq.	65	126	
VI, 133	222	*Panicum miliaceum* L.	65	126	
VI, 134	222	*Panicum obtusum* H. B. K.			
VI, 135	221	*Panicum purpurascens* Raddi			
VI, 136	221	*Panicum ramosum* L.	65	126	
VI, 137	221	*Panicum texanum* Buckl.			
VI, 138	222	*Panicum virgatum* L.	65	126	
		Panicum spp.	65	126	
XVI, 307		*Papaver somniferum* L.			
XVI, 305–308		Papaveraceae			
		Parentucellia sp. Viv.	56		
	222	*Paspalum*			
VII, 139	222	*Paspalum boscianum* Flügge			
VII, 140	222	*Paspalum dilatatum* Poir.	58	126	

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Botanical name	Purity	Germination	
Plate	*Page*		*Page*	*Page*	*Figure*
VII, 141	222	*Paspalum distichum* L.			
VII, 142	222	*Paspalum floridanum* Michx.			
VII, 143	222	*Paspalum laeve* Michx.			
VII, 144	223	*Paspalum malacophyllum* Trin.			
VII, 145	223	*Paspalum notatum* Flügge	58	126	
VII, 146	222	*Paspalum plicatulum* Michx.			
VII, 147	222	*Paspalum setaceum* Michx.	58	126	
VII, 148	222	*Paspalum urvillei* Steud.	80	167	
		Pastinaca sativa L.			
XXX, 632		Pedaliaceae			
	223	*Pennisetum*			
VII, 149	223	*Pennisetum glaucum* (L.) R. Br.	62	126	
VII, 150	223	*Pennisetum purpureum* Schumach.	62	126	
		Petroselinum crispum (Mill.) Nym. (see *P. hortense*).			
XXVI, 537		*Petroselinum hortense* (see *P. crispum*).	80	167	
		Petroselinum segetum (see *Apium segetum*).			
XXVII, 568		*Phacelia* sp.			
	223	*Phalaris*			
VII, 151	224	*Phalaris angusta* Nees. ex Trin.			
VII, 152	223	*Phalaris arundinacea* L.	60	126	
VII, 155	223	*Phalaris canariensis* L.	60	126	
	224	*Phalaris caroliniana* Walt.			
VII, 153	224	*Phalaris minor* Retz.			
VII, 156	224	*Phalaris paradoxa* L.			
VII, 154	224	*Phalaris tuberosa* var. *stenoptera* (Hack.) Hitchc.	60	126	
XX, 410	248	*Phaseolus angularis* (Willd.) W. F. Wight.	73	142	
XX, 411	248	*Phaseolus aureus* Roxb.	73	142	
		Phaseolus coccineus (L.) Willd.	73	142	
		Phaseolus lunatus var. *macrocarpus* (Benth.) Van Es.	73	142	45, 46, 47
		Phaseolus vulgaris L.	73	142	44
V, 120		*Phleum pratense* L.	66	126	43
XXIX, 614		*Physalis lobata* Torr.			
XXIX, 615		*Physalis longifolia* Nutt.			
		Physalis pubescens L.	80	167	
XXIX, 616		*Physalis subglabrata* Mackenz. and Bush.			
XXXIII, 720		*Picris echioides* L.			
XXXIII, 721		*Picris hieracioides* L.			
XXVI, 538		*Pimpinella saxifraga* L.			
		Piptochaetium trichotoma (see *Nassella trichotoma*).			
		Pisum sativum L.	73	142	
XXI, 412	249	*Pisum sativum* var. *arvense* (L.) Poir.	73	142	48, 49
XXVIII, 580		*Plagiobothrys* sp. Fisch. and Mey.			
XXX, 633–644		Plantaginaceae			
XXX, 638		*Plantago arenaria* Waldst. and Kit.			
XXX, 636		*Plantago aristata* Michx.			
XXX, 643		*Plantago coronopus* L.			
		Plantago elongata (see *P. pusilla*).			

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Botanical name	Purity	Germination	
Plate	*Page*		*Page*	*Page*	*Figure*
XXX, 642		*Plantago hirtella* H. B. K			
XXX, 639		*Plantago lanceolata* L			
XXX, 633		*Plantago major* L			
XXX, 644		*Plantago ovata* Forsk			
XXX, 637		*Plantago psyllium* L			
XXX, 641		*Plantago pusilla* Nutt			
XXX, 640		*Plantago rhodosperma* Dcne			
XXX, 634		*Plantago rugelii* Dcne			
XXX, 635		*Plantago virginica* L			
	224	*Poa*			
VIII, 160, X, 171*l*	226	*Poa ampla* Merr			
VIII, 159, X, 171*h*	226	*Poa annua* L	67	126	
VIII, 161, X, 171*f*	226	*Poa arachnifera* Torr	67	126	
VIII, 162, X, 171*g*	227	*Poa arida* Vasey			
VIII, 163	227	*Poa bulbosa* L	67	126	
X, 171*m*		*Poa canbyi* (Scribn.) Piper			
VIII, 164, X, 171*d*	225	*Poa compressa* L	67	126	
X, 171*n*	226	*Poa cusickii* Vasey			
X, 171*r*	226	*Poa fendleriana* (Steud.) Vasey			
X, 171*o*	226	*Poa glaucifolia* Scribn. and Will.			
IX, 165, X, 171*p*	226	*Poa interior* Rydb			
X, 171*i*	226	*Poa juncifolia* Scribn			
X, 171*q*	226	*Poa longiligula* Scribn. and Will.			
IX, 166, X, 171*c*	226	*Poa nemoralis* L	67	126	
IX, 167, X, 171*k*	226	*Poa nevadensis* Vasey ex Scribn	67	126	
IX, 168, X, 171*e*	227	*Poa palustris* L			
IX, 169, X, 171*a*	225	*Poa pratensis* L	67	126	
X, 171*j*	227	*Poa secunda* Presl			
X, 171*s*		*Poa stenantha* Trin			
IX, 170, X, 171*b*	225	*Poa trivialis* L	67	126	
X, 171		*Poa* spp. (paleas)			
XXVII, 563–567		Polemoniaceae			
XIII–XIV, 227–245.		Polygonaceae	81	167	
XIII, 227		*Polygonum argyrocoleon* Steud. ex Kunze.			
XIII, 228		*Polygonum aviculare* L			
XIII, 229		*Polygonum aviculare* (Cleistogenes).			
XIII, 230		*Polygonum convolvulus* L			
XIII, 231		*Polygonum hydropiper* L			
XIII, 232		*Polygonum lapathifolium* L			
XIII, 234		*Polygonum pensylvanicum* L			
XIII, 233		*Polygonum persicaria* L			
VII, 157		*Polypogon monspeliensis* (L.) Desf.			
XV, 272		*Portulaca oleracea* L			
XV, 272		Portulacaceae			
XVIII, 347		*Potentilla canadensis* L			
XVIII, 348		*Potentilla monspeliensis* L			
XXVI, 541		Primulaceae			
		Prionopsis ciliata (see *Aplopappus ciliatus*).			
XXVIII, 598		*Prunella vulgaris* L			
XXI, 413	249	*Pueraria thunbergiana* (Sieb. and Zucc.) Benth.	74	142	
XXVIII, 599		*Pycnanthemum* sp			
		Quincula labata (see *Physalis lobata*).			

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Botanical name	Purity	Germination	
Plate	*Page*		*Page*	*Page*	*Figure*
----------	------	*Raimannia laciniata* (see *Oenothera laciniata*).	------	------	------
XVI, 294–304	------	Ranunculaceae	------	------	------
XVI, 299	------	*Ranunculus acris* L	------	------	------
XVI, 300	------	*Ranunculus bulbosus* L	------	------	------
XVI, 301	------	*Ranunculus parviflorus* L	------	------	------
----------	------	*Ranunculus parvulus* (see *R. sardous*).	------	------	------
XVI, 302	------	*Ranunculus repens* L	------	------	------
XVI, 303	------	*Ranunculus sardous* Crantz	------	------	------
XVII, 336	------	*Raphanus raphanistrum* L	------	------	------
XVII, 337	------	*Raphanus sativus* L	83	119	32, 33
XVII, 338	------	*Rapistrum rugosum* (L.) All	------	------	------
XXXIII, 722	------	*Ratibida columnaris* (Sims.) D. Don.	------	------	------
XVIII, 345	------	*Reseda lutea* L	------	------	------
XVIII, 345	------	Resedaceae	------	------	------
----------	------	*Rheum rhaponticum* L	81	167	------
XII, 213	------	*Rhynchospora macrostachya* Torr.	------	------	------
XVI, 308	------	*Roemeria refracta* DC	------	------	------
XVII, 339	237	*Rorippa austriaca* (Crantz.) Bess.	------	------	------
----------	------	*Rorippa nasturtium-aquaticum* (L.) Britt. and Rendle.	83	119	------
XVIII, 340	237	*Rorippa sylvestris* (L.) Bess	------	------	------
XVIII, 349	------	*Rosa* sp	------	------	------
XVIII, 346–352	------	Rosaceae	------	------	------
XIV, 265	------	*Roubieva multifida* (L.) Moq	------	------	------
XXX, 645–650	------	Rubiaceae	------	------	------
XVIII, 350	------	*Rubus* sp	------	------	------
XXXIII, 723	------	*Rudbeckia hirta* L	------	------	------
XIII, 235	------	*Rumex acetosa* L	81	167	------
XIII, 236	------	*Rumex acetosella* L	------	------	------
XIII, 237	------	*Rumex altissimus* Wood	------	------	------
XIII, 238	------	*Rumex conglomeratus* Murr	------	------	------
XIII, 239	------	*Rumex crispus* L	------	------	------
XIII, 240	------	*Rumex obtusifolius* L	------	------	------
XIII, 241	------	*Rumex occidentalis* Wats	------	------	------
XIII, 242	------	*Rumex persicarioides* L	------	------	------
XIII, 243	------	*Rumex pulcher* L	------	------	------
XIV, 244	------	*Rumex salicifolius* Weinm	------	------	------
XIV, 245	------	*Rumex venosus* Pursh	------	------	------
XIV, 266	------	*Salsola kali* var. *tenuifolia* Tausch.	------	------	------
----------	------	*Salvia lanceaefolia* (see *S. lanceolata*).	------	------	------
XXVIII, 600	------	*Salvia lanceolata* Willd	------	------	------
XXVIII, 601	------	*Salvia verticillata* L	------	------	------
XVIII, 351	------	*Sanguisorba annua* Nutt	------	------	------
XVIII, 352	------	*Sanguisorba minor* Scop	------	------	------
XV, 281	------	*Saponaria vaccaria* L	------	------	------
XXVIII, 602	------	*Satureja acinos* (L.) Scheele	------	------	------
XXVIII, 603	------	*Satureja nepeta* (L.) Scheele	------	------	------
XXIX, 604	------	*Satureja vulgaris* (L.) Fritsch	------	------	------
XXXI, 657	------	*Scabiosa arvensis* L	------	------	------
XXXI, 658	------	*Scabiosa* sp	------	------	------
VII, 158	------	*Schedonnardus paniculatus* (Nutt.) Trel.	------	------	------
XII, 214	------	*Scirpus* sp	------	------	------
XV, 282	------	*Scleranthus annuus* L	------	------	------

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Botanical name	Purity	Germination	
Plate	*Page*		*Page*	*Page*	*Figure*
XXIX, 627		*Scrophularia marilandica* L.			
XXIX–XXX, 623–631.		Scrophulariaceae			
XI, 184		*Secale cereale* L.	62	126	36, 37
XXXIV, 724		*Senecio jacobaea* L.			
XXXIV, 725		*Senecio vulgaris* L.			
XXX, 632		*Sesamum orientale* L.			
XXI, 414	249	*Sesbania exaltata* (Raf.) Torr.	74	142	
	227	*Setaria*			
X, 172	229	*Setaria faberi* Herrm.			
X, 173	228	*Setaria geniculata* (Lam.) Beauv.			
X, 174	228	*Setaria grisebachii* Fourn.			
	229	*Setaria italica* (L.) Beauv.	65	126	
XI, 180	229	Hort. vars.: Common			
XI, 182	229	German			
XI, 181	229	Hungarian			
XI, 183	229	White Wonder			
X, 175	229	*Setaria lutescens* (Weigel) Hubb.			
X, 176	228	*Setaria macrostachya* H. B. K.			
X, 177	228	*Setaria magna* Griseb.			
X, 178	228	*Setaria verticillata* (L.) Beauv.			
X, 179	228	*Setaria viridis* (L.) Beauv.			
XXX, 650		*Sherardia arvensis* L.			
XXIV, 497		*Sida hederacea* (Dougl.) Torr.			
XXIV, 498		*Sida spinosa* L.			
XXIV, 499		*Sidalcea campestris* Greene			
XXIV, 500		*Sidalcea hendersonii* Wats.			
XXIX, 605		*Sideritis montana* L.			
XXIV, 501		*Sidopsis hispida* (Pursh.) Rybd.			
	232	*Silene*			
		Silene anglica Am. auth., not L. (see *S. gallica*).			
XV, 283	233	*Silene antirrhina* L.			
XV, 285	233	*Silene conica* L.			
XV, 286	233	*Silene conoidea* L.			
XV, 287	233	*Silene cretica* L.			
XV, 288	233	*Silene cserei* Baumg.			
XV, 289	232	*Silene cucubalus* Wibel			
XV, 290	233	*Silene dichotoma* Ehrh.			
		Silene fabaria Rydb. (see *S. cserei*).			
XV, 284	233	*Silene gallica* L.			
		Silene latifolia (see *S. cucubalus*).			
XV, 291	233	*Silene noctiflora* L.			
XVIII, 341		*Sisymbrium altissimum* L.			
	237	*Sisymbrium irio* L.			
XVIII, 342		*Sisymbrium officinale* (L.) Scop.			
XIII, 224		*Sisyrinchium* sp.			
		Soja max (see *Glycine max*)			
XXIX, 612–622		Solanaceae	80	167	
XXIX, 617		*Solanum carolinense* L.			
XXIX, 618		*Solanum elaeagnifolium* Cav.			
		Solanum melongena var. *esculentum* Nees.	80	167	
XXIX, 619		*Solanum nigrum* L.			
XXIX, 620		*Solanum rostratum* Dunal			
XXIX, 621		*Solanum triflorum* Nutt.			
XXXIV, 726		*Sonchus arvensis* L.			
XXXIV, 727		*Sonchus asper* (L.) Hill			

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Botanical name	Purity	Germination	
Plate	*Page*		*Page*	*Page*	*Figure*
XXXIV, 728		*Sonchus oleraceus* L.			
		Sorghastrum nutans (L.) Nash	57	126	
	229	*Sorghum*			
XI, 185	230	*Sorghum halepense* (L.) Pers.	70	126	
XI, 187	230	*Sorghum* (Sorghum-Sudan hybrids).			
XI, 186	230	*Sorghum sudanense* (Piper) Stopf. (*S. vulgare* var. *sudanense* Hitchc.)	70	126	
	230	*Sorghum vulgare* Pers.	70	126	41, 42
XI, 188	230	Hort. vars.: Black Amber			
XI, 189	230	Sumac			
XI, 193	230	Feterita			
XI, 192	230	Hegari			
XI, 191	230	Kafir			
XI, 190	230	Milo			
XI, 194	230	*Sorghum vulgare* var. *technicum* (L.) Boerl.	70	126	
XXXI, 659		*Specularia perfoliata* (L.) A. DC.			
XVI, 292		*Spergula arvensis* L.			
XVI, 293		*Spergula pentandra* L.			
XXIV, 502		*Sphaeralcea coccinea* (Pursh.) Rydb.			
		Spinacia oleracea L.	84	107	26
	231	*Sporobolus*			
	231	*Sporobolus airoides* Torr.			
XII, 196	231	*Sporobolus clandestinus* (Biel.) Hitchc.			
XII, 197	231	*Sporobolus cryptandrus* (Torr.) Gray.	66	126	
XII, 198	231	*Sporobolus neglectus* Nash			
XXIX, 606		*Stachys annua* L.			
XXIX, 607		*Stachys palustris* L.			
XV, 274		*Stellaria graminea* L.			
XV, 275		*Stellaria media* (L.) Cyrill			
XXIV, 503		Sterculiaceae			
XI, 195		*Stipa viridula* Trin.			
XXI, 415	249	*Stizolobium deeringianum* Bort.	73	142	
XXIX, 622		"Stone cells" (in Solanum fruits).			
XXI, 416	249	*Strophostyles leiosperma* (T. and G.) Piper.			
		Strophostyles pauciflora (see *S. leiosperma*).			
XIV, 262		*Suaeda depressa* (Pursh.) S. Wats.			
XXI, 417	250	*Swainsona salsula* (Pall.) Taub.			
XXX, 651		*Symphoricarpos occidentalis* Hook.			
XXXIV, 729		*Tanacetum vulgare* L.			
XXXIV, 731		*Taraxacum erythrospermum* Andrz.			
XXXIV, 730		*Taraxacum officinale* Weber	84	113	
XVIII, 343		*Teesdalia nudicaulis* (L.) R. Br.			
		Tetragonia expansa Thunb.	84	107	
XXIX, 608		*Teucrium botrys* L.			
XXIX, 609		*Teucrium canadense* L.			
XVI, 304		*Thalictrum* sp.			
XXXIV, 732		*Thelesperma* sp.			
XVIII, 344		*Thlaspi arvense* L.			
XXVI, 539		*Torilis anthriscus* (L.) Bernh.			

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Botanical name	Purity	Germination	
Plate	*Page*		*Page*	*Page*	*Figure*
XXVI, 540		*Torilis nodosa* (L.) Gaertn			
XII, 216		*Tradescantia virginiana* L			
		Tragopogon porrifolius L	84	113	
XXXIV, 733		*Tragopogon pratensis* L			
XV, 271		*Trianthema portulacastrum* L			
XXIII, 478		*Tribulus terrestris* L			
XXIX, 610		*Trichostema dichotomum* L			
XXIX, 611		*Trichostema lanceolatum* Benth			
XII, 199		*Tridens flavus* (L.) Hithchc			
	250	*Trifolium*			
XXI, 425	252	*Trifolium agrarium* L			
XXII, 446	254	*Trifolium alexandrinum* L	77	142	
XXII, 445	254	*Trifolium ambiguum* Bieb			
XXI, 418	252	*Trifolium angulatum* Waldst. and Kitt.			
XXI, 426	253	*Trifolium arvense* L			
XXII, 436	254	*Trifolium bifidum* A. Gray			
XXI, 422	252	*Trifolium carolinianum* Michx			
XXI, 420	252	*Trifolium cernuum* Brot			
XXI, 424	252	*Trifolium depauperatum* Desv			
XXI, 427	252	*Trifolium dubium* Sibth	77	142	
		Trifolium fimbriatum Lindl. (see *T. wildenovii*).			
XXII, 437	253	*Trifolium fragiferum* L	77	142	
XXI, 419	252	*Trifolium glomeratum* L	77	142	
XXII, 438	254	*Trifolium gracilentum* T. and G			
XXII, 447	254	*Trifolium hirtum* All			
XXII, 439	253	*Trifolium hybridum* L	77	142	
XXII, 448	254	*Trifolium incarnatum* L	77	142	
		Trifolium involucratum Ortega., not Lam. (see *T. wildenovii*).			
XXI, 429	253	*Trifolium lappaceum* L	77	142	
XXII, 449	254	*Trifolium medium* L			
XXI, 434	253	*Trifolium michelianum* Savi			
XXII, 440	254	*Trifolium microcephalum* Pursh			
XXII, 441	254	*Trifolium microdon* Hook. and Arn.			
XXI, 430	252	*Trifolium nigrescens* Viv			
	253	*Trifolium ornithopodioides* (L.) Smith.			
XXI, 423	252	*Trifolium parviflorum* Ehrh			
XXI, 431	253	*Trifolium pratense* L	77	142	
XXI, 428	252	*Trifolium procumbens* L	77	142	
XXI, 421	252	*Trifolium reflexum* L			
XXI, 432	253	*Trifolium repens* L	77	142	
XXI, 435	253	*Trifolium resupinatum* L	77	142	
XXI, 433	253	*Trifolium striatum* L			
		Trifolium suaveolens (see *T. resupinatum*).			
XXII, 450	254	*Trifolium subterraneum* L	77	142	
XXII, 442	253	*Trifolium tridentatum* Lindl			
XXII, 443	253	*Trifolium variegatum* Nutt			
XXII, 444	253	*Trifolium wildenovii* Spreng			
		Trifolium wormskoldii Lehm. (see *T. wildenovii*).			
	250	*Trifolium* spp			
	254	*Trigonella*			
XXII, 451	254	*Trigonella foenum-graecum* L			
XXII, 452	255	*Trigonella polycerata*			
		Triodia flava (see *Tridens flavus*).			
XII, 200		*Trisetum flavescens* (L.) Beauv			

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Botanical name	Purity	Germination	
Plate	*Page*		*Page*	*Page*	*Figure*
XII, 201		*Triticum aestivum* L.			
		Triticum spp.	62	126	
XXV, XXVI, 521–540		Umbelliferae	80	167	
XIII, 226		*Urtica dioica* L.			
XIII, 226		Urticaceae			
		Vaccaria pyramidata (see *Saponaria vaccaria*).			
XXXI, 652–654		Valerianaceae	80	167	
XXXI, 653		*Valerianella dentata* Pollich			
XXXI, 654		*Valerianella eriocarpa* Desv.			
XXXI, 652		*Valerianella locusta* var. *olitoria* L.	80	167	
XXX, 628		*Verbascum thapsus* L.			
XXVIII, 582		*Verbena hastata* L.			
XXVIII, 583		*Verbena officinalis* L.			
XXVIII, 584		*Verbena stricta* Vent.			
XXVIII, 585		*Verbena urticaefolia* L.			
XXVIII, 581–585		Verbenaceae			
XXXIV, 734		*Vernonia noveboracensis*			
XXX, 629		*Veronica agrestis* L.			
XXX, 630		*Veronica arvensis* L.			
XXX, 631		*Veronica peregrina* L.			
	255	*Vicia*			
	257	*Vicia americana*			
XXIII, 463–464	257	*Vicia angustifolia* (L.) Reich.	79	142	
	257	*Vicia articulata* Hornem.	79	142	
XXII, 459	257	*Vicia atropurpurea* D.	79	142	
XXIII, 460	257	*Vicia cracca* L.			
XXIII, 466	257	*Vicia dasycarpa* Ten.	79	142	
		Vicia faba L.	79	142	
XXIII, 461	257	*Vicia grandiflora* Scop.			
XXII, 453	257	*Vicia hirsuta* (L.) S. F. Gray			
XXII, 458	256	*Vicia hybrida* L.			
XXII, 457	256	*Vicia lutea* L.			
XXII, 456	256	*Vicia melanops* Sibth. and Sn.			
		Vicia monantha (see *V. articulata*).			
XXII, 455	256	*Vicia pannonica* Crantz	79	142	
XXIII, 462	257	*Vicia sativa* L.	79	142	
XXII, 454	257	*Vicia tetrasperma* (L.) Moench			
XXIII, 465	257	*Vicia villosa* Roth	79	142	
		Vigna sesquipedalis W. F. Wight.	73	142	
XXIII, 467–468	257	*Vigna sinensis* (Torner) Hassk.	73	142	
XXIV, 505		*Viola tricolor* L.			
XXIV, 505		Violaceae			
		Weingaertneria canescens (see *Corynephorus canescens*).			
XXXIV, 735		*Xeranthemum cylindraceum*			
		Zea mays L.	62	126	39, 40
		Zea mays var. *everta* (Sturter.) Bailey.	62	126	
		Zea mays var. *saccharata* Bailey.	62	126	
	231	*Zoysia*			
XII, 202	231	*Zoysia japonica* Steud.	65	126	
XII, 203	231	*Zoysia matrella* (L.) Merr.	65	126	
	231	*Zoysia tenuifolia* Willd. ex Trin.			
XXIII, 478		Zygophyllaceae			

LIST OF PLANT NAMES

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION

Identification		Common name	Botanical name	Purity	Germination	
Plate	*Page*			*Page*	*Page*	*Figure*
IV, 79		African millet	*Eleusine coracana*			
		Asia poppy, spotted (see Roemeria poppy).				
XX, 402	247	Alfalfa	*Medicago sativa*	77	142	53
XXIII, 469		Alfilaria	*Erodium cicutarium*	82	167	
	231	Alkali sacaton	*Sporobolus airoides*			
XVI, 314		Alyssum, hoary	*Berteroa incana*			
XVI, 310		Alyssum, pale	*Alyssum alyssoides*			
		Amaranth, redroot (see Rough pigweed).				
		Amaranth, spreading (see Spreading pigweed).				
		Amaranth, tumble (see Tumbling pigweed).				
XXV, 522		Ammi, greater	*Ammi majus*			
XVI, 294		Anemone, meadow	*Anemone canadensis*			
II, 30	203	Angleton grass	*Andropogon nodosus*			
		Artichoke	*Cynara scolymus*	84	113	
		Asparagus	*Asparagus officinalis*	82	160	
XVIII, 346		Avens	*Geum* sp			
XXXII, 679		Bachelor's-button	*Centaurea cyanus*			
VII, 145	223	Bahia grass	*Paspalum notatum*	58	126	
XVII, 323	235	Ballcress	*Cardaria pubescens* (*Hymenophysa pubescens*).			
XVII, 335		Ball mustard	*Neslia paniculata*			
		Balloon mustard (see False-flax, big seed).				
	218	Barley	*Hordeum*			
V, 104	218	Barley	*Hordeum vulgare*	62	126	
V, 107	219	Barley, foxtail; wild barley; squirreltail barley.	*Hordeum jubatum*			
V, 105	219	Barley, little	*Hordeum pusillum*			
V, 106	219	Barley, meadow	*Hordeum brachyantherum* (*H. nodosum*).			
V, 108	219	Barley, mouse; wild barley	*Hordeum leporinum* (*H. murinum*).			
		Barnaby's thistle (see Star-thistle, yellow).				
IV, 77	214	Barnyard grass	*Echinochloa crusgalli*			
XVIII, 345		Base-rocket	*Reseda lutea*			
XXIX, 604		Basil	*Satureja vulgaris*			
		Basil-thyme (see Savory, spring).				
XIV, 250		Bassia, fivehook	*Bassia hyssopifolia*			
XX, 410	248	Bean, Adzuki	*Phaseolus angularis*	73	142	
		Bean, asparagus; yardlong	*Vigna sesquipedalis*	73	142	
		Bean, field and garden	*Phaseolus vulgaris*	73	142	44
		Bean, lima	*Phaseolus lunatus* var. *macrocarpus*.	73	142	45, 46, 47
XX, 411	248	Bean, mung	*Phaseolus aureus*	73	142	
		Bean, runner	*Phaseolus coccineus*	73	142	
XXI, 416	249	Bean, wild	*Strophostyles leiosperma* (*S. pauciflora*).			

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Common name	Botanical name	Purity	Germination	
Plate	*Page*			*Page*	*Page*	*Figure*
		Bean, yardlong (see Bean, asparagus).				
II, 28		Beardgrass, yellow	*Andropogon ischaemum*			
	203	Beardgrass, Queensland (see Bluestem, silky).				
		Bedstraw (see Cleavers)				
XXX, 648		Bedstraw, white	*Galium mollugo*			
		Beet, field (mangel)	*Beta vulgaris*	84	107	
		Beet, garden	*Beta vulgaris*	84	107	24, 25
		Beet, sugar	*Beta vulgaris* var. *saccharifera*.	84	107	
XIX, 375	241	Beggarweed, Florida	*Desmodium tortuosum*	74	142	
		Belvedere (see Summer cypress).				
	196	Bentgrass	*Agrostis*			
I, 2	196	Bentgrass, colonial (browntop; Rhode Island bent). Hort. vars.:	*Agrostis tenuis*	55	126	
	198	Astoria				
	197	Highland (Dryland bent).				
	198	Bentgrass, creeping (Seaside)	*Agrostis palustris*	55	126	
I, 6	198	Bentgrass, Elliott	*Argostis elliottiana*			
I, 3–4	198	Bentgrass, spike	*Agrostis exarata*			
I, 5	198	Bentgrass, velvet	*Agrostis canina*	55	126	
I, 7	198	Bentgrass, winter	*Agrostis hiemalis*			
III, 62		Bermuda grass	*Cynodon dactylon* (*Capriola dactylon*).	60	126	
XXIX, 606		Betony, field	*Stachys annua*			
XXIX, 607		Betony, marsh	*Stachys palustris*			
	258	Bindweed	*Convolvulus*			
XXVI, 549	258	Bindweed, field	*Convolvulus arvensis*			
XXVI, 550	258	Bindweed:Hedge; great; wild; bracted.	*Convolvulus sepium*			
		Bird-rape (see Turnip)				
XVIII, 350		Blackberry	*Rubus* sp			
XXVIII, 587		Black horehound	*Ballota nigra*			
XIII, 230		Black bindweed	*Polygonum convolvulus*			
XXXIII, 723		Black-eyed-susan	*Rudbeckia hirta*			
		Bladder ketmia (see Flower-of-an-hour).				
XXXI, 662		Blowwives	*Achyrachaena mollis*			
		Blue-bur (see Stickseed, European).				
		Blue cockle (see Corncockle)				
XXIX, 610		Bluecurls, forked	*Trichostema dichotomum*			
XXIX, 611		Bluecurls, vinegar	*Trichostema lanceolatum*			
		Blue devil (see Blueweed)				
XIII, 224		Blue-eyed-grass	*Sisyrinchium* sp			
	224	Bluegrass	*Poa*			
X, 171*i*	226	Bluegrass, alkali	*Poa juncifolia*			
VIII, 159, X, 171*h*	226	Bluegrass, annual	*Poa annua*	67	126	
VIII, 160, X, 171*l*	226	Bluegrass, big	*Poa ampla*			
VIII, 163	227	Bluegrass, bulbous	*Poa bulbosa*	67	126	
VIII, 164, X, 171*d*	225	Bluegrass, Canada	*Poa compressa*	67	126	
X, 171*m*		Bluegrass, Canby	*Poa canbyi*			
X, 171*n*	226	Bluegrass, Cusick	*Poa cusickii*			
IX, 168, X, 171*e*	227	Bluegrass, fowl	*Poa palustris*			
IX, 165, X, 171*p*	226	Bluegrass, inland	*Poa interior*			
IX, 169, X, 171*a*	225	Bluegrass, Kentucky	*Poa pratensis*	67	126	
	226	Bluegrass, Merion	*Poa pratensis*			
IX, 167, X, 171*k*	226	Bluegrass, Nevada	*Poa nevadensis*	67	126	

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Common name	Botanical name	Purity	Germination	
Plate	*Page*			*Page*	*Page*	*Figure*
VIII, 162, X, 171*g*	227	Bluegrass, plains	*Poa arida*			
IX, 170, X, 171*b*	225	Bluegrass; rough, roughstalk	*Poa trivialis*	67	126	
X, 171*j*	227	Bluegrass, Sandberg	*Poa secunda*			
VIII, 161, X, 171*f*	226	Bluegrass, Texas	*Poa arachnifera*	67	126	
X, 171*s*		Bluegrass, Trinius	*Poa stenantha*			
IX, 166, X, 171*c*	226	Bluegrass, wood	*Poa nemoralis*	67	126	
		Blue sailors (see Chicory)				
	202	Bluestem	*Andropogon* sp			
II, 29	203	Bluestem, Australian	*Andropogon intermedius*			
II, 25	203	Bluestem, big	*Andropogon gerardi* (*A. furcatus*).	57	126	
		Bluestem, East Indies (see Beardgrass, yellow).				
II, 27	203	Bluestem, little	*Andropogon scoparius*	57	126	
II, 26	203	Bluestem, sand	*Andropogon hallii*	57	126	
II, 31	203	Bluestem, silky	*Andropogon sericeus*			
		Bluestem, Western (see Wheatgrass, Western).				
		Blue thistle (see Blueweed)				
XXX, 649		Bluets, purple	*Houstonia purpurea*			
XXVII, 573		Blueweed	*Echium vulgare*			
XXXIII, 703		Blueweed; Texas blueweed	*Helianthus ciliaris*			
XXV, 510		Boisduvalia, dense-flowered	*Boisduvalia densiflora*			
XXV, 511		Boisduvalia, stiff	*Boisduvalia stricta*			
		Bristlegrass	*Setaria*			
X, 178	227	Bristlegrass, bur	*Setaria verticillata*			
X, 177	228	Bristlegrass, giant	*Setaria magna*			
		Bristlegrass, green (see Foxtail, green).				
X, 174	228	Bristlegrass, Grisebach	*Setaria grisebachii*			
X, 173	228	Bristlegrass, knotroot	*Setaria geniculata*			
X, 176	228	Bristlegrass, plains	*Setaria macrostachya*			
		Bristlegrass, yellow (see Foxtail, yellow).				
		Broadbean (see Horsebean)				
		Broccoli	*Brassica oleracea* var. *botrytis*.	83	119	
XIII, 221		Brodiaea, harvest	*Brodiaea coronaria*			
XIII, 222		Brodiaea, large-flowered	*Brodiaea grandiflora*			
	210	Brome, California	*Bromus carinatus*			
		Brome, downy (see Chess, downy).				
	209	Bromegrass	*Bromus*			
		Brome, Japanese (see Chess, Japanese).				
III, 57	210	Brome, mountain	*Bromus marginatus*	59	126	
III, 55	210	Brome, smooth	*Bromus inermis*	59	126	
XI, 194	230	Broomcorn	*Sorghum vulgare* var. *technicum*.	70	126	
		Broomcorn millet (see Proso)				
II, 32	203	Broomsedge	*Andropogon virginicus*			
VI, 136	221	Browntop millet (see Panicum, browntop).	*Panicum ramosum* [1]	65	126	
		Browntop (see Bent grass, colonial).				
		Brussels sprouts	*Brassica oleracea* var. *gemmifera*.	83	119	
		Buckhorn (see Plantain, buckhorn)				

[1] The name browntop millet has been applied to browntop panicum (*P. fasciculatum*); *P. ramosum* is the species in cultivation.

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Common name	Botanical name	Purity	Germination	
Plate	*Page*			*Page*	*Page*	*Figure*
		Buckwheat, common	*Fagopyrum esculentum*	81	167	
XXIX, 620		Buffalo-bur	*Solanum rostratum*			
II, 45	208	Buffalo grass	*Buchloë dactyloides*	67	126	
XXVIII, 586		Bugle, ground	*Ajuga chamaepitys*			
XXVIII, 593		Bugleweed, American	*Lycopus virginicus*			
		Bug-seed (see Tickseed)				
		Bullnettle (see Horsenettle)				
XII, 214		Bulrush	*Scirpus* sp			
XX, 401	246	Bur-clover, button	*Medicago orbicularis*			
XX, 399	246	Bur-clover, California	*Medicago hispida*	77	142	
XX, 398	246	Bur-clover, spotted	*Medicago arabica*	77	142	
XXXI, 670		Burdock, great	*Arctium lappa*			
XVIII, 352		Burnet, little	*Sanguisorba minor*			
XVIII, 351		Burnet, prairie	*Sanguisorba annua*			
		Bur-ragweed (see Bur-sage, skeletonleaf).				
XXXII, 694		Burnweed	*Erechtites hieracifolia*			
XXXII, 695		Burnweed, Australian	*Erechtites prenanthoides*			
XXXII, 698		Bur-sage, skeletonleaf	*Franseria discolor* (*Gaertneria discolor*).			
XXXII, 699		Bur-sage, slimleaf	*Franseria tenuifolia*			
XXIX, 625		Butter-and-eggs	*Linaria vulgaris* (*L. linaria*).			
XVI, 300		Buttercup, bulbous	*Ranunculus bulbosus*			
		Buttercup, common (see Buttercup, tall).				
XVI, 302		Buttercup, creeping	*Ranunculus repens*			
XVI, 301		Buttercup: sticktight; small-flowered.	*Ranunculus parviflorus*			
XVI, 299		Buttercup, tall	*Ranunculus acris*			
XVI, 303		Buttercup: wartseed; hairy	*Ranunculus sardous* (*R. parvulus*).			
XXVI, 547		Butterfly-weed	*Asclepias tuberosa*			
		Butterprint (see Velvet-leaf).				
XX, 401	246	Buttonclover	*Medicago orbicularis*			
XXX, 645		Buttonweed, rough	*Diodia teres*			
XXX, 646		Buttonweed, Virginia	*Diodia virginiana*			
		Cabbage	*Brassica oleracea* var. *capitata*.	83	119	
		Caley pea (see Rough pea)				
XVI, 305		California-poppy	*Eschscholtzia californica*			
		Caltrop (see Puncturevine)				
		Caltrops (see Star-thistle, purple).				
XVIII, 355	238	Camelthorn	*Alhagi pseudalhagi* (*A. camelorum*).			
		Camomile, field (see Corn-chamomile).				
		Camomile, golden (see Chamomile, yellow).				
	232	Campion	*Lychnis*			
XV, 289	232	Campion, bladder	*Silene cucubalus* (*S. latifolia*).			
XV, 280	232	Campion, red	*Lychnis dioica*			
		Campion: White; evening (see Cockle, white).				
	223	Canary grass	*Phalaris*			
VII, 155	223	Canary grass	*Phalaris canariensis*	60	126	
	224	Canary grass, Carolina	*Phalaris caroliniana*			
VII, 156	224	Canary grass, hood	*Phalaris paradoxa*			
VII, 153	224	Canary grass, little	*Phalaris minor*			

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Common name	Botanical name	Purity	Germination	
Plate	*Page*			*Page*	*Page*	*Figure*
VII, 152	223	Canary grass, reed	*Phalaris arundinacea*	60	126	
VII, 151	224	Canary grass, timothy	*Phalaris angusta*			
		Cantaloup (muskmelon)	*Cucumis melo*	82	124	
XXV, 531		Caraway	*Carum carvi*			
		Cardoon	*Cynara cardunculus*	84	113	
		Carolina geranium (see Cranesbill, carolina).				
		Carolina horsenettle (see Horsenettle).				
	208	Carpet grass	*Axonopus*			
II, 43	208	Carpet grass, broad-leaved	*Axonopus compressus*			
II, 42	208	Carpet grass, narrow-leaved	*Axonopus affinis*	58	126	
XXVI, 535		Carrot (cult.)	*Daucus carota*	80	167	61
XXVI, 535		Carrot, wild	*Daucus carota*			
XV, 285	233	Catchfly, conical	*Silene conica*			
XV, 287	233	Catchfly, Cretian	*Silene cretica*			
XV, 284	233	Catchfly, English	*Silene gallica* (*S. anglica*)			
XV, 290	233	Catchfly: Forked; clover	*Silene dichotoma*			
XV, 291	233	Catchfly, night-flowering	*Silene noctiflora*			
XV, 283	233	Catchfly, sleepy	*Silene antirrhina*			
		Catchweed (see Cleavers)				
XXVIII, 597		Catnip	*Nepeta cataria*			
XXXIII, 707		Cats-ear, spotted	*Hypochaeris radicata*			
		Cattail millet (see Pearl millet).				
		Cauliflower	*Brassica oleracea* var. *botrytis.*	83	119	
		Celeriac	*Apium graveolens* var. *rapaceum.*	80	167	
		Celery	*Apium graveolens* var. *dulce*	80	167	
XXV, 525		Celery, wild	*Apium ammi*			
IV, 91		Centipede grass	*Eremochloa ophiuroides*			
XXXI, 655		Cephalaria	*Cephalaria transylvanica*			
XXXI, 668		Chamomile, yellow	*Anthemis tinctoria*			
		Chard, Swiss	*Beta vulgaris* var. *cicla*	84	107	
XVII, 317	235	Charlock	*Brassica kaber* (*B. arvensis*)			
		Cheat (see Chess)				
XXIV, 499		Cheesemallow, plains	*Sidalcea campestris*			
XXIV, 500		Cheesemallow, Henderson	*Sidalcea hendersonii*			
		Cheeses (see Mallow, running).				
XXVI, 532		Chervil	*Chaerophyllum* sp			
III, 53	211	Chess	*Bromus secalinus*			
III, 50	211	Chess, barren	*Bromus sterilis*			
III, 49	210	Chess, downy	*Bromus tectorum*			
	210	Chess, foxtail	*Bromus rubens*			
III, 52	211	Chess, hairy	*Bromus commutatus*			
III, 51	211	Chess, Japanese	*Bromus japonicus*			
		Chess, poverty (see Chess, barren).				
III, 54	211	Chess, soft	*Bromus mollis* (*B. hordeaceus*).			
XIX, 366	239	Chickpea	*Cicer arietinum*	73	142	
XV, 277		Chickweed, big mouse-ear	*Cerastium vulgatum*			
XV, 275		Chickweed, common	*Stellaria media* (*Alsine media*).			
XXXII, 690		Chicory	*Cichorium intybus*	84	113	
III, 58	212	Chloris, slender	*Chloris divaricata*			
		Chufa (see Nutgrass, yellow)				
		Cinquefoil, Montpelier (see Strawberryweed).				
XVIII, 347		Cinquefoil, oldfield	*Potentilla canadensis*			

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Common name	Botanical name	Purity	Germination	
Plate	*Page*			*Page*	*Page*	*Figure*
		Citron	*Citrullus vulgaris*	82	124	
XXX, 647		Cleavers	*Galium aparine*			
	250	Clover	*Trifolium* spp			
XXII, 439	253	Clover, alsike	*Trifolium hybridum*	77	142	
XVIII, 356	238	Clover, alyce	*Alysicarpus vaginalis*	77	142	
XXI, 430	252	Clover, ball	*Trifolium nigrescens*			
XXII, 446	254	Clover, berseem	*Trifolium alexandrinum*	77	142	
XXI, 434	253	Clover, big-flowered	*Trifolium michelianum*			
XXI, 421	252	Clover, buffalo	*Trifolium reflexum*			
XX, 399	246	Clover, bur	*Medicago hispida*	77	142	
		Clover, burdock (see Clover, lappa).				
XXI, 422	252	Clover, Carolina	*Trifolium carolinianum*			
XXI, 419	252	Clover, cluster	*Trifolium glomeratum*	77	142	
XXII, 448	254	Clover, crimson	*Trifolium incarnatum*	77	142	
XXI, 418	252	Clover, crooked	*Trifolium angulatum*			
XXI, 420	252	Clover, drooping-flowered	*Trifolium cernuum*			
		Clover, dwarf sack (see Clover, poverty).				
		Clover, knotted (see Clover, striate).				
XXII, 445	254	Clover, kura	*Trifolium ambiguum*			
		Clover, ladino (see Clover, white).				
XXI, 429	253	Clover, lappa	*Trifolium lappaceum*	77	142	
XXI, 428	252	Clover: Large hop; low hop	*Trifolium procumbens*	77	142	
XXI, 435	253	Clover, Persian	*Trifolium resupinatum*	77	142	
XXII, 436	254	Clover, pinole	*Trifolium bifidum*			
XXII, 438	254	Clover, pinpoint	*Trifolium gracilentum*			
XXI, 424	252	Clover, poverty	*Trifolium depauperatum*			
XXI, 426	253	Clover, rabbitfoot	*Trifolium arvense*			
XXI, 431	253	Clover, red	*Trifolium pratense*	77	142	
XXII, 447	254	Clover, rose	*Trifolium hirtum*			
XXII, 444	253	Clover, seaside	*Trifolium wildenovii*			
XXII, 440	254	Clover, smallheaded	*Trifolium microcephalum*			
		Clover, small hop (see Clover, suckling).				
XX, 406	248	Clover, sour	*Melilotus indica*	75	142	
XXII, 437	253	Clover, strawberry	*Trifolium fragiferum*	77	142	
XXI, 433	253	Clover, striate	*Trifolium striatum*			
XXII, 450	254	Clover, sub	*Trifolium subterraneum*	77	142	
XXI, 427	252	Clover, suckling	*Trifolium dubium*	77	142	
XXI, 423	252	Clover, teasel	*Trifolium parviflorum*			
XXII, 441	254	Clover, thimble	*Trifolium microdon*			
XXII. 442	253	Clover, tomcat	*Trifolium tridentatum*			
XX, 404	247	Clover, white sweet	*Melilotus alba*	75	142	
XXI, 432	253	Clover, white	*Trifolium repens*	77	142	
XXII, 443	253	Clover, whitetip	*Trifolium variegatum*			
XXI, 425	252	Clover: Yellow hop; yellow	*Trifolium agrarium*			
XX, 405	247	Clover, yellow sweet	*Melilotus officinalis*	75	142	
XXII, 449	254	Clover, zigzag	*Trifolium medium*			
III, 61	212	Club-awn	*Corynephorus canescens*			
		Coast dandelion (see Cats-ear, spotted).				
		Coast blite (see Goosefoot, red).				
		Cockle (see Corncockle)				
		Cockle, pink (see Cow-cockle).				
		Cockle, sticky (see Catchfly, night-flowering).				
XV, 279	232	Cockle, white	*Lychnis alba*			

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Common name	Botanical name	Purity	Germination	
Plate	*Page*			*Page*	*Page*	*Figure*
		Cocksfoot grass (see Orchard grass).				
		Coco grass (see Nutgrass)				
		Coffee bean (see Sesbania)				
XX, 403	247	Cogwheel clover	*Medicago tuberculata*			
		Collards	*Brassica oleracea* var. *acephala.*	83	119	
XXXI, 672		Cone-flower, purple	*Brauneria angustifolia*			
		Cornbind (see Black bindweed).				
XV, 273		Corncockle	*Agrostemma githago*			
XXXI, 666		Corn-chamomile	*Anthemis arvensis*			
		Corn, field	*Zea mays*	62	126	39, 40
		Cornflower (see Bachelor's-button).				
		Corn, pop	*Zea mays* var. *everta*	62	126	
XXXI, 652		Cornsalad	*Valerianella locusta* var. *olitoria.*	80	167	
XXXI, 654		Cornsalad, Italian	*Valerianella eriocarpa*			
XXXI, 653		Cornsalad, toothed	*Valerianella dentata*			
		Corn, sweet	*Zea mays* var. *saccharata*	62	126	
XIX, 367	240	Coronilla, scorpion	*Coronilla scorpioides*			
		Cotton	*Gossypium* spp	81	164	59
		Couch grass (see Quackgrass).				
XV, 281		Cowcockle	*Saponaria vaccaria*			
		Cowherb (see Cowcockle)				
XXIII, 467–468	257	Cowpea	*Vigna sinensis*	73	142	
		Cowpea, yardlong	*Vigna sesquipedalis*	73	142	
XXIX, 626		Cow wheat	*Melampyrum arvense*			
IV, 75		Crabgrass; large crabgrass	*Digitaria sanguinalis* (*Syntherisma sanguinalis*).			
IV, 73		Crabgrass, slender	*Digitaria filiformis*			
IV, 74		Crabgrass, smooth	*Digitaria ischaemum* (*Syntherisma ischaemum*).			
XXIII, 470		Cranesbill, Carolina	*Geranium carolinianum*			
XXIII, 472		Cranesbill, cutleaf	*Geranium dissectum*			
XXIII, 473		Cranesbill, dovefoot	*Geranium molle*			
XXIII, 471		Cranesbill, longstalk	*Geranium columbinum*			
XXIII, 474		Cranesbill, small	*Geranium pusillum*			
		Creeping Jennie (see Bindweed, field).				
		Cress, garden	*Lepidium sativum*	83	119	
XVII, 322	235	Cress, hoary	*Cardaria draba*			
		Cress, water	*Rorippa nasturtium-aquaticum.*	83	119	
	240	Crotalaria	*Crotalaria* spp			
XIX, 370	240	Crotalaria, lance	*Crotalaria lanceolata*	74	142	
XIX, 372	240	Crotalaria, showy	*Crotalaria spectabilis*	74	142	56
XIX, 369	240	Crotalaria, slenderleaf	*Crotalaria intermedia*	74	142	
XIX, 371	240	Crotalaria, striate	*Crotalaria mucronata* (*C. striata*).	74	142	
	240	Crotalaria, Sunn	*Crotalaria juncea*	74	142	
XXIII, 480		Croton	*Croton* sp			
XIX, 368	239	Crownvetch	*Coronilla varia*			
XIX, 367	240	Crownvetch, scorpion	*Coronilla scorpioides*			
		Cucumber	*Cucumis sativus*	82	124	34
IV, 92		Cupgrass, Louisiana	*Eriochloa punctata*			
XXVII, 568		Curlybloom	*Phacelia* sp			
XXXII, 689		Daisy: Oxeye; field; white	*Chrysanthemum leucanthemum.*			
VII, 140	222	Dallis grass	*Paspalum dilatatum*	58	126	

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Common name	Botanical name	Purity	Germination	
Plate	*Page*			*Page*	*Page*	*Figure*
XXXIV, 730	------	Dandelion	*Taraxacum officinale*	84	113	------
XXXIV, 731	------	Dandelion, red-seeded	*Taraxacum erythrospermum.*	------	------	------
V, 113	220	Darnel; bearded darnel	*Lolium temulentum*	------	------	------
XII, 215	------	Dayflower, common	*Commelina communis*	------	------	------
------	------	Dead nettle (see Henbit)	------	------	------	------
------	------	Deathweed (see Sumpweed, poverty).	------	------	------	------
------	------	Deervetch, American (see Prairie-trefoil).	------	------	------	------
XX, 392	245	Deervetch, hispid	*Lotus hispidus*	------	------	------
XX, 390	245	Deervetch, slenderpod	*Lotus angustissimus*	------	------	------
XV, 278	------	Deptford pink	*Dianthus armeria*	------	------	------
------	------	Desert purslane (see Horse-purslane).	------	------	------	------
------	------	Devil's paintbrush (see Hawkweed, orange).	------	------	------	------
XIII, 240	------	Dock: Broad-leaved; bitter	*Rumex obtusifolius*	------	------	------
XIII, 238	------	Dock: Clustered; green	*Rumex conglomeratus*	------	------	------
XIII, 239	------	Dock: Curly; sour; yellow	*Rumex crispus*	------	------	------
XIII, 243	------	Dock, fiddleleaf	*Rumex pulcher*	------	------	------
XIII, 242	------	Dock, golden	*Rumex persicarioides*	------	------	------
XIII, 237	------	Dock: Peach-leaved; smooth	*Rumex altissimus*	------	------	------
------	------	Dock, sour (see Sorrel, garden).	------	------	------	------
XIV, 245	------	Dock, veiny	*Rumex venosus*	------	------	------
XIII, 241	------	Dock, western	*Rumex occidentalis*	------	------	------
XIV, 244	------	Dock, willow-leaved	*Rumex salicifolius*	------	------	------
------	259	Dodder	*Cuscuta*	------	------	------
XXVII, 559	260	Dodder: Bigseed; large-seeded alfalfa.	*Cuscuta indecora*	------	------	------
XXVII, 561	260	Dodder, Chilean	*Cuscuta racemosa* var. *chiliana*	------	------	------
XXVII, 557	260	Dodder, clover	*Cuscuta epithymum*	------	------	------
XXVII, 560	260	Dodder: Field; large seeded	*Cuscuta pentagona* (*C. arvensis*).	------	------	------
XXVII, 558	260	Dodder, flax	*Cuscuta epilinum*	------	------	------
XXVII, 562	260	Dodder, Gronovius	*Cuscuta gronovii*	------	------	------
XXVII, 556	260	Dodder: Littleseed; small-seeded alfalfa.	*Cuscuta planiflora*	------	------	------
XXVI, 543	------	Dogbane, hemp	*Apocynum cannabinum*	------	------	------
XXVI, 542	------	Dogbane, spreading	*Apocynum androsaemifolium.*	------	------	------
XXXI, 667	------	Dogfennel	*Anthemis cotula*	------	------	------
------	212	Dogtail	*Cynosurus*	------	------	------
III, 65	213	Dogtail, bristly	*Cynosurus echinatus*	------	------	------
III, 64	213	Dogtail, crested	*Cynosurus cristatus*	60	126	------
XXVIII, 596	------	Dragonhead, American	*Moldavica parviflora* (*Dracocephalum parviflorum*).	------	------	------
XII, 198	231	Dropseed, puff	*Sporobolus neglectus*	------	------	------
XII, 197	231	Dropseed, sand	*Sporobolus cryptandrus*	60	126	------
XII, 196	231	Dropseed, scratch	*Sporobolus clandestinus*	------	------	------
XXV, 527	------	Earth nut	*Bunium bulbocastrum* (*Carum bulbocastrum*).	------	------	------
------	214	Echinochloa	*Echinochloa*	------	------	------
------	------	Eggplant	*Solanum melongena* var. *esculentum.*	80	167	------
------	------	Endive	*Cichorium endivia*	84	113	------
XVII, 329	------	Erysimum, smallflower	*Erysimum inconspicuum* (*E. parviflorum*).	------	------	------
XXV, 518	------	Evening-primrose	*Oenothera biennis*	------	------	------

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Common name	Botanical name	Purity	Germination	
Plate	*Page*			*Page*	*Page*	*Figure*
XXV, 519		Evening-primrose, cutleaf	*Oenothera laciniata* (*Raimannia laciniata*).			
XXIX, 623		Eyebright	*Euphrasia* sp.			
XXXIII, 715		Fall-dandelion	*Leontodon autumnalis*			
V, 109	219	Fall witchgrass	*Leptoloma cognatum*			
XXXIII, 719		False-camomile	*Matricaria inodora*			
XVII, 321		Falseflax, bigseed	*Camelina sativa*			
XVII, 320		Falseflax: Little-seed; small-seeded.	*Camelina microcarpa*			
		False-mallow, red (see Globe-mallow, scarlet).				
XXIV, 501		False-mallow, yellow	*Sidopsis hispida*			
		Fanweed (see Pennycress)				
XIV, 246		Fat-hen	*Atriplex patula* var. *hastata*.			
		Fennel-flower (see Love-in-a-mist).				
XVI, 298		Fennel-flower, garden	*Nigella sativa* (*N. arvensis*)			
XXII, 451	254	Fenugreek	*Trigonella foenum-graecum*			
	216	Fescue	*Festuca*			
	217	Fescue, Chewings	*Festuca rubra* var. *commutata*.	61	126	
	217	Fescue, hair	*Festuca capillata*	61	126	
IV, 93	218	Fescue, meadow	*Festuca elatior*	61	126	
IV, 96	217	Fescue, rattail	*Festuca myuros*			
IV, 95	217	Fescue, red	*Festuca rubra*	61	126	
	217	Fescue, sheep	*Festuca ovina*	61	126	
IV, 94	218	Fescue, tall	*Festuca arundinacea*	61	126	
		Hort. vars.: Alta				
		Ky-31				
XI, 193	230	Feterita	*Sorghum vulgare* var.			
		Fetticus (see Cornsalad)				
XXVII, 571		Fiddleneck	*Amsinckia tesselata*			
XXVII, 570		Fiddleneck: Coast; fireweed	*Amsinckia intermedia*			
		Field camomile (see Camomile, field).				
XVII, 339	237	Fieldcress, yellow	*Rorippa austriaca*			
XXX, 649		Field houstonia	*Houstonia purpurea*			
XXX, 650		Field madder	*Sherardia arvensis*			
XXIX, 627		Figwort, American	*Scrophularia marilandica*			
	211	Fingergrass	*Chloris*			
III, 58	212	Fingergrass, Australian	*Chloris divaricata*			
	212	Fingergrass, feather	*Chloris virgata*			
		Fireweed (see Burnweed)				
		Fivefinger (see Cinquefoil, oldfield).				
XXX, 628		Flannel mullein	*Verbascum thapsus*			
XIX, 383	243	Flat pea	*Lathyrus sylvestris*			
XIV, 265		Flatweed	*Roubieva multifida*			
XXIII, 476		Flax	*Linum usitatissimum*	81	162	58
XXIII, 477		Flax, woodland	*Linum virginianum*			
		Fleabane, Canada (see Horseweed).				
XXXII, 696		Fleabane: Daisy; whitetop	*Erigeron annuus*			
XIX, 375	241	Florida beggarweed	*Desmodium tortuosum*	74	142	
		Florida velvetbean (see Velvetbean).				
XXIV, 491		Flower-of-an-hour	*Hibiscus trionum*			
XXV, 521		Fool's parsley	*Aethusa cynapium*			
XXVII, 579		Forget-me-not	*Myosotis arvensis*			
XV, 270		Four-o'clock, wild	*Mirabilis nyctaginea*			

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Common name	Botanical name	Purity	Germination	
Plate	*Page*			*Page*	*Page*	*Figure*
	202	Foxtail	*Alopecurus*			
	227	Foxtail	*Setaria*			
I, 20	202	Foxtail, Carolina	*Alopecurus carolinianus*			
X, 172	227	Foxtail, giant	*Setaria faberi*			
X, 179	228	Foxtail, green	*Setaria viridis*			
		Foxtail, meadow (see Meadow foxtail).				
I, 19	202	Foxtail, short-awn	*Alopecurus aequalis*			
I, 23	202	Foxtail, slender	*Alopecurus myosuroides*			
I, 21	202	Foxtail, water	*Alopecurus geniculatus*			
X, 175	229	Foxtail, yellow	*Setaria lutescens*			
		French weed (see Pennycress) (see also Galinsoga).				
XVI, 309		Fumitory, common	*Fumaria officinalis*			
		Gaertneria (see Bur-sage, skeletonleaf).				
		Galega (see Goatsrue)				
XXXIII, 700		Galinsoga	*Galinsoga parviflora*			
XIII, 220		Garlic, wild	*Allium vineale*			
XXV, 515		Gaura, hairy	*Gaura villosa*			
XXV, 512		Gaura, scarlet	*Gaura coccinea*			
XXV, 513		Gaura, scented	*Gaura odorata*			
XXV, 514		Gaura, wavy-leaved	*Gaura sinuata*			
XXIX, 609		Germander, American	*Teucrium canadense*			
XXIX, 608		Germander, cut-leaf	*Teucrium botrys*			
X, 172	227	Giant foxtail	*Setaria faberi*			
XXVII, 563		Gilia	*Collomia gracilis*			
XXVII, 564		Gilia, bigflower	*Collomia grandiflora*			
XXVII, 565		Gilia, globe	*Gilia capitata*			
XXIV, 502		Globemallow, scarlet	*Sphaeralcea coccinea*			
		Goats-beard (see Salsify, meadow).				
XIX, 376	241	Goatsrue, common	*Galega officinalis*			
		Goatweed (see St. Johnswort).				
XXV, 516		Godetia	*Godetia tenella*			
XXXI, 669		Goldenweed, hairy	*Aplopappus ciliatus* (*Prionopsis ciliata*).			
		Goosefoot (see Lambsquarters)				
XIV, 255		Goosefoot, bigseed	*Chenopodium hybridum* var. *gigantospermum*.			
XIV, 254		Goosefoot, mapleleaf	*Chenopodium hybridum*			
XIV, 256		Goosefoot, narrowleaf	*Chenopodium leptophyllum*			
XIV, 257		Goosefoot, nettleleaf	*Chenopodium murale*			
XIV, 252		Goosefoot, pitseed	*Chenopodium berlandieri*			
XIV, 258		Goosefoot, red	*Chenopodium rubrum*			
IV, 80		Goosegrass	*Eleusine indica*			
II, 47	209	Grama, blue	*Bouteloua gracilis*	57	126	
	209	Grama grass	*Bouteloua*			
II, 48	209	Grama, hairy	*Bouteloua hirsuta*			
II, 46	209	Grama, side-oats	*Bouteloua curtipendula*	57	126	
XIII, 223		Grape-hyacinth, tassel	*Muscari comosum*			
XXXIV, 732		Greenthread	*Thelesperma* sp			
XXVII, 578		Gromwell: Field; corn	*Lithospermum arvense*			
XXIX, 615		Groundcherry, perennial	*Physalis longifolia*			
XXIX, 614		Groundcherry, purple-flowered.	*Physalis lobata* (*Quincula lobata*).			
XXIX, 616		Groundcherry, taperleaf	*Physalis subglabrata*			
XIX, 385	243	Groundnut pea	*Lathyrus tuberosus*			
XXXIV, 725		Groundsel, common	*Senecio vulgaris*			

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Common name	Botanical name	Purity	Germination	
Plate	*Page*			*Page*	*Page*	*Figure*
		Groundsel, ragwort (see Ragwort, tansy).				
XIX, 373	240	Guar	*Cyamopsis tetragonolobus*			
VI, 132	221	Guinea grass	*Panicum maximum*	65	126	
XXXIII, 701		Gumweed, curlycup	*Grindelia squarrosa*			
	201	Hairgrass	*Aira*			
III, 70	213	Hairgrass, crinkled	*Deschampsia flexuosa*			
I, 17	201	Hairgrass, fine	*Aira elegans* (*Aira capillaris*)			
I, 18	201	Hairgrass, silver	*Aira caryophyllea*			
III, 69	213	Hairgrass, tufted	*Deschampsia caespitosa*			
XIV, 263		Halogeton	*Halogeton glomeratus*			
VII, 154	224	Harding grass	*Phalaris tuberosa* var. *stenoptera*.	60	126	
XVII, 325	236	Hares-ear-mustard	*Conringia orientalis*			
XXXIII, 716		Hawkbit, rough	*Leontodon nudicaulis*			
XXXII, 693b		Hawksbeard, hairy	*Crepis setosa*			
XXXII, 693a		Hawksbeard, smooth	*Crepis capillaris*			
XXXIII, 706		Hawkweed, orange	*Hieracium aurantiacum*			
XXXIII, 721		Hawkweed, picris	*Picris hieracioides*			
XXVIII, 598		Heal-all	*Prunella vulgaris*			
XXVI, 550	258	Hedge-bindweed	*Convolvulus sepium*			
XVIII, 342		Hedgemustard	*Sisymbrium officinale* (*Erysimum officinale*).			
		Hedgenettle (see Betony, field).				
XXVI, 539		Hedgeparsley, erect	*Torilis anthriscus*			
XXVI, 540		Hedgeparsley, knotted	*Torilis nodosa*			
XI, 192	230	Hegari	*Sorghum vulgare* var			
XXVII, 575		Heliotrope, common	*Heliotropium europaeum*			
XXVII, 574		Heliotrope, salt	*Heliotropium curassavicum*			
XXXIII, 704		Hemizonia	*Hemizonia luzulaefolia*			
XIII, 225		Hemp	*Cannabis sativa*	84	167	
XXVIII, 589		Hempnettle, bristlestem	*Galeopsis tetrahit*			
XXVIII, 588		Hempnettle, red	*Galeopsis ladanum*			
XXIX, 613		Henbane, black	*Hyoscyamus niger*			
XXVIII, 591		Henbit	*Lamium amplexicaule*			
		Herd's-grass (see Redtop)				
XXVIII, 594		Horehound, white	*Marrubium vulgare*			
XVII, 322	235	Hoary cress	*Cardaria draba* (*Lepidium draba*).			
XII, 213		Horned-rush	*Rhynchospora macrostachya*			
		Hornpoppy, blackspot (see Sea-poppy).				
		Horsebean	*Vicia faba*	79	142	
XXIX, 617		Horsenettle; Carolina horsenettle.	*Solanum carolinense*			
		Horsenettle, white (see Nightshade, silverleaf).				
XV, 271		Horse-purslane	*Trianthema portulacastrum*.			
XXXII, 697		Horseweed	*Erigeron canadensis*			
		Husk tomato	*Physalis pubescens*	80	167	
XI, 187		Hybrids; Sorghum—Sudan				
XXV, 509		Hyssop loosestrife	*Lythrum hyssopifolia*			
XXXIV, 735		Immortelle, cylinder	*Xeranthemum cylindraceum*.			
		Indian grass, yellow	*Sorghastrum nutans*	57	126	
		Indian hemp (see Dogbane, hemp).				
XXXI, 660		Indian-tobacco	*Lobelia inflata*			
		Indigo, curly (see Jointvetch, Northern).				

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Common name	Botanical name	Purity	Germination	
Plate	*Page*			*Page*	*Page*	*Figure*
XIX, 380	242	Indigo, hairy	*Indigofera hirsuta*			
XXXIV, 734		Ironweed, New York	*Vernonia noveboracensis*			
XII, 202	231	Japanese lawn grass	*Zoysia japonica*	65	126	
IV, 78	214	Japanese millet	*Echinochloa crusgalli* var. *frumentacea.*	65	126	
		Jim Hill mustard (see Tumblemustard).				
XXIX, 612		Jimsonweed	*Datura stramonium*			
XI, 185	230	Johnson grass	*Sorghum halepense*	70	126	
XVIII, 354	238	Jointvetch, Northern	*Aeschynomene virginica*			
IV, 76	214	Jungle-rice	*Echinochloa colonum*			
XI, 191	230	Kafir	*Sorghum vulgare* var			
		Kale	*Brassica oleracea* var. *acephala.*	83	119	
	234	Kale, Siberian	*Brassica napus* var. *pabularia*			
XVIII, 357	238	Kidneyvetch	*Anthyllis vulneraria*			
		King devil weed (see St. Johnswort).				
		Klamath-weed (see St. Johnswort).				
XXXII, 681		Knapweed, brownscale	*Centaurea jacea*			
XXXII, 684		Knapweed, Russian	*Centaurea picris* (*C. repens*)			
XXXII, 682		Knapweed, spotted	*Centaurea maculosa*			
XV, 282		Knawel	*Scleranthus annuus*			
		Knotgrass (see Wiregrass)				
XIII, 228, 229		Knotweed	*Polygonum aviculare*			
		Knotweed, Pennsylvania (see Ladysthumb, bigseed).				
		Knotweed, prostrate (see Knotweed).				
XIII, 227		Knotweed, silversheath	*Polygonum argyrocoleon*			
		Kohlrabi	*Brassica oleracea* var. *gongylodes.*	83	119	
XXI, 413	249	Kudzu	*Pueraria thunbergiana*	74	142	
XII, 212		Kyllinga	*Kyllinga* sp			
IV, 85	216	Lacegrass	*Eragrostis capillaris*			
XIII, 233		Ladysthumb	*Polygonum persicaria*			
XIII, 234		Ladysthumb, bigseed	*Polygonum pensylvanicum*			
XIII, 232		Ladysthumb, pale	*Polygonum lapathifolium*			
XIV, 251		Lambsquarters; goosefoot	*Chenopodium album*			
XXXI, 671		Lamb-succory	*Arnoseris minima*			
XVI, 295		Larkspur, field	*Delphinium consolida*			
XVI, 296		Larkspur, Menzies field	*Delphinium menziesii*			
		Lavender grass (see Moorgrass).				
		Leek	*Allium porrum*	82	160	
	244	Lespedeza, bicolor	*Lespedeza bicolor*			
XIX, 386	244	Lespedeza, common (striate)	*Lespedeza striata*	74	142	
XIX, 387	244	Lespedeza, Kobe	*Lespedeza striata* var Kobe	74	142	
XX, 388	244	Lespedeza, Korean	*Lespedeza stipulacea*	74	142	
XX, 389	244	Lespedeza: Sericea; Chinese	*Lespedeza cuneata* (*L. sericea*)	74	142	
	244	Lespedeza, shrub	*Lespedeza bicolor*			
	244	Lespedeza, Siberian	*Lespedeza hedysaroides*	74	142	
		Lettuce	*Lactuca sativa*	84	113	27, 28, 29
XXXIII, 713		Lettuce: Blue; chicory	*Lactuca pulchella*			
XXXIII, 712		Lettuce, prickly	*Lactuca scariola* var. *integrifolia* (L. *integrata*).			
XXXIII, 711		Lettuce, tall	*Lactuca canadensis*			

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Common name	Botanical name	Purity	Germination	
Plate	*Page*			*Page*	*Page*	*Figure*
XXI, 416	249	Little flower mealybean	*Strophostyles leiosperma* (*S. pauciflora*).			
V, 101		Lizard-tail grass	*Hackelochloa granularis*			
XVI, 297		Love-in-a-mist	*Nigella damescena*			
	215	Lovegrass	*Eragrostis*			
IV, 87	216	Lovegrass, Boer	*Eragrostis chloromelas*			
IV, 89	216	Lovegrass, Lehmann	*Eragrostis lehmanniana*			
IV, 90	216	Lovegrass, sand	*Eragrostis trichodes*			
IV, 88	216	Lovegrass, weeping	*Eragrostis curvula*			
		Lovevine (see Dodder, field)				
XX, 396	246	Lupine, blue	*Lupinus angustifolius*	73	142	51, 52
	246	Lupine, white	*Lupinus albus*	73	142	
XX, 397	246	Lupine, yellow	*Lupinus luteus*	73	142	
XXVII, 572		Madwort, German	*Asperugo procumbens*			
XXIV, 497		Mallow: Alkali; white; creeping.	*Sida hederacea*			
XXIV, 495		Mallow, high	*Malva sylvestris*			
XXIV, 493		Mallow, little	*Malva parviflora*			
XXIV, 492		Mallow, musk	*Malva moschata*			
XXIV, 498		Mallow, prickly	*Sida spinosa*			
XXIV, 494		Mallow, running	*Malva rotundifolia*			
		Mangel (see Beet, field)				
XII, 203	231	Manila grass	*Zoysia matrella*	65	126	
V, 98		Mannagrass	*Glyceria fluitans*			
V, 99		Mannagrass, American	*Glyceria grandis*			
V, 100		Mannagrass, fowl	*Glyceria striata*			
XIII, 225		Marijuana	*Cannabis sativa*	84	167	
		Marsh elder (see Sumpweed, poverty).				
	231	Mascarene grass	*Zoysia tenuifolia*			
		Mayweed (see Dogfennel)				
		Mayweed, scentless (see False-camomile).				
I, 22	202	Meadow foxtail	*Alopecurus pratensis*	66	126	
XVI, 304		Meadow-rue	*Thalictrum* sp			
		Meadow softgrass (see Velvetgrass).				
	246	Medic	*Medicago*			
XX, 400	247	Medic, black	*Medicago lupulina*	77	142	
XX, 403	247	Medic, cogwheel	*Medicago tuberculata*			
XXV, 508		Mentzelia, bractless	*Mentzelia nuda*			
XXIV, 507		Mentzelia, bushy	*Mentzelia dispersa*			
XXIV, 506		Mentzelia, whitestem	*Mentzelia albicaulis*			
		Merker grass (see Napier grass).				
		Mignonette, yellow (see Base-rocket).				
XVIII, 359	239	Milkvetch, chickpea	*Astragalus cicer*			
XVIII, 358	239	Milkvetch, Chinese	*Astragalus chinensis*			
XVIII, 361	239	Milkvetch, flexuous	*Astragalus flexuosus*			
XVIII, 362	239	Milkvetch, nuttall	*Astragalus nuttallianus*			
XVIII, 363	239	Milkvetch, ruby	*Astragalus rubyi*			
XVIII, 360	239	Milkvetch, sicklepod	*Astragalus falcatus*			
XXVI, 548		Milkweed, climbing	*Gonolobus laevis*			
XXVI, 546		Milkweed, common	*Asclepias syriaca*			
XXVI, 544		Milkweed, Mexican	*Asclepias mexicana*			
XXVI, 545		Milkweed: whorled; poison	*Asclepias galioides*			
	227	Millet	*Setaria*			
	229	Millet, foxtail	*Setaria italica*	65	126	
XI, 180	229	Hort. vars.: Common	*Setaria italica*			
XI, 182	229	German	*Setaria italica*			
XI, 181	229	Hungarian	*Setaria italica*			
XI, 183	229	White Wonder	*Setaria italica*			

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Common name	Botanical name	Purity	Germination	
Plate	*Page*			*Page*	*Page*	*Figure*
XI, 190	230	Milo	*Sorghum vulgare* var			
XXVIII, 595		Mint, field	*Mentha arvensis*			
V, 114		Molasses grass	*Melinis minutiflora*	66	126	
V, 115		Moorgrass	*Molinia caerulea*			
	259	Morning-glory	*Ipomoea*			
		Morning-glory, bigroot (see Wild potato vine).				
XXVI, 553		Morning-glory, common	*Ipomoea purpurea*			
		Morning-glory, European (see Bindweed, field).				
XXVI, 555	259	Morning-glory, hairy	*Jacquemontia tamnifolia*			
XXVI, 552	259	Morning-glory, ivy-leaf	*Ipomoea hederacea*			
	259	Morning-glory, small-flowered white.	*Ipomoea lacunosa*			
XXVIII, 592		Motherwort	*Leonurus cardiaca*			
XXVIII, 599		Mountain-mint	*Pycnanthemum* sp. (*Koellia* sp.).			
		Mouse-ear (see Chickweed, big mouse-ear).				
XXX, 628		Mullein: Common; flannel	*Verbascum thapsus*			
		Muskmelon	*Cucumis melo*	82	124	
		Mustard	*Brassica* spp	83	119	
XVII, 319	235	Mustard: Black; Trieste	*Brassica nigra*	83	119	
XVII, 324	236	Mustard, blue	*Chorispora tenella*			
XVII, 316	235	Mustard: Brown; India	*Brassica juncea*	83	119	
XVII, 330		Mustard, hairy	*Hirschfeldia incana* (*Brassica adpressa*).			
XVII, 333	237	Mustard, perennial	*Lepidium latifolium*			
	235	Mustard, spinach	*Brassica perviridis*	83	119	
		Mustard, Trieste (see Mustard, black).				
	234	Mustard: White; yellow; white London.	*Brassica hirta* (*B. alba*)	83	119	
		Mustard, wild (see Charlock).				
X, 171*r*	226	Muttongrass	*Poa fendleriana*			
X, 171*q*	226	Muttongrass, longtongue	*Poa longiligula*			
		Napa thistle (see Star-thistle, Malta).				
VII, 150	223	Napier grass	*Pennisetum purpureum*	62	126	
XXVII, 566		Navarretia, needle-leaved	*Navarretia intertexta*			
		Neckweed (see Speedwell, purslane).				
XI, 195		Needlegrass, green	*Stipa viridula*			
XIII, 226		Nettle, stinging	*Urtica dioica*			
XXIX, 619		Nightshade, black	*Solanum nigrum*			
XXIX, 621		Nightshade: Cutleaf; three-flowered.	*Solanum triflorum*			
XXIX, 618		Nightshade: Silver-leaf; purple.	*Solanum elaeagnifolium*			
XXXIII, 714		Nipplewort	*Lapsana communis*			
V, 97		Nitgrass	*Gastridium ventricosum*			
XII, 207		Nutgrass	*Cyperus rotundus*			
XII, 206		Nutgrass, yellow	*Cyperus esculentus*			
	205	Oat	*Avena*			
II, 36	207	Oat, common or Northern	*Avena sativa*	57	126	35
II, 38	207	Oat, fatuoid (homozygous)	*Avena*			
II, 37	207	Oat, red or Southern	*Avena byzantina*	57	126	
II, 41	208	Oat, sand	*Avena strigosa*			
II, 40	207	Oat, slender	*Avena barbata*			
II, 39	207	Oat, wild	*Avena fatua*			

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Common name	Botanical name	Purity	Germination	
Plate	*Page*			*Page*	*Page*	*Figure*
III, 67-68	213	Oatgrass, poverty	*Danthonia spicata*			
II, 35	205	Oatgrass, tall	*Arrhenatherum elatius*	66	126	
		Okra	*Hibiscus esculentus*	81	164	60
		Onion	*Allium cepa*	82	160	57
XIII, 220		Onion, wild	*Allium vineale*			
XX, 408	248	Ononis, cammock	*Ononis repens*			
		Orach, halberd-leaved (see Fat-hen).				
XIV, 247		Orach, red	*Atriplex rosea*			
XIV, 248		Orach, wedgescale	*Atriplex truncata*			
III, 66	213	Orchard grass	*Dactylis glomerata*	60	126	
XXIII, 475		Oxalis, yellow	*Oxalis stricta*			
XXXII, 689		Ox-eye daisy	*Chrysanthemum leucanthemum.*			
XXXIII, 720		Oxtongue, bristly	*Picris echioides*			
	235	Pakchoi	*Brassica chinensis*	83	119	
VI, 122	221	Panicgrass, blue	*Panicum antidotale*	65	126	
	220	Panicum	*Panicum*			
VI, 121	221	Panicum, beaked	*Panicum anceps*			
VI, 123	221	Panicum, Berg	*Panicum bergii*			
		Panicum, blue (see Panicgrass, blue).				
VI, 128	221	Panicum, browntop (see footnote 1, p. 397).	*Panicum fasciculatum*	65	126	
		Panicum, fall (see Witchgrass, spreading).				
		Panicum, Gattinger (see Witchgrass, Gattinger).				
VI, 131	221	Panicum, hairy	*Panicum huachucae*			
VI, 130	221	Panicum, Hillman	*Panicum hillmani*			
		Panicum, spreading (see Witchgrass, spreading).				
VI, 137	221	Panicum, Texas	*Panicum texanum*			
XXIV, 505		Pansy, wild	*Viola tricolor*			
VI, 135	221	Para grass	*Panicum purpurascens*			
XXVI, 537		Parsley	*Petroselinum hortense* (*P. crispum*).	80	167	
		Parsnip	*Pastinaca sativa*	80	167	
	222	Paspalum	*Paspalum*			
VII, 146	222	Paspalum, brownseed	*Paspalum plicatulum*			
VII, 139	222	Paspalum, bull	*Paspalum boscianum*			
VII, 143	222	Paspalum, field	*Paspalum laeve*			
VII, 142	222	Paspalum, Florida	*Paspalum floridanum*			
VII, 144	223	Paspalum, ribbed	*Paspalum malacophyllum*			
VII, 147	222	Paspalum, slender	*Paspalum setaceum*			
XXI, 412	249	Pea, field	*Pisum sativum arvense*	73	142	48, 49
		Pea, garden	*Pisum sativum*	73	142	
		Peanut	*Arachis hypogaea*	73	142	
VII, 149	223	Pearl millet	*Pennisetum glaucum*	62	126	
XXI, 417	250	Peaweed, Austrian	*Swainsona salsula*			
	223	Pennisetum	*Pennisetum*			
XVIII, 344		Pennycress	*Thlaspi arvense*			
XXVIII, 590		Pennyroyal, American	*Hedeoma pulegioides*			
		Pepper	*Capsicum* sp	80	167	
XVII, 331	236	Peppercress, field	*Lepidium campestre*			
XVII, 322	235	Peppercress, hoary	*Cardaria draba* (*Lepidium draba*).			
	235	Peppercress, lens	*Cardaria draba* var. *repens*			
		Peppercress, perennial (see Mustard, perennial).				
XVII, 334		Peppergrass, American	*Lepidium virginicum*			

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Common name	Botanical name	Purity	Germination	
Plate	*Page*			*Page*	*Page*	*Figure*
		Peppergrass, field (see Pepperecress, field).				
XVII, 332		Peppergrass, prairie	*Lepidium densiflorum*			
		Peppergrass, Virginia (see Peppergrass, American).				
		Perennial mustard (see Mustard, perennial).				
	235	Pe-tsai (Chinese cabbage)	*Brassica pekinensis*	83	119	
XXVI, 541		Pimpernel, scarlet	*Anagallis arvensis*			
XXVI, 538		Pimpinella, saxifrage	*Pimpinella saxifraga*			
XXX, 634		Plantain: Blackseed; Rugel's; rattail.	*Plantago rugelii*			
XXX, 644		Plantain, blond	*Plantago ovata*			
XXX, 638		Plantain, branching	*Plantago arenaria*			
XXX, 636		Plantain: Bracted; bottlebrush.	*Plantago aristata*			
XXX, 639		Plantain: Buckhorn; narrowleaved; English; ribgrass.	*Plantago lanceolata*			
XXX, 643		Plantain, crowfoot	*Plantago coronopus*			
XXX, 635		Plantain: Paleseed; dwarf	*Plantago virginica*			
XXX, 637		Plantain: Psyllium; fleaseed	*Plantago psyllium*			
XXX, 640		Plantain, redseed	*Plantago rhodosperma*			
XXX, 633		Plantain: Ripplesced; broadleaved.	*Plantago major*			
XXX, 641		Plantain, slender	*Plantago pusilla* (*P. elongata*).			
XXXI, 674		Plumeless thistle	*Carduus acanthoides*			
XXXI, 675		Plumeless thistle, largeheaded.	*Carduus macrocephalus*			
XXVI, 534		Poison hemlock	*Conium maculatum*			
		Poison ryegrass (see Darnel)				
XXVI, 551		Ponyfoot, creeping	*Dichondra repens*			
XXVIII, 580		Popcorn flower	*Plagiobothrys* sp.			
XVI, 307		Poppy, opium	*Papaver somniferum*			
I, 24	204	Poverty-grass, three-awn	*Aristida dichotoma*			
		Povertyweed (see Sumpweed, poverty)				
		Prairie-rocket (see Rough blistercress).				
XXXIII, 722		Prairie-coneflower	*Ratibida columnaris*			
XX, 393	245	Prairie-trefoil	*Lotus purshianus* (*L. americanus*).			
VI, 133	222	Proso; broomcorn millet	*Panicum miliaceum*	65	126	
		Pumpkin	*Cucurbita pepo*	82	124	
XXIII, 478		Puncturevine	*Tribulus terrestris*			
XII, 199		Purpletop	*Tridens flavus*			
		Pursh seepweed (see Seablite).				
XV, 272		Purslane, common	*Portulaca oleracea*			
I, 9	201	Quackgrass	*Agropyron repens*			
		Queen Anne's-lace (see Carrot, wild).				
VII, 157		Rabbitfoot grass	*Polypogon monspeliensis*			
XVII, 337		Radish	*Raphanus sativus*	83	119	32, 33
XVII, 336		Radish, wild	*Raphanus raphanistrum*			
		Ragi (see African millet)				
		Ragweed	*Ambrosia*	51		
XXXI, 665		Ragweed, giant	*Ambrosia trifida*			
XXXI, 663		Ragweed, common	*Ambrosia artemisiifolia* (*A. elatior*).			
XXXI, 664		Ragweed: Western; perennial.	*Ambrosia psilostachya*			

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Common name	Botanical name	Purity	Germination	
Plate	*Page*			*Page*	*Page*	*Figure*
XXXIV, 724		Ragwort, tansy	*Senecio jacobaea*			
	234	Rape, summer	*Brassica napus* var. *annua*	83	119	
XVII, 318	234	Rape, winter	*Brassica napus* var. *biennis*	83	119	
XIX, 374	240	Rattlebox	*Daubentonia texana*			
		Redscale (see Orach, red)				
I, 1	197	Redtop	*Agrostis alba*	55	126	
III, 56	210	Rescue grass	*Bromus catharticus*	59	126	
III, 60	212	Rhodes grass	*Chloris gayana*	66	126	
		Rhubarb	*Rheum rhaponticum*	81	167	
		Ribgrass; ribwort (see Plantain, buckhorn).				
V, 117		Rice	*Oryza sativa*	62	126	38
		Rice, red	*Oryza sativa* var	63		
V, 118		Ricegrass, Indian	*Oryzopsis hymenoides*	65	126	
XIV, 261		Ringwing	*Cycloloma atriplicifolium*			
	211	Ripgut grass	*Bromus rigidus*			
XVI, 308		Roemeria poppy	*Roemeria refracta*			
XVIII, 349		Rose	*Rosa* sp			
XVII, 327		Rough blistercress	*Erysimum asperum*			
XIX, 382	243	Rough pea	*Lathyrus hirsutus*	74	142	
XIV, 267*a*		Rough pigweed	*Amaranthus retroflexus*			
		Rushgrass (see Dropseed, scratch).				
XII, 219		Rush, path	*Juncus tenuis*			
XIX, 379	241	Rushpea	*Hoffmannseggia* sp			
XIV, 249		Russian pigweed	*Axyris amaranthoides*			
XIV, 266		Russian-thistle	*Salsola kali* var. *tenuifolia* (*S. pestifer*).			
	234	Rutabaga; Swede turnip	*Brassica napus* var. *napobrassica*.	83	119	
XI, 184		Rye	*Secale cereale*	62	126	36, 37
	219	Ryegrass	*Lolium* spp	64	126	
V, 111	220	Ryegrass, Italian	*Lolium multiflorum*	64	126	
V, 110	220	Ryegrass, perennial; English ryegrass.	*Lolium perenne*	64	126	
V, 112	220	Ryegrass, Persian	*Lolium persicum*			
		Ryegrass, poison (see Darnel).				
	220	Ryegrass, Wimmera	*Lolium rigidum*			
XXXII, 677		Safflower	*Carthamus tinctorius*			
XXVIII, 600		Sage, lanceleaf	*Salvia lanceolata*			
XXVIII, 601		Sage, lilac	*Salvia verticillata*			
XX, 407	248	Sainfoin	*Onobrychis viciaefolia*	74	142	
XVII, 326	236	Salad-rocket	*Eruca sativa*			
		Salsify	*Tragopogon porrifolius*	84	113	
XXXIV, 733		Salsify, meadow	*Tragopogon pratensis*			
		Saltbush (see Orach, wedgescale).				
	214	Saltgrass	*Distichlis*			
III, 71	214	Saltgrass: Desert; inland	*Distichlis stricta*			
III, 72	214	Saltgrass, seashore	*Distichlis spicata*			
		Sandbrier (see Horsenettle, Carolina).				
III, 63	211	Sandbur, field	*Cenchrus pauciflorus*			
		Sandvine (see Milkweed, climbing).				
XV, 276		Sandwort, thymeleaf	*Arenaria serpyllifolia*			
XXVIII, 603		Savory, catnip	*Satureja nepeta*			
XXVIII, 602		Savory, spring	*Satureja acinos*			
		Savory, wild basil (see Basil).				
XXXI, 658		Scabiosa	*Scabiosa* sp			

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Common name	Botanical name	Purity	Germination	
Plate	*Page*			*Page*	*Page*	*Figure*
XXXI, 657		Scabiosa, field	*Scabiosa arvensis*			
		Scaleweed (see Pennycress)				
XXVII, 569		Scorpionweed	*Allocarya* sp			
XIV, 262		Sea-blite	*Suaeda depressa* (*Dondia depressa*).			
XVI, 306		Sea-poppy	*Glaucium corniculatum*			
XII, 204		Sedge	*Carex festucacea*			
XII, 205		Sedge, hairyseed	*Carex trichocarpa*			
XXV, 517		Seedbox	*Ludwigia alternifolia*			
		Seepweed, Pursh (see Sea-blite).				
		Selfheal (see Heal-all)				
XIX, 364	239	Sensitive-pea	*Cassia nictitans*			
XX, 409	248	Serradella	*Ornithopus sativus*			
XXX, 632		Sesame	*Sesamum orientale*			
XXI, 414	249	Sesbania	*Sesbania exaltata*	74	142	
XIX, 365	239	Sicklepod	*Cassia tora*			
XXVI, 536		Sickleweed	*Falcaria rivini*			
		Sida, spiny (see Mallow, prickly).				
		Sidalcea, meadow (see Checsemallow, plains).				
		Singletary pea (see Rough pea).				
XXXII, 688		Skeleton weed	*Chondrilla juncea*			
XXVII, 567		Skunkweed	*Navarretia squarrosa*			
II, 44	208	Sloughgrass, American	*Beckmannia syzigachne*			
XIII, 231		Smartweed, common	*Polygonum hydropiper*			
		Smartweed, pale (see Ladysthumb, pale).				
		Smartweed, Pennsylvania (see Ladysthumb, bigseed).				
		Smartweed, spotted (see Ladysthumb).				
V, 119		Smilo	*Oryzopsis miliacea*	65	126	
XXX, 651		Snowberry, Western	*Symphoricarpos occidentalis.*			
XXIV, 486		Snow-on-the-mountain	*Euphorbia marginata*			
V, 103		Soft grass	*Holcus mollis*			
XI, 188-193	230	Sorghum	*Sorghum vulgare*	70	126	41, 42
XI, 187		Sorghum-Sudan hybrids				
XIII, 235		Sorrel, garden	*Rumex acetosa*	81	167	
XIII, 236		Sorrel: Sheep; field; red	*Rumex acetosella*			
XXXIV, 728		Sowthistle, common	*Sonchus oleraceus*			
XXXIV, 726		Sowthistle: Perennial; creeping.	*Sonchus arvensis*			
XXXIV, 727		Sowthistle: Spiny; prickly	*Sonchus asper*			
XIX, 377	241	Soybean	*Glycine max*	73	142	50
XXVIII, 581		Spatulate fog-fruit	*Lippia nodiflora*			
XXX, 630		Speedwell, corn	*Veronica arvensis*			
XXX, 629		Speedwell, field	*Veronica agrestis*			
XXX, 631		Speedwell, purslane	*Veronica peregrina*			
XV, 269		Spiderling	*Boerhaavia erecta*			
XII, 216		Spiderwort, Virginia	*Tradescantia virginiana*			
		Spike redtop (see Bentgrass, spike).				
XII, 210		Spikerush, autumn	*Fimbristylis autumnalis*			
XII, 211		Spikerush, Baldwin	*Fimbristylis baldwiniana*			
XII, 208		Spikerush, blunt	*Eleocharis obtusa*			
XII, 209		Spikerush, slender	*Eleocharis tenuis*			
XXXII, 687		Spikeweed	*Centromadia* sp			
		Spinach, common	*Spinacia oleracea*	84	107	26

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Common name	Botanical name	Purity	Germination	
Plate	*Page*			*Page*	*Page*	*Figure*
		Spinach, New Zealand	*Tetragonia expansa*	84	107	
XV, 268		Spreading pigweed	*Amaranthus graecizans*			
XXIII, 482		Spurge, flowering	*Euphorbia corollata*			
XXIII, 483		Spurge, leafy	*Euphorbia esula*			
XXIV, 487		Spurge, nodding	*Euphorbia nutans*			
XXIV, 488		Spurge, spotted	*Euphorbia supina* (*E. maculata*).			
XXIV, 485		Spurge, sun	*Euphorbia helioscopia*			
XXIV, 484		Spurge, toothed	*Euphorbia dentata*			
XVI, 292		Spurry, corn	*Spergula arvensis*			
XVI, 293		Spurry, wingseed	*Spergula pentandra*			
		Squash	*Cucurbita moschata*	82	124	
			C. maxima	82	124	
XXXII, 680		Star-thistle, Iberian	*Centaurea iberica*			
XXXII, 683		Star-thistle, Malta	*Centaurea melitensis*			
XXXII, 678		Star-thistle, purple	*Centaurea calcitrapa*			
XXXII, 685		Star-thistle, scabiosa	*Centaurea scabiosa*			
		Star-thistle, spotted (see Knapweed, spotted).				
XXXII, 686		Star-thistle, yellow	*Centaurea solstitialis*			
XV, 274		Starwort, little	*Stellaria graminea* (*Alsine graminea*)			
XXVII, 576		Stickseed, European	*Lappula echinata*			
XXVII, 577		Stickseed: Western; hairy	*Lappula occidentalis*			
IV, 86	216	Stinkgrass	*Eragrostis cilianensis*			
		Stinkweed (see Pennycress)				
XXIV, 504		St. Johnswort	*Hypericum perforatum*			
XXIX, 622		"Stone cells" in Solanum fruits.				
XVIII, 348		Strawberryweed	*Potentilla monspeliensis*			
XI, 186	230	Sudan grass: Common; sweet; Tift.	*Sorghum sudanense*	70	126	
XIX, 378	241	Sulla	*Hedysarum coronarium*			
XIV, 264		Summer cypress	*Kochia scoparia*			
XXXIII, 710		Sumpweed, bigleaf	*Iva xanthifolia*			
XXXIII, 708		Sumpweed, poverty	*Iva axillaris*			
XXXIII, 709		Sumpweed, rough	*Iva ciliata*			
XXXIII, 702		Sunflower, common	*Helianthus annuus*	84	113	
	247	Sweetclover	*Melilotus*			
XX, 404	247	Sweetclover, white-blossom	*Melilotus alba*	75	142	
XX, 405	247	Sweetclover, yellow-blossom	*Melilotus officinalis*	75	142	
		Swine-cress (see Wart-cress).				
		Swiss chard	*Beta vulgaris* var. *cicla*	84	107	
VI, 138	222	Switch grass	*Panicum virgatum*	65	126	
		Tall hedge mustard (see Tumblemustard).				
		Tall indigo (see Sesbania)				
XIX, 384	243	Tangier pea	*Lathyrus tingitanus*			
XXXIV, 729		Tansy, common	*Tanacetum vulgare*			
	237	Tansy mustard	*Sisymbrium irio*			
XXXIV, 724		Tansy ragwort	*Senecio jacobaea*			
XXXIII, 718		Tarweed, Chilean	*Madia sativa*			
XXXIII, 717		Tarweed, cluster	*Madia glomerata*			
XXXIII, 704		Tarweed, hay-field	*Hemizonia luzulaefolia*			
XXXI, 656		Teasel, wild	*Dipsacus sylvestris*			
	216	Teff	*Eragrostis tef*			
		Texas-millet (see Panicum, Texas).				
XXXII, 692		Thistle, bull	*Cirsium vulgare* (*C. lanceolatum*).			
XXXII, 691		Thistle, Canada	*Cirsium arvense*			
XXXI, 673		Thistle, curly	*Carduus crispus*			

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Common name	Botanical name	Purity	Germination	
Plate	*Page*			*Page*	*Page*	*Figure*
XXXII, 676		Thistle, Italian	*Carduus pycnocephalus*			
		Thistle, Turkistan (see Knapweed, Russian).				
		Thorn-apple (see Jimsonweed).				
XXV, 529		Thoroughwax, roundleaf	*Bupleurum rotundifolium*			
I, 24	204	Three-awn, poverty	*Aristida dichotoma*			
XXIII, 479		Three-seeded mereury	*Acalypha virginica*			
I, 8	198	Ticklegrass	*Agrostis scabra*			
XIV, 259		Tickseed	*Corispermum hyssopifolium.*			
XIV, 260		Tickseed, hairy	*Corispermum villosum*			
		Tievine (see Bindweed, field).				
V, 120		Timothy	*Phleum pratense*	66	126	43
		Tipton-weed (see St. Johnswort).				
XXIX, 624		Toadflax, roundleaf	*Kickxia spuria*			
		Toadflax, yellow (see Butter-and-eggs).				
		Tocalote (see Star-thistle, Malta).				
		Tomato, common	*Lycopersicon esculentum*	80	167	62
		Tomato, husk	*Physalis pubescens*	80	167	
XXV, 523		Toothpick plant	*Ammi visnaga*			
XVI, 311		Towermustard	*Arabis glabra*			
XVII, 328		Treacle-mustard	*Erysimum cheiranthoides*			
	245	Trefoil	*Lotus*			
XX, 394	245	Trefoil, big	*Lotus uliginosus* var. *villosus.*			
XX, 395	245	Trefoil, big	*Lotus uliginosus* var. *glabrisculus.*			
XX, 391	245	Trefoil, birdsfoot	*Lotus corniculatus*	75	142	54, 55
XX, 393	245	Trefoil, prairie	*Lotus purshianus*			
	254	Trigonella	*Trigonella*			
XII, 200		Trisetum, yellow	*Trisetum flavescens*			
		Trompillo (see Nightshade, silverleaf).				
VII, 158		Tumblegrass	*Schedonnardus paniculatus*			
XVIII, 341		Tumblemustard	*Sisymbrium altissimum*			
XIV, 267b		Tumbling pigweed	*Amaranthus albus*			
XXIII, 481		Turkey mullein	*Eremocarpus setigerus*			
		Turkistan thistle (see Knapweed, Russian).				
XVI, 315	235	Turnip; turnip-rape; wild turnip.	*Brassica campestris* or *B. rapa.*	83	119	
V, 116	220	Tussack grass	*Nassella trichotoma*			
VII, 148	222	Vasey grass	*Paspalum urvillei*	58	126	
XXI, 415	249	Velvetbean; Florida velvetbean.	*Stizolobium deeringianum*	73	142	
V, 103		Velvetgrass, German	*Holcus mollis*			
V, 102		Velvetgrass	*Holcus lanatus*	66	126	
XXIV, 489		Velvet-leaf	*Abutilon theophrasti*			
XXXI, 659		Venus's-looking-glass	*Specularia perfoliata*			
	203	Vernalgrass	*Anthoxanthum*			
	204	Vernalgrass, annual	*Anthoxanthum aristatum*			
II, 33	204	Vernalgrass, sweet	*Anthoxanthum odoratum*	66	126	
XXVIII, 583		Vervain	*Verbena officinalis*			
XXVIII, 582		Vervain, blue	*Verbena hastata*			
XXVIII, 584		Vervain, hoary	*Verbena stricta*			
XXVIII, 585		Vervain, white	*Verbena urticaefolia*			

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Common name	Botanical name	Purity	Germination	
Plate	*Page*			*Page*	*Page*	*Figure*
	255	Vetch	*Vicia* spp			
	257	Vetch, American	*Vicia americana*			
XXIII, 460	257	Vetch, bird	*Vicia cracca*			
XXIII, 462	257	Vetch, common	*Vicia sativa*	79	142	
		Vetch, cow (see Vetch, bird)				
XXII, 454	257	Vetch, fourseed	*Vicia tetrasperma*			
XXIII, 465	257	Vetch, hairy	*Vicia villosa*	79	142	
XXII, 455	256	Vetch, Hungarian	*Vicia pannonica*	79	142	
	257	Vetch, Monantha	*Vicia articulata* (*V. monantha*).	79	142	
XXIII, 463–464	257	Vetch, narrowleaf	*Vicia angustifolia*	79	142	
XXII, 459	257	Vetch, purple	*Vicia atropurpurea*	79	142	
XXIII, 461	257	Vetch, showy	*Vicia grandiflora*			
XXII, 453	257	Vetch, tiny	*Vicia hirsuta*			
XXIII, 466	257	Vetch, woollypod	*Vicia dasycarpa*	79	142	
XXII, 457	256	Vetch, yellow	*Vicia lutea*			
	242	Vetchling	*Lathyrus*			
	243	Vetchling	*Lathyrus pusillus*			
		Vetchling (see Groundnut pea).				
	243	Vetchling, low	*Lathyrus pusillus*			
	243	Vetchling, slender	*Lathyrus stipularis*			
XIX, 381	242	Vetchling yellow	*Lathyrus aphaca*			
VI, 134	222	Vine-mesquite	*Panicum obtusum*			
		Wallflower, western (see Rough blistercress).				
	236	Wart-cress; swine's-cress	*Coronopus didymus*			
XXVI, 533		Water-hemlock, spotted	*Cicuta maculata*			
		Watermelon	*Citrullus vulgaris*	82	124	
		Western bluestem (see Wheatgrass, Western).				
XII, 201		Wheat (Common; club; Polish, including spelt and emmer).	*Triticum* spp	62	126	
	198	Wheatgrass	*Agropyron* spp			
	200	Wheatgrass, bearded	*Agropyron subsecundum*			
	201	Wheatgrass, beardless	*Agropyron inerme*			
I, 13	200	Wheatgrass, Fairway crested	*Agropyron cristatum*	55	126	
I, 16	200	Wheatgrass, hairy intermediate.	*Agropyron trichophorum*			
	200	Wheatgrass, hairy western	*Agropyron smithii* var. *molle*.			
I, 15	201	Wheatgrass, intermediate (including Ree wheatgrass).	*Agropyron intermedium*			
		Wheatgrass, pubescent (see Wheatgrass, hairy intermediate).				
I, 11	200	Wheatgrass, slender	*Agropyron trachycaulum* (*A. pauciflorum*).	55	126	
I, 14	200	Wheatgrass, standard crested	*Agropyron desertorum* (formerly *A. cristatum*)	55	126	
	200	Wheatgrass, streambank	*Agropyron riparium*			
I, 12	201	Wheatgrass, tall	*Agropyron elongatum*			
	200	Wheatgrass, thickspike	*Agropyron dasystachyum*			
I, 10	201	Wheatgrass, Western	*Agropyron smithii*	55	126	
XV, 279	232	White cockle; white campion	*Lychnis alba*			
XXVIII, 594		White horehound	*Marrubium vulgare*			
		White horsenettle (see Nightshade, silver-leaf).				

INDEX FOR IDENTIFICATION, PURITY, AND GERMINATION—Continued

Identification		Common name	Botanical name	Purity	Germination	
Plate	*Page*			*Page*	*Page*	*Figure*
		White-leaved povertyweed (see Bur-sage, skeleton-leaf).				
XVII, 322, 323	235	Whitetop (see also: Hoary cress; Perennial pepper-cress; Daisy fleabane).	*Cardaria*			
XXV, 524		Wild chervil	*Anthriscus sylvestris*			
		Wild flax (see Falsefiax, big seed).				
XV, 270		Wild four-o'clock	*Mirabilis nyctaginea*			
		Wild madder (see Bedstraw, white).				
XXVI, 554	258	Wild potato vine	*Ipomoea pandurata*			
	214	Wild-rye	*Elymus* spp			
	215	Wild-rye, beardless	*Elymus triticoides*			
IV, 82	215	Wild-rye, blue	*Elymus glaucus*			
IV, 81	215	Wild-rye, Canada	*Elymus canadensis*	55	126	
	215	Wild-rye, riverbank	*Elymus riparius*			
IV, 83	215	Wild-rye, Russian	*Elymus junceus*			
IV, 84	215	Wild-rye, Virginia	*Elymus virginicus*			
		Willow-herb	*Epilobium* spp	56		
II, 34	204	Windgrass	*Apera spica-venti*			
III, 59	212	Windmill grass	*Chloris acicularis*			
		Winged pigweed (see Ringwing).				
XVI, 313		Wintercress, common	*Barbarea vulgaris*			
XVI, 312		Wintercress, early	*Barbarea verna*			
VII, 141	222	Wiregrass	*Paspalum distichum*			
		Witchgrass (see Quackgrass)				
VI, 125	221	Witchgrass, common	*Panicum capillare*			
V, 109	219	Witchgrass, fall	*Leptoloma cognatum*			
VI, 129	221	Witchgrass, Gattinger	*Panicum gattingeri*			
VI, 127	221	Witchgrass, spreading	*Panicum dichotomiflorum*			
VI, 126	221	Witchgrass, western	*Panicum capillare* var. *occidentale*.			
		Wolfberry (see Snowberry, Western).				
		Wood meadow grass (see Bluegrass, wood).				
XII, 217		Woodrush, field	*Luzula campestris*			
XII, 218		Woodrush, grove	*Luzula luzuloides*			
XXIII, 475		Wood sorrel; yellow wood sorrel.	*Oxalis stricta*			
		Wormseed mustard (see Treacle-mustard).				
		Woundwort (see Betony, marsh).				
XXXI, 661		Yarrow	*Achillea millefolium*			
XVIII, 340	237	Yellowcress, creeping	*Rorippa sylvestris*			
X, 175	229	Yellow foxtail	*Setaria lutescens*			
		Yellow hop-clover (see Clover, yellow).				
XIX, 381	242	Yellow pea	*Lathyrus aphaca*			
		Yellow rocket (see Wintercress, common).				
		Yellow trefoil (see Medic, black).				
		Yorkshire fog (see Velvetgrass).				
XII, 202, 203	231	Zoysia	*Zoysia*	65	126	

LIST OF BOTANICAL AND COMMON NAMES

This list gives the common name equivalents for certain species illustrated in the seed plates, but not included in the keys and descriptions. The common names of other species included in the lists of botanical and plant names, beginning on pages 373 and 395, respectively, may be found under the heading "Identification of Seeds," pages 194 to 261.

Botanical Name	*Common Name*
Abutilon theophrasti	Velvet-leaf
Acalypha virginica	Three-seeded mercury
Achillea millefolium	Yarrow
Achyrachaena mollis	Blowwives
Aethusa cynapium	Fool's parsley
Agrostemma githago	Corncockle
Ajuga chamaepitys	Ground bugle
Allium vineale	Wild garlic
Allocarya sp.	Scorpionweed
Althaea hirsuta	No common name
Alyssum alyssoides	Pale alyssum
Amaranthus albus	Rough pigweed
Amaranthus graecizans	Spreading pigweed
Amaranthus retroflexus	Redroot amaranth
Ambrosia artemisiifolia	Common ragweed
Ambrosia psilostachya	Perennial ragweed
Ambrosia trifida	Giant ragweed
Ammi majus	Greater ammi
Ammi visnaga	Toothpick plant
Amsinckia intermedia	Coast fiddleneck
Amsinckia tesselata	Fiddleneck
Anagallis arvensis	Scarlet pimpernel
Anemone canadensis	Meadow anemone
Anthemis arvensis	Corn-chamomile
Anthemis cotula	Dogfennel
Anthemis tinctoria	Yellow chamomile
Anthriscus sylvestris	Wild chervil
Apium ammi	Wild celery
Apium segetum	No common name
Aplopappus ciliatus	Hairy goldenweed
Apocynum androsaemifolium	Spreading dogbane
Apocynum cannabinum	Hemp dogbane
Arabis glabra	Towermustard
Arctium lappa	Great burdock
Arenaria serpyllifolia	Thymeleaf sandwort
Arnoseris minima	Lamb-succory
Asclepias galioides	Whorled milkweed
Asclepias mexicana	Mexican milkweed
Asclepias syriaca	Common milkweed
Asclepias tuberosa	Butterflyweed
Asperugo procumbens	German madwort
Atriplex patula var. *hastata*	Fat-hen
Atriplex rosea	Red orach
Atriplex truncata	Wedgescale orach

Botanical Name	*Common Name*
Axyris amaranthoides	Russian pigweed
Ballota nigra	Black horehound
Barbarea verna	Early wintercress
Barbarea vulgaris	Bitter wintercress
Bassia hyssopifolia	Five-hook bassia
Berteroa incana	Hoary alyssum
Boerhaavia erecta	Spiderling
Boisduvalia densiflora	Dense-flowered Boisduvalia
Boisduvalia stricta	Stricta Boisduvalia
Brauneria angustifolia	Purple coneflower
Brodiaea coronaria	Harvest brodiaea
Brodiaea grandiflora	Large-flowered brodiaea
Bunium bulbocastrum	Earthnut
Bupleurum protractum	Thoroughwax
Bupleurum rotundifolium	Roundleaf thoroughwax
Bupleurum tenuissimum	Thoroughwax
Camelina microcarpa	Littleseed falseflax
Camelina sativa	Bigseed falseflax
Cannabis sativa	Hemp
Caperonia palustris	No common name
Carduus acanthoides	Plumeless thistle
Carduus crispus	Curly thistle
Carduus macrocephalus	Large-headed plumeless thistle
Carduus pycnocephalus	Italian thistle
Carex festucacea	Sedge
Carex trichocarpa	Hairyseed sedge
Carthamus tinctorius	Safflower
Carum carvi	Caraway
Centaurea calcitrapa	Purple star-thistle
Centaurea cyanus	Bachelor's-button
Centaurea iberica	Iberian star-thistle
Centaurea jacea	Brownscale knapweed
Centaurea maculosa	Spotted knapweed
Centaurea melitensis	Malta star-thistle
Centaurea picris	Russian-thistle
Centaurea scabiosa	Scabiosa star-thisle
Centaurea solstitialis	Yellow star-thistle
Centromadia sp.	Spikeweed
Cephalaria transylvanica	Cephalaria
Cerastium vulgatum	Big mouse-ear chickweed
Chaerophyllum sp.	Chervil
Chenopodium album	Lambsquarters
Chenopodium berlandieri	Pitseed goosefoot
Chenopodium hircinum	No common name
Chenopodium hybridum	Mapleleaf goosefoot
Chenopodium hybridum var. *gigantospermum*	Bigseed goosefoot
Chenopodium leptophyllum	Narrowleaf goosefoot
Chenopodium murale	Nettleleaf goosefoot
Chenopodium rubrum	Red goosefoot
Chondrilla juncea	Skeletonweed
Chrysanthemum leucanthemum var. *pinnatifidum.*	Ox-eye daisy
Cichorium intybus	Chicory
Cicuta maculata	Spotted waterhemlock
Cirsium arvense	Canada thistle
Cirsium vulgare	Bull thistle
Collomia gracilis	Gilia
Collomia grandiflora	Bigflower gilia
Commelina communis	Common dayflower
Conium maculatum	Poisonhemlock
Corispermum hyssopifolium	Tickseed
Corispermum villosum	Hairy tickseed
Crepis capillaris	Smooth hawksbeard
Crepis setosa	Hairy hawksbeard

Botanical Name	*Common Name*
Cycloloma atriplicifolium	Ringwing
Cynodon dactylon	Bermuda grass
Cyperus esculentus	Yellow nutgrass
Cyperus rotundus	Nutgrass
Datura stramonium	Jimsonweed
Daucus carota	Carrot; wild carrot
Delphinium consolida	Field larkspur
Delphinium menziesii	Menzies larkspur
Dianthus armeria	Deptford pink
Dichondra repens	Ponyfoot
Digitaria filiformis	Slender crabgrass
Digitaria ischaemum	Smooth crabgrass
Digitaria sanguinalis	Large crabgrass
Diodia teres	Rough buttonweed
Diodia virginiana	Virginia buttonweed
Dipsacus sylvestris	Wild teasel
Echium vulgare	Blueweed
Eleocharis obtusa	Blunt spikerush
Eleocharis tenuis	Slender spikerush
Eleusine coracana	African millet
Eleusine indica	Goosegrass
Erechtites hieracifolia	Burnweed
Erechtites prenanthoides	Australian burnweed
Eremocarpus setigerus	Turkey mullein
Ercmochloa ophiuroides	Centipede grass
Erigeron annuus	Daisy fleabane
Erigeron canadensis	Horseweed
Eriochloa punctata	Louisiana cupgrass
Erodium cicutarium	Alfilaria
Erysimum asperum	Rough blistercress
Erysimum cheiranthoides	Treacle-mustard
Erysimum inconspicuum	Smallflower Erysimum
Eschscholtzia californica	California-poppy
Euphorbia corollata	Flowering spurge
Euphorbia dentata	Toothed spurge
Euphorbia esula	Leafy spurge
Euphorbia helioscopia	Sun spurge
Euphorbia marginata	Snow-on-the-mountain
Euphorbia nutans	Nodding spurge
Euphorbia supina	Spotted spurge
Euphrasia sp.	Eyebright
Falcaria rivini	Sickleweed
Fimbristylis autumnalis	Autumn spikerush
Fimbristylis baldwiniana	Baldwin spikerush
Franseria discolor	Skeletonleaf bur-sage
Franseria tenuifolia	Slimweed bur-sage
Fumaria officinalis	Common fumitory
Galega officinalis	Common goatsrue
Galeopsis ladanum	Red hempnettle
Galeopsis tetrahit	Bristlestem hempnettle
Galinsoga parviflora	Galinsoga
Galium aparine	Cleavers
Galium mollugo	White bedstraw
Gastridium ventricosum	Nitgrass
Gaura coccinea	Scarlet gaura
Gaura odorata	Scented gaura
Gaura sinuata	Wavyleaved gaura
Gaura villosa	Hairy gaura
Geranium carolinianum	Carolina cranesbill
Geranium columbinum	Longstalk cranesbill
Geranium dissectum	Cutleaf cranesbill
Geranium molle	Dovefoot cranesbill
Geranium pusillum	Small cranesbill
Geum sp.	Avens
Gilia capitata	Globe gilia

Botanical Name	*Common Name*
Glaucium corniculatum	Sea-poppy
Glyceria fluitans	Mannagrass
Glyceria grandis	American mannagrass
Glyceria striata	Fowl mannagrass
Godetia tenella	Godetia
Gonolobus laevis	Climbing milkweed
Grindelia squarrosa	Curleycup gumweed
Hackelochloa granularis	Lizard-tail
Halogeton glomeratus	Halogeton
Hedeoma pulegioides	American pennyroyal
Helianthus annuus	Common sunflower; wild sunflower.
Helianthus ciliaris	Texas blueweed
Heliotropium curassavicum	Salt heliotrope
Heliotropium europaeum	European heliotrope
Hemizonia luzulaefolia	Hay-field tarweed
Heterotheca grandiflora	No common name
Hibiscus trionum	Flower-of-an-hour
Hieracium aurantiacum	Orange hawkweed
Hirschfeldia incana	Hairy mustard
Holcus lanatus	Velvetgrass
Holcus mollis	German velvetgrass
Houstonia purpurea	Purple bluets
Hyoscyamus niger	Black henbane
Hypericum perforatum	St. Johnswort
Hypochaeris radicata	Spotted cats-ear
Iva axillaris	Poverty sumpweed
Iva ciliata	Rough sumpweed
Iva xanthifolia	Bigleaf sumpweed
Juncus tenuis	Path rush
Kickxia spuria	Roundleaf toadflax
Kochia scoparia	Summer cypress
Kyllinga sp.	Kyllinga
Lactuca canadensis	Tall lettuce
Lactuca pulchella	Blue lettuce
Lactuca scariola var. *integrifolia*	Prickly lettuce
Lamium amplexicaule	Henbit
Lappula echinata	European stickseed
Lappula occidentalis	Western stickseed
Lapsana communis	Nipplewort
Leontodon autumnalis	Fall-dandelion
Leontodon nudicaulis	Rough hawkbit
Leonurus cardiaca	Motherwort
Lepidium densiflorum	Prairie peppergrass
Lepidium virginicum	American peppergrass
Linaria vulgaris	Butter-and-eggs
Linum usitatissimum	Flax
Linum virginianum	Woodland flax
Lippia nodiflora	Spatulate fog-fruit
Lithospermum arvense	Field gromwell
Lobelia inflata	Indian-tobacco
Ludwigia alterniflora	Seedbox
Luzula campestris	Field woodrush
Luzula luzuloides	Grove woodrush
Lycopus virginicus	American bugleweed
Lythrum hyssopifolia	Hyssop loosestrife
Madia glomerata	Cluster tarweed
Madia sativa	Chilean tarweed
Malva moschata	Musk mallow
Malva parviflora	Little mallow
Malva rotundifolia	Running mallow
Malva sylvestris	High mallow

Botanical Name	*Common Name*
Malvastrum coromandelianum	No common name
Marrubium vulgare	White horehound
Matricaria inodora	False-camomile
Melampyrum arvense	Cow wheat
Melinis minutiflora	Molasses grass
Melochia corchorifolia	No common name
Mentha arvensis	Field mint
Mentzelia albicaulis	Whitestem Mentzelia
Mentzelia dispersa	Bushy Mentzelia
Mentzelia nuda	Bractless Mentzelia
Mirabilis nyctaginea	Wild four-o'clock
Moldavica parviflora	American dragonhead
Molinia caerulea	Moorgrass
Muscari comosum	Tassel grape-hyacinth
Myosotis arvensis	Forget-me-not
Navarretia intertexta	Needleleaved Navarretia
Navarretia squarrosa	Skunkweed
Nepeta cataria	Catnip
Neslia paniculata	Ball mustard
Nigella damescena	Love-in-a-mist
Nigella sativa	Garden fennelflower
Oenothera biennis	Evening-primrose
Oenothera laciniata	Cutleaf evening-primrose
Oenothera parodiana	No common name
Oryza sativa	Rice
Oryzopsis hymenoides	Indian ricegrass
Oryzopsis miliacea	Smilo
Oxalis stricta	Yellow oxalis
Papaver somniferum	Opium poppy
Petroselinum crispum (*P. hortense*)	Parsley
Phleum pratense	Timothy
Physalis lobata	Purple-flowered groundcherry
Physalis longifolia	Perennial groundcherry
Physalis subglabrata	Taperleaf groundcherry
Picris echioides	Bristly oxtongue
Picris hieracioides	Hawkweed picris
Pimpinella saxifraga	Saxifrage pimpernella
Plagiobothrys sp.	Popcorn flower
Plantago arenaria	Branching plantain
Plantago aristata	Bracted plantain
Plantago coronopus	Crowfoot plantain
Plantago hirtella	No common name
Plantago lanceolata	Buckhorn plantain
Plantago major	Broadleaf plantain
Plantago ovata	Blond plantain
Plantago psyllium	Psyllium plantain
Plantago pusilla	Slender plantain
Plantago rhodosperma	Redseed plantain
Plantago rugelii	Blackseed plantain
Plantago virginica	Paleseed plantain
Polygonum argyrocoleon	Silversheath knotweed
Polygonum aviculare	Knotweed
Polygonum convolvulus	Black bindweed
Polygonum hydropiper	Common smartweed
Polygonum lapathifolium	Pale ladysthumb
Polygonum pensylvanicum	Bigseed ladysthumb
Polygonum persicaria	Ladysthumb
Polypogon monspeliensis	Rabbitfoot grass
Portulaca oleracea	Common purslane
Potentilla canadensis	Oldfield cinquefoil
Potentilla monspeliensis	Strawberryweed
Prunella vulgaris	Heal-all
Pycnanthemum sp.	Mountain-mint
Ranunculus acris	Tall buttercup
Ranunculus bulbosus	Bulbous buttercup

Botanical Name	*Common Name*
Ranunculus parviflorus	Small-flowered buttercup
Ranunculus repens	Creeping buttercup
Ranunculus sardous	Hairy buttercup
Raphanus raphanistrum	Wild radish
Raphanus sativus	Radish
Rapistrum rugosum	No common name
Ratibida columnaris	Prairie coneflower
Reseda lutea	Base-rocket
Rhynchospora macrostachya	Horned rush
Roemeria refracta	Roemeria poppy
Rosa sp.	Wild rose
Roubieva multifida	Flatweed
Rubus sp.	Blackberry
Rudbeckia hirta	Black-eyed-susan
Rumex acetosa	Sorrel; garden sorrel
Rumex acetosella	Sheep sorrel
Rumex altissimus	Peach-leaved dock
Rumex conglomeratus	Clustered dock
Rumex crispus	Curly dock
Rumex obtusifolius	Broad-leaved dock
Rumex occidentalis	Western dock
Rumex persicarioides	Golden dock
Rumex pulcher	Fiddleleaf dock
Rumex salicifolius	Willow-leaved dock
Rumex venosus	Veiny dock
Salsola kali var. *tenuifolia*	Russian-thistle
Salvia lanceolata	Lanceleaf sage
Salvia verticillata	Lilac sage
Sanguisorba annua	Prairie burnet
Sanguisorba minor	Little burnet
Saponaria vaccaria	Cowcockle
Satureja acinos	Spring savory
Satureja nepeta	Catnip savory
Satureja vulgaris	Basil
Scabiosa arvensis	Field scabiosa
Scabiosa sp.	Scabiosa
Schedonnardus paniculatus	Tumblegrass
Scirpus sp.	Bulrush
Scleranthus annuus	Knawel
Scrophularia marilandica	American figwort
Secale cereale	Rye
Senecio jacobaea	Tansy ragwort
Senecio vulgaris	Common groundsel
Sesamum orientale	Sesame
Sherardia arvensis	Field madder
Sida hederacea	Alkali mallow
Sida spinosa	Prickly mallow
Sidalcea campestris	Plains cheesemallow
Sidalcea hendersonii	Henderson's cheesemallow
Sideritis montana	No common name
Sidopsis hispida	Yellow false-mallow
Sisymbrium altissimum	Tumblemustard
Sisymbrium officinale	Hedgemustard
Sisyrinchium sp.	Blue-eyed-grass
Solanum carolinense	Horsenettle
Solanum elaeagnifolium	Silver-leaf nightshade
Solanum nigrum	Black nightshade
Solanum rostratum	Buffalo-bur
Solanum triflorum	Cutleaf nightshade
Sonchus arvensis	Perennial sowthistle
Sonchus asper	Spiny sowthistle
Sonchus oleraceus	Common sowthistle
Specularia perfoliata	Venus's-looking-glass
Spergula arvensis	Corn spurry
Spergula pentandra	Wingseed spurry

Botanical Name	*Common Name*
Sphaeralcea coccinea	Scarlet globemallow
Stachys annua	Field betony
Stachys palustris	Marsh betony
Stellaria graminea	Little starwort
Stellaria media	Common chickweed
Stipa viridula	Green needlegrass
Sudeda depressa	Sea-blite
Symphoricarpos occidentalis	Western snowberry
Tanacetum vulgare	Common tansy
Taraxacum erythrospermum	Red-seeded dandelion
Taraxacum officinale	Dandelion
Teesdalia nudicaulis	No common name
Teucrium botrys	Cutleaf germander
Teucrium canadense	American germander
Thalictrum sp.	Meadowrue
Thelesperma sp.	Greenthread
Thlaspi arvense	Pennycress
Torilis anthriscus	Erect hedgeparsley
Torilis nodosa	Knotted hedgeparsley
Tradescantia virginiana	Virginia spiderwort
Tragopogon pratensis	Meadow salsify
Trianthema portulacastrum	Horse-purslane
Tribulus terrestris	Puncturevine
Trichostema dichotomum	Forked bluecurls
Trichostema lanceolatum	Vinegar bluecurls
Tridens flavus	Purpletop
Trisetum flavescens	Yellow trisetum
Triticum aestivum	Wheat
Urtica dioica	Stinging nettle
Valerianella dentata	Toothed cornsalad
Valerianella eriocarpa	Italian cornsalad
Valerianella locusta var. *olitoria*	Cornsalad
Verbascum thapsus	Common mullein
Verbena hastata	Blue vervain
Verbena officinalis	Vervain
Verbena stricta	Hoary vervain
Verbena urticaefolia	White vervain
Vernonia noveboracensis	New York ironweed
Veronica agrestis	Field speedwell
Veronica arvensis	Corn speedwell
Veronica peregrina	Purslane speedwell
Viola tricolor	Wild pansy
Xeranthemum cylindraceum	Cylinder immortelle

INDEX

	Page
Abnormal seedlings, causes	97
Abutilon	373, 417
Acalypha	373, 417
Achillea	373, 417
Achyrachaena	373, 417
Adesmia	237, 373
Adesmia	237
Adzuki bean	73, 142, 248, 395
Aeschynomene	238, 373
Aethusa	373, 417
African millet	395, 419
Agropyron	55, 127, 198, 373
Agrostemma	373, 417
Agrostis	55, 127, 196, 373
Aizoaceae (carpetweed family):	
dormancy treatments	107
kinds of seed	107
seedling interpretation	109
substrata for tests	108
Aira	201, 373
Air-oven methods	183
Alabama White lupine	246
Alfalfa	77, 142, 246, 295, 395
Alfilaria	82. 167, 395, 419
Ajuga	374, 417
Alhagi	238, 374
Alkali bluegrass	226, 396
Alkali mallow	407, 422
Alkali sacaton	231, 395
Allionia	374
Allium	82, 160, 374, 417
Allocarya	374, 417
Alopecurus	66, 128, 202, 374
Alsike clover	77, 142, 250, 253
Alsine	374
Althaea	374, 417
Alyce clover	77, 142, 238
Alysicarpus	77, 142, 238, 374
Alyssum	374, 417
Alyssum	395, 417, 418
Amaranth	395, 417
Amaranthus	374, 417
Ambrosia	374, 417
American bugleweed	398, 420
American dragonhead	402, 421
American figwort	403, 422
American germander	404, 423
American mannagrass	407, 420
American pennyroyal	409, 420
American peppergrass	409, 420
American sloughgrass	208
American vetch	256, 257
Ammi	374, 417
Ammi	395, 417
Amsinckia	374, 417
Anagallis	374, 417
Analysis of the seed	329
Andropogon	57, 127, 202, 374
Anemone	374, 417
Anemone	395, 417
Angleton grass	202, 395
Annual bluegrass	67, 127, 226, 396
Annual rape	83, 119
Annual vernalgrass	204, 414
Anthemis	374, 417
Anthoxanthum	66, 128, 203, 374
Anthriscus	375, 417
Anthyllis	238, 375
Apargia	375
Apera	204, 375
Apium	80, 167, 375, 417
Aplopappus	375, 417
Apocynum	375, 417
Arabis	375, 417
Arachis	73, 143, 375
Arctium	375, 417
Arenaria	375, 417
Aristida	204, 375
Arnoseris	375, 417
Arrhenatherum	66, 128, 204, 375
Artichoke	84, 113, 395
Asclepias	375, 417
Asia poppy	395
Asparagus	82, 160, 375
Asparagus	82, 160, 395
Asparagus bean	73, 142, 395
Asperugo	375, 417
Astoria bentgrass	55, 127, 196, 396
Astragalus	238, 375
Atriplex	375, 417
Australian bluestem	203, 397
Australian burnweed	419
Austrian peaweed	250, 409
Austrian winter pea	249
Autumn spikerush	419
Avena	57, 126, 205, 375
Avens	395, 419
Axonopus	58, 127, 208, 375
Axyris	375, 418
Bachelor's-button	395, 418
Bahia grass	58, 127, 222, 395
Baldwin spikerush	412, 419
Ball clover	250, 252
Ballcress	235, 395
Ball mustard	395, 421
Balloon mustard	395
Ballota	376, 418
Barbarea	376, 418
Barbed witchgrass	221
Barkhausia	376
Barley	62, 126, 218, 219, 395
Barnaby's thistle	395
Barnyard grass	214, 395
Barren chess	211, 399
Base-rocket	395, 422
Basil	395, 422
Basil-thyme	395
Bassia	376, 418
Bassia	395, 418
Beaked panicum	221, 409
Bean	73, 142, 248, 294, 395

	Page
Beardgrass	202, 396, 417
Beardless wild-rye	215, 416
Beckmannia	208, 376
Bedstraw	396, 419
Beet	84, 107, 294, 396
Beet seed washer	35
Beggarweed	74, 142, 241, 396
Belvedere	396
Bentgrass	55, 127, 196, 396
Berg's panicgrass	221
Bermuda grass	60, 127, 396, 419
Berseem clover	77, 142, 251, 400
Berteroa	376, 418
Beta	84, 107, 376
Betony	396, 423
Bicolor lespedeza	244, 406
Big bluegrass	226, 396
Big bluestem	127, 203, 397
Big-flowered clover	250, 253
Bigflower gilia	404, 418
Bigleaf sumpweed	413, 420
Big mouse-ear chickweed	399, 418
Bigseed falseflax	403, 418
Bigseed goosefoot	404, 418
Bigseed ladysthumb	406, 421
Big trefoil	75, 143, 245
Bindweed	258, 396
Bird rape	83, 119, 396
Bird vetch	256, 257, 415
Birdsfoot trefoil	75, 143, 245, 414
Bitter wintercress	418
Blackberry	396, 422
Black bindweed	396, 421
Black-eyed-susan	396, 422
Black henbane	405, 420
Black horehound	396, 418
Black medic	77, 143, 246, 407
Black mustard	83, 119, 235, 408
Black nightshade	408, 422
Blackseed plantain	410, 421
Bladder campion	232, 398
Bladder ketmia	396
Blond plantain	410, 421
Blotters	87
Blowers for cleaning dividers	12
Blowers, seed	15, 46
Blowwives	396, 417
Blue-bur	396
Blue cockle	396
Bluecurls	396, 423
Blue devil	396
Blue-eyed grass	396, 422
Blue grama	127, 209, 404
Bluegrass	67, 127, 224, 396
Blue lettuce	406, 420
Blue lupine	143, 245, 407
Blue panic grass	65, 128, 221, 409
Blue sailors	397
Bluestem	57, 127, 202, 397, 417
Bluets	397, 420
Blue thistle	397
Blue vervain	414, 423
Blueweed	397, 419, 420
Blunt spikerush	412, 419
Boerhaavia	376, 418
Boer lovegrass	216, 407
Boerner divider	5, 8
Boisduvalia	376, 418
Boisduvalia	397, 418
Botanical and common names	417–423
Botanical names	373–394
Bouteloua	57, 127, 209, 376
Boxes, soil and sand	21
Bracted plantain	410, 421
Bractless Mentzelia	407, 421
Branching plantain	410, 421
Brassica	83, 119, 234, 376
Brauneria	377, 418
Bristlegrass	228, 397
Bristlestem hempnettle	405, 419
Bristly dogtail	213, 402
Bristly ox tongue	409, 421
Broad bean	79, 142, 294, 397
Broadleaf plantain	410, 421
Broad-leaved carpet grass	208, 399
Broad-leaved dock	402, 422
Broccoli	83, 119, 397
Brodiaea	377, 418
Brodiaea	397, 418
Broken and cracked seeds	48
Brome	59–60, 127, 210, 397
Bromegrass	209, 397
Bromus	59, 127, 209, 377
Broomcorn	70, 127, 230, 397
Broomcorn millet	222, 397
Broomsedge	203, 397
Brown-Duvel distillation method	185
Brown mustard	234, 408
Brownscale knapweed	406, 418
Brownseed paspalum	222, 409
Browntop millet	65, 127, 221, 397
Browntop panicum	221, 409
Brussels sprouts	83, 119, 397
Buchloë	67, 127, 208, 377
Buckhorn	397
Buckhorn plantain	410, 421
Buckhorn seeds, shriveled	51
Buckwheat	81, 167, 398
Buffalo-bur	398, 422
Buffalo clover	251, 252
Buffalo grass	67, 127, 208, 398
Bugle	398
Bugleweed	398, 420
Bugseed	398
Bulblets, wild onion and wild garlic	52
Bulbous bluegrass	67, 127, 227, 396
Bulbous buttercup	398, 421
Bullnettle	398
Bull paspalum	222, 409
Bull thistle	413, 418
Bulrush	398, 422
Bunium	377, 418
Bupleurum	377, 418
Bur bristlegrass	228, 397
Bur-clover	77, 142, 246, 398
Burdock	398, 417
Burnet	398, 422
Burnweed	398, 419
Bur-ragweed	398
Bursa	377
Bur-sage	398, 419
Bushy Mentzelia	407, 421

Page

Butter-and-eggs 398, 420
Buttercup 398, 421
Butterflyweed 398, 417
Butterprint 398
Buttonclover 246, 247, 398
Buttonweed 398, 419

Cabbage 83, 119, 234, 294, 398
Calculating test results 191–193
Caley pea 398
California brome 210, 397
California bur-clover 246, 398
California-poppy 398, 419
Caltrop 398
Caltrops 398
Camelina 377, 418
Camelthorn 238, 398
Camomile 398
Campe 377
Campion 232, 398
Canada bluegrass 67, 127, 225, 396
Canada thistle 413, 418
Canada wild-rye 55, 128, 215, 416
Canary grass 60, 127, 223, 398
Canby bluegrass 396
Cannabinaceae (hemp family):
  dormancy treatments 167
  kind of seed 167
  seedling interpretation 169
  subtrata for tests 168
Cannabis 84, 167, 377, 418
Cantaloup 82, 124, 399
Caperonia 378, 418
Capsella 237, 378
Capsicum 80, 167, 378
Caraway 399, 418
Cardaria 235, 378
Cardoon 84, 113, 399
Carduus 378, 418
Carex 378, 418
Carnation pests and injuries 294
Carolina canary grass 224, 398
Carolina clover 250, 252
Carolina cranesbill 401, 419
Carolina foxtail 202, 404
Carolina geranium 399
Carolina horsenettle 399, 405
Carpet grass 58, 127, 208, 399
Carrot 80, 167, 294, 399, 419
Carthamus 378, 418
Carum 378, 418
Caryophyllaceae pests and injuries 294
Cassia 239, 378
Catchfly 232–233, 399
Catchweed 399
Catnip 399, 421
Catnip savory 411, 422
Cats-ear 399, 420
Cattail millet 399
Caucalis 378
Cauliflower 83, 119, 399
Celeriac 80, 167, 399
Celery 80, 167, 294, 399
Celery-mustard 235
Cellulose paper, substratum 91
Cenchrus 211, 378

Page

Centaurea 378, 418
Centipede grass 399, 419
Centromadia 378, 418
Cephalaria 378, 418
Cephalaria 399, 418
Cerastium 378, 418
Cereals 126, 294
Chaerophyllum 378, 418
Chamomile 399, 417
Chamomilla 378
Chard, Swiss 399
Charlock 235, 399
Cheat 399
Checking for accuracy 47
Cheesemallow 399, 422
Cheeses 399
Cheirinia 378
Chenopodiaceae (goosefoot family):
  dormancy tratments 107
  kinds of seed 107
  seedling interpretation 109
  substrata for tests 108
Chenopodium 378, 418
Chervil 399, 418
Chess 399
Chewings fescue 61, 127, 217
Chickpea 73, 142, 239, 399
Chickpea milkvetch 239, 407
Chickweed 399, 418
Chicory 84, 113, 399, 418
Chilean tarweed 413, 420
China aster pests and injuries 294
Chinese cabbage 235
Chinese lespedeza 74, 143, 243
Chinese milkvetch 239, 407
Chloris 66, 128, 211, 378
Chloris 399
Chondrilla 379, 418
Chorispora 236, 379
Chufa 399
Chrysanthemum 379, 418
Cicer 73, 142, 239, 379
Cichorium 84, 113, 379, 418
Cicuta 379, 418
Cinquefoil 399, 421
Cirsium 379, 418
Citron 82, 124, 400
Citrullus 82, 124, 379
Classification of seedlings, guides 96–97
Cleavers 400, 419
Climbing milkweed 407, 420
Clinopodium 379
Clover 77, 142, 238, 250, 295, 400
Club-awn 212, 400
Cluster clover 77, 142, 250, 252
Clustered blue morning-glory 258
Clustered dock 402, 422
Cluster tarweed 413, 420
Coast blite 400
Coast dandelion 400
Coast fiddleneck 403, 417
Coated or pelleted seed 52, 105
Cockle 400
Cocksfoot grass 401
Coco grass 401
Coffee bean 401
Cogwheel clover 246, 401

	Page
Cold test	105
Collards	83, 119, 401
Collomia	379, 418
Colonial bentgrass	55, 127, 196, 396
Commelina	379, 418
Common chickweed	399, 423
Common dayflower	402, 418
Common fumitory	404, 419
Common goatsrue	404, 419
Common groundsel	404, 422
Common lespedeza	74, 143, 243, 406
Common milkweed	407, 417
Common millet	228, 229, 407
Common morning-glory	259, 408
Common mullein	408, 423, 407
Common oat	205, 207, 408
Common purslane	410, 421
Common ragweed	410, 417
Common smartweed	412, 421
Common sowthistle	412, 422
Common Sudan grass	229, 413
Common sunflower	413, 420
Common tansy	413, 423
Common vetch	79, 143, 255, 415
Compositae (composite or sunflower family):	
dormancy treatments	113
kinds of seed	113
seedling interpretation	114
substrata for tests	113
Cone-flower	401, 418
Conical catchfly	233, 399
Conium	379, 418
Conringia	236, 379
Containers, seed	14, 43
Convolvulus	258, 379
Corispermum	379, 418
Corn	62, 126, 295, 401
Cornbind	401
Corn-chamomile	401, 417
Corncockle	401, 417
Corn, field	401
Cornflower	401
Cornsalad	80, 167, 401, 423
Corn speedwell	412, 423
Corn spurry	413, 422
Coronilla	239, 379
Coronilla	401
Coronopus	236, 379
Corynephorus	212, 379
Cotton	81, 164, 295, 401
Cotton, substratum	90
Couch grass	401
Counters, seed	22
Counting the seeds	93
Cowcockle	401, 422
Cowherb	401
Cowpea	73, 143, 257, 401
Cow wheat	401, 421
Crabgrass	401, 419
Cracked and broken seeds	48
Cranesbill	401, 419
Creeping bentgrass	55, 127, 197, 396
Creeping buttercup	398, 422
Creeping crownvetch	240
Creeping Jennie	401
Creeping yellowcress	237, 416
Crepis	379, 418
Cress (crops)	83, 119, 401
Cress (weeds)	235, 237
Crested dogtail	60, 127, 213, 402
Crimson clover	77, 142, 250, 254
Crinkled hairgrass	213, 405
Crooked clover	251, 252
Crop and weed seed illustrations	262
Crop judging	181
Crop seed interpretation	47
Crotalaria	74, 143, 240, 379
Crotalaria	74, 143, 240, 401
Croton	379, 401
Crowfoot plantain	410, 421
Crownvetch	239–240, 401
Cruciferae (mustard family):	
dormancy treatments	119
kinds of seed	119
seedling interpretation	120
substrata for tests	120
Cruciferae pests	294
Crucifers and legumes devoid of seed coats	49, 51
Cucumber	82, 124, 401
Cucumis	82, 124, 379
Cucurbita	82, 124, 379, 380
Cucurbitaceae (cucurbit family):	
dormancy treatments	124
kinds of seed	124
seedling interpretation	125
substrata for tests	125
Cultivated oats	205
Cupgrass	401, 419
Curlybloom	401
Curlycup gumweed	405, 420
Curly dock	402, 422
Curly thistle	413, 418
Cuscuta	259, 260, 380
Cusick bluegrass	226, 396
Cutleaf cranesbill	401, 419
Cutleaf evening-primrose	403, 421
Cutleaf germander	404, 423
Cutleaf nightshade	408, 422
Cyamopsis	240, 380
Cycloloma	380, 419
Cylinder immortelle	405, 423
Cynara	84, 113, 380
Cynodon	60, 127, 380, 419
Cynosurus	60, 127, 212, 380
Cyperus	380, 419
Dactylis	60, 128, 213, 380
Daisy	401, 418
Daisy fleabane	419
Dallis grass	58, 127, 222, 401
Dandelion	84, 113, 402, 423
Danthonia	380
Darnel	220, 402
Dates, germination count	96
Datura	380, 419
Daubentonia	240, 380
Daucus	80, 167, 380, 419
Dayflower	402, 418
Dead nettle	402
Deathweed	402
Deervetch	245, 402
Delphinium	380, 419

Page

Dense-flowered Boisduvalia 397, 418
Deptford pink 402, 419
Deschampsia 213, 380
Desert purslane 402
Desert saltgrass 214, 411
Desks and tables 42
Desmodium 74, 142, 241, 380
Development of seeds 263, 265, 269
Devil's paintbrush 402
Dianthus 380, 419
Diaphanoscope 14
Dichondra 380, 419
Digestion 273
Digitaria 380, 419
Diodia 380, 419
Dipsacus 380, 419
Diseases identifiable during germination 287
Diseases identifiable prior to germination 286
Dissection of seed 50
Distichlis 214, 380
Divider(s):
  Boerner 5, 8
  Gamet 8, 10
  Hay-Bates 8, 11
  Kny-Scheerer 7, 9
  Ottawa 9, 11
  seed 43–44
  soil 5, 7
Dock 402, 422
Dodder 50–51, 259–261, 402
Dogbane 402, 417
Dogfennel 402, 417
Dogtail 60, 212–213, 402
Dondia 380
Dormancy, methods of overcoming 101
Dormancy treatments:
  Aizoaceae 107
  Chenopodiaceae 107
  Compositae 113
  Cruciferae 119
  Cucurbitaceae 124
  Gramineae 128
  Leguminosae 143
  Liliaceae 160
  Linaceae 162
  Malvaceae 164
  Polygonaceae 167
  Solanaceae 167
  Umbelliferae 167
Dormant and dead seeds 100
Dormant embryos 280
Dovefoot cranesbill 401, 419
Downingia 380
Downy chess 210, 399
Dracocephalum 380
Dragonhead 402, 421
Drooping-flowered clover 251, 252
Dropseed 66, 127, 231, 402

Early wintercress 416, 418
Earth nut 402, 418
Echinacea 381
Echinochloa 65, 127, 214, 381, 402
Echium 381, 419

Page

Eggplant 80, 167, 402
Egyptian clover 251
Electric moisture meters 186
Eleocharis 381, 419
Eleusine 381, 419
Elliott bentgrass 198, 396
Elymus 55, 128, 214, 381
Embryo 265, 269
Embryo, rudimentary 50, 280
Emmer 62
Empty fruits 48, 51
Endive 84, 113, 402
Endosperm 266, 269
English catchfly 233, 399
Eragrostis 66, 127, 215, 381
Erechtites 381, 419
Erect hedgeparsley 405, 423
Eremocarpus 381, 419
Eremochloa 381, 419
Erigeron 381, 419
Eriochloa 381, 419
Eriocoma 381
Erodium 82, 167, 381, 419
Eruca 236, 381
Erysimum 381, 419
Erysimum 402, 419
Eschscholtzia 382, 419
Euphorbia 382, 419
Euphrasia 382, 419
European heliotrope 420
European stickseed 413, 420
Evening-primrose 402, 403, 421
Examination of seed 50, 338
Eyebright 403, 419

Fagopyrum 81, 167, 382
Fairway crested wheatgrass 55, 127
Falcaria 382, 419
Falcatula 382
Fall-dandelion 403, 420
Fall panicum 221
Fall witchgrass 219, 403
False-camomile 403, 421
Falseflax 403, 418
False-mallow 403, 422
Fanweed 403
Fat-hen 403, 417
Fatuoids and wild oats 206
Fava bean pests 294
Feather fingergrass 212
Fennelflower 403, 421
Fenugreek 254, 403
Fescue 61, 127, 217–218, 403
Festuca 61, 127, 216, 382
Feterita 230, 403
Fetticus 167, 403
Fiddleleaf dock 402, 422
Fiddleneck 403, 417
Field bean 73, 142, 395
Field beet 396
Field betony 396, 423
Field bindweed 396
Field camomile 403
Fieldcress 237, 403
Field gromwell 404, 420
Field houstonia 403
Field larkspur 406, 419

Page

Field madder 403, 422
Field mint 408, 421
Field mustard 236
Field paspalum 222, 409
Field pea 73, 143, 409
Field peppergrass 410
Field sandbur 211, 411
Field scabiosa 412, 422
Field soybean 143
Field speedwell 412, 423
Field tests 179
Field woodrush 416, 420
Figwort 403, 422
Filing samples 40
Filter paper 90
Fimbristylis 382, 419
Fine hairgrass 201, 405
Fine-leaved fescues 216–217
Fingergrass 211–212, 403
Fireweed 403
Fivefinger 403
Five-hook bassia 395, 418
Flannel mullein 403
Flat pea 243, 403
Flatweed 403, 422
Flax 81, 162, 403, 420
Flax pests and injuries 295
Fleabane 403, 419
Flexuous milkvetch 239, 407
Florets, grass, with immature caryopses 51
Florida beggarweed 241, 403
Florida paspalum 222, 409
Florida speckled lupine 246
Florida velvetbean 249, 403
Flower-of-an-hour 403, 420
Flowering spurge 413, 419
Fluorescence test on ryegrass 103, 339
Fluorescent-light grids 33
Fog-fruit, spatulate 412, 420
Fool's parsley 403, 417
Forceps 13, 21
Forget-me-not 403, 421
Forked bluecurls 396, 423
Forked catchfly 233, 399
Four-o'clock, wild 403
Fourseed vetch 256, 257
Fowl bluegrass 227, 396
Fowl mannagrass 407, 420
Foxtail 66, 127, 202, 404
Foxtail barley 219, 395
Foxtail chess 210, 399
Foxtail fescue 217
Foxtail millet 65, 127, 229, 407
Franseria 382, 419
French weed 404
Fumaria 382, 419
Fumitory 404, 419
Fungi 99

Gaertneria 404
Galega 241, 382, 419
Galega 241, 404
Galeopsis 382, 419
Galinsoga 382, 419
Galinsoga 404, 419
Galium 382, 419

Page

Gamet divider 8, 10
Garbanzo 239
Garden bean 73, 142, 395
Garden beet 396
Garden fennelflower 403, 421
Garden pea 73, 143, 409
Garden sorrel 412, 422
Garlic and onion, wild, bulblets 52
Garlic, wild 404, 417
Gastridium 382, 419
Gattinger's witchgrass 221, 416
Gaura 382, 419
Gaura 404, 419
Geraniaceae (geranium family):
  dormancy treatments 167
  kind of seed 167
  seedling interpretation 169
  subtrata for tests 168
Geranium 382, 419
Geranium family 167
German madwort 407, 417
German millet 228, 229, 407
German velvetgrass 414, 420
Germander 404, 423
Germination determination 86–106
Germination procedures for specific groups 107–171
Germination testing equipment:
  beet seed washer 35
  fluorescent-light grids 33
  forceps 21
  germination trays 30
  germinators 25
  glassware 21
  magnifiers and microscope 21
  sample pans 21
  seed counters 22
  soil and sand—
    boxes 21
    sterilizers 22
  sprinkling devices 22
  thermometers 25
  ultraviolet lamp 32
Germination records 192, 193
Germination trays 30
Germinators 25
Geum 382, 419
Giant bristlegrass 228, 397
Giant foxtail 229, 404
Giant ragweed 410, 417
Gilia 383, 419
Gilia 404, 418, 419
Glassware 21
Glaucium 383, 420
Globe gilia 404, 419
Globemallow 404, 423
Glossary of terms 319–327
Glumes, effect on germination 277
Glyceria 383, 420
Glycine 73, 143, 241, 383
Goats-beard 404
Goatsrue 404, 419
Goatweed 404
Godetia 383, 420
Godetia 404, 420
Golden dock 402, 422
Goldenweed 404, 417

Page

Goldmine millet 229
Gonolobus 383, 420
Goosefoot 404, 418
Goosegrass 404, 419
Gossypium 81, 164, 383
Grain sorghum 127
Grama 57, 127, 209, 404
Gramineae (grass family):
dormancy treatments 128
kinds of seed 128
seedling interpretation 131
substrata for tests 130
Grape-hyacinth 404, 421
Grass florets, immature 51
Grass pests and injuries 295
Grass seeds, damaged and immature 50, 51
Great burdock 398, 417
Greater ammi 395, 417
Green foxtail 228, 404
Greenhouse tests 180
Green needlegrass 408, 423
Greenthread 404, 423
Grindelia 383, 420
Grisebach bristlegrass 228, 397
Gromwell 404, 420
Ground bugle 398, 417
Groundcherry 404, 421
Groundnut 404
Groundnut pea 243, 404
Groundsel 404, 405, 422
Grove woodrush 416, 420
Guar 240, 405
Guinea grass 65, 127, 221, 405
Gumweed 405, 420

Hackelochloa 383, 420
Hair fescue 127, 217, 403
Hairgrass 201, 213, 405
Hairy buttercup 398, 422
Hairy chess 211, 399
Hairy gaura 404, 419
Hairy goldenweed 404, 417
Hairy grama 209, 404
Hairy hawksbeard 405, 418
Hairy indigo 242, 406
Hairy morning-glory 259, 408
Hairy mustard 408, 420
Hairy panicgrass 221
Hairyseed sedge 412, 418
Hairy tickseed 414, 418
Hairy vetch 79, 143, 255, 257, 415
Halogeton 383, 420
Halogeton 405, 420
Halving method 39
Hand lens 13, 45
Harding grass 60, 127, 223, 224, 405
Hares-ear-mustard 236, 405
Harvest brodiaea 397, 418
Hastings lupine 246
Hawkbit 405, 420
Hawksbeard 405, 418
Hawkweed 405, 420
Hawkweed, picris 405, 421
Hay-Bates divider 8, 11
Hay-field tarweed 413, 420
Heal-all 405, 421

Page

Hedeoma 383, 420
Hedge bindweed 258, 405
Hedgemustard 405, 422
Hedgenettle 405
Hedgeparsley 405, 423
Hedysarum 241, 383
Hegari 230, 405
Helianthus 84, 113, 383, 420
Heliotrope 405, 420
Heliotropium 383, 420
Hemizonia 383, 420
Hemizonia 405
Hemp 84, 167, 405, 418
Hemp dogbane 402, 417
Hempnettle 405, 419
Henbane 405, 420
Henbit 405, 420
Henderson's cheesemallow 399, 422
Herbarium, seed 20
Herd's-grass 405
Hereditary characteristics of seeds 263, 271
Heterotheca 383, 420
Hibiscus 81, 164, 383, 420
Hieracium 383, 420
Highland bentgrass 55, 127, 196, 396
High mallow 407, 420
High temperatures 102
Hillman panicgrass 221
Hirschfeldia 383, 420
Hispid deervetch 245, 402
Hoary alyssum 395, 418
Hoary cress 235, 405
Hoary vervain 414, 423
Hoffmannseggia 241, 383
Holcus 66, 128, 383, 420
Hood canary grass 224, 398
Hookera 383
Hop clover 251, 252
Hordeum 62, 126, 218, 383
Horehound 405, 421
Horned-rush 405, 422
Hornpoppy 405
Horse bean 142, 405
Horsenettle 405, 422
Horse-purslane 405, 423
Horseweed 405, 419
Hosackia 383
Houstonia 383, 420
How to draw the sample 37
Hungarian millet 220, 408
Hungarian vetch 79, 143, 255, 256, 415
Husk tomato 80, 167, 405
Hybrids, sorghum-Sudan 405
Hymenophysa 383
Hyoscyamus 383, 420
Hypericum 383, 420
Hypochaeris 383, 420
Hyssop loosestrife 405, 420

Iberian star-thistle 413, 418
Identification of seeds 194–261
Illustrations, crop and weed seeds 262
Immature and shriveled seeds 48
Immortelle 405, 423
Impermeable seed coats 278

	Page
Imported seed	3
India mustard	83, 119, 234, 408
Indian grass	57, 127, 405
Indian hemp	405
Indian ricegrass	65, 128, 411, 421
Indian tobacco	405, 420
Indigo	405, 406
Indigofera	242, 383
Indigo, hairy	242, 406
Inhibiting substances	281
Inland bluegrass	226, 396
Insect-damaged seed	49
Integuments (seed coats) and ovary wall (pericarp)	268
Integuments or seed coats	269
Interpretation of crop seed, applicable rule	47
Interpretation of weed seed, applicable rule	49
Interstate commerce, seed	3
Illahee fescue	216, 217
Ipomoea	258, 259, 383, 384
Ironweed	406, 423
Italian cornsalad	401, 423
Italian ryegrass	103, 127, 220
Italian thistle	414, 418
Iva	384, 420
Ivyleaf morning-glory	259, 408
Jacquemontia	258, 259, 384
Japanese chess	211, 399
Japanese lawngrass	65, 127, 231, 406
Japanese millet	65, 127, 214, 406
Jim Hill mustard	406
Jimsonweed	406, 419
Johnson grass	70, 127, 229, 230, 406
Jointvetch	238, 406
Juncoides	384
Juncus	384, 420
Jungle rice	214, 406
Kafir	230, 406
Kale	83, 119, 406
Kentucky bluegrass	127, 225, 227, 396
Kickxia	384, 420
Kidneyvetch	238, 406
Kimpak	91
King devil weed	406
Klamath-weed	406
Knapweed	406, 418
Knautia	384
Knawel	406, 422
Knotgrass	222, 406
Knotroot bristlegrass	228, 397
Knotted clover	250
Knotted hedgeparseley	405, 423
Knotweed	406, 421
Knotweed family	167
Kny-Scheerer divider	7, 9
Kobe lespedeza	74, 143, 243, 244
Kochia	384, 420
Koellia	384
Kohlrabi	83, 119, 406
Korean lespedeza	74, 143, 243, 244, 406
Kudzu	74, 143, 249, 406
Kura clover	250, 254
Kursk millet	229
Kyllinga	384, 420
Kyllinga	406, 420
Labeling of seed	3
Laboratories, seed-testing	4
Laboratory space and light	42
Lacegrass	216, 406
Lactuca	84, 113, 384, 420
Ladino clover	142, 250
Ladysthumb	406, 421
Lambsquarters	406, 418
Lamb-succory	406, 417
Lamium	384, 420
Lamp, ultraviolet	32
Lamps	20
Lance crotalaria	240, 401
Lanceleaf sage	411, 422
Lappa clover	77, 142, 250, 253
Lappula	384, 420
Lapsana	384, 420
Large crabgrass	401, 419
Large-flowered brodiaea	397, 418
Large-headed plumeless thistle	418
Large hop clover	77, 142, 250, 252, 400
Large-seeded legumes	73
Larkspur	406, 419
Lathyrus	143, 242, 384
Lavender grass	406
Law(s):	
Federal Seed Act	3
State seed	3
Truth-in-Labeling	3
Leafy spurge	413, 419
Leek	82, 160, 406
Legumes and crucifers devoid of seed coats	49, 51
Legumes of limited use	74
Leguminosae (legume or pea family):	
dormancy treatments	143
hard seeds	144
kinds of seed	142
seedling interpretation	146
substrata for tests	144
Lehman lovegrass	216, 407
Lens peppercress	235, 409
Leontodon	384, 420
Leonurus	384, 420
Lepidium	83, 119, 236, 384, 420
Leptoloma	219, 385
Lespedeza	74, 143, 243, 385
Lespedeza	74, 143, 243, 244, 406
Lettuce	84, 113, 406, 420
Light, effect on germination	95, 102, 276
Lilac sage	411, 422
Liliaceae (lily family):	
dormancy treatments	160
hard seeds	160
kinds of seed	160
seedling interpretation	160
substrata for tests	160
Lima bean	73, 142, 395
Linaceae (flax family):	
dormancy treatments	162
kind of seed	162
seedling interpretation	162
substrata for tests	162

Page

Linaria 385, 420
Linum 81, 162, 385, 420
Lippia 385, 420
Lithospermum 385, 420
Little barley 219, 395
Little bluestem 127, 203, 397
Little burnet 398, 422
Little canary grass 224, 398
Little flower mealybean 407
Little mallow 407, 420
Little-seed falseflax 403, 418
Little starwort 413, 423
Lizard-tail grass 407, 420
Lobelia 385, 420
Loco 238
Lolium 64, 127, 219, 385
Longstalk cranesbill 401, 419
Long-tongue mutton grass 226, 408
Loosestrife, hyssop 405, 420
Lotus 75, 143, 245, 385
Louisiana cupgrass 401, 419
Lovegrass 66, 127, 215, 407
Love-in-a-mist 407, 421
Lovevine 407
Low vetchling 243, 415
Lucerne 246
Ludwigia 385, 420
Lupine 73, 143, 245, 407
Lupinus 73, 143, 245, 385
Luzula 385, 386, 420
Lychnis 232, 386
Lycopersicon 80, 167, 386
Lycopus 386, 420
Lythrum 386, 420

Madia 386, 420
Madwort 407, 417
Magnifiers 13, 21
Mallow 407, 420, 422
Malta star-thistle 413, 418
Malva 386, 420
Malvaceae (mallow family):
- dormancy treatments 164
- hard seeds 164
- kinds of seed 164
- seedling interpretation 165
- substrata for tests 164

Malvastrum 386, 421
Mangel 84, 107, 407
Manila grass 65, 127, 231, 407
Mannagrass 407, 420
Mapleleaf goosefoot 404, 418
Marijuana 407
Marrubium 386, 421
Marsh betony 396, 423
Marsh elder 407
Mascarene grass 231, 407
Matricaria 386, 421
Mayweed 407
Meadow anemone 395, 417
Meadow barley 219, 395
Meadow fescue 127, 218, 403
Meadow foxtail 66, 128, 202, 407
Meadowrue 407, 423
Meadow salsify 411, 423
Meadow softgrass 407
Mechanical dividers, use of 39

Page

Medicago 77, 142, 143, 246, 386
Medic, black 77, 143, 246, 407
Meibomia 386
Melampyrum 386, 421
Melilotus 75, 143, 247, 386
Melinis 66, 128, 386, 421
Melochia 386, 421
Mentha 386, 421
Mentzelia 386, 421
Mentzelia 407, 421
Menzies larkspur 406, 419
Merion bluegrass 226, 396
Merker grass 407
Methods of examination 50
Mexican milkweed 407, 417
Mica 92
Microscope 13, 21
Mignonette 407
Milkvetch 238–239, 407
Milkweed 407, 417
Millet (crops) 65, 127, 221, 227, 407
Millet (weeds) 221, 227, 228
Milo 230, 408
Mint 408, 421
Mirabilis 386, 421
Moisture and aeration 94
Moisture effects on seed 275, 282
Moisture tests 183–186
Molasses grass 66, 128, 408, 421
Moldavica 386, 421
Molinia 386, 421
Monantha vetch 79, 143, 255, 257, 415
Moorgrass 408, 421
Morning-glory 408, 420
Morning-glory family 258–259
Motherwort 408, 420
Mountain brome 127, 210, 397
Mountain-mint 408, 421
Mouse-ear 408
Mullein 403, 408, 423
Mung bean 73, 142, 248, 395
Muscari 386, 421
Musk mallow 407, 420
Muskmelon 82, 124, 399, 408
Mustard 83, 119, 233, 408, 420
Mutton grass 226, 408
Myosotis 386, 421

Naked ragweed seed 51
Napa thistle 408
Napier grass 128, 223, 408
Narrowleaf goosefoot 404, 418
Narrowleaf vetch 79, 143, 255–257, 415
Narrow-leaved carpet grass 208, 399
Nassella 220, 386
Navarretia 386, 421
Navarretia 408, 421
Neckweed 408
Needlegrass 408
Needle-leaved Navarretia 408, 421
Nepeta 387, 421
Neslia 387, 421
Nettle 408, 423
Nettleleaf goosefoot 404, 418
Nevada bluegrass 67, 127, 226, 396
New York ironweed 406, 423
New Zealand spinach 84, 107, 413

	Page
Nicotiana	334, 387
Nigella	387, 421
Night-flowering catchfly	233, 399
Nightshade	408, 422
Nightshade family	80, 167
Nipplewort	408, 420
Nitgrass	408, 419
Nitrate solutions	277
Nodding spurge	413, 419
Nomograph, for fluorescence tests	339, 340
Northern jointvetch	238, 406
Northern oat	207, 408
Noxious-weed seed:	
examinations	172–174, 338
State requirements	3
tolerances	189, 362–363
Number of seeds in germination test	92
Numbers of seeds per gram	330–336
Nutgrass	408, 419
Nuttall milkvetch	239, 407
Oat	57, 126, 205–208, 408
Oatgrass	66, 128, 204, 213, 409
Oenothera	387, 421
Official rules for testing seeds	328–368
Okra	81, 164, 409
Oldfield cinquefoil	399, 421
Onion	82, 160, 409
Onion and garlic, wild, bulblets	52
Onobrychis	143, 248, 387
Ononis	248, 387
Ononis	248, 409
Opium poppy	410, 421
Orach	409, 417
Orange hawkweed	405, 420
Orchard grass	60, 128, 213, 409
Origin determination	175–177
Ornithopus	248, 387
Oryza	62, 126, 387, 421
Oryzopsis	65, 128, 387, 421
Ottawa divider	9, 11
Ovary wall	268–269
Overcoming dormancy	101
Oxalis	387, 421
Oxalis	409, 421
Ox-eye daisy	409, 418
Oxtongue	409, 421
Oxybaphus	387
Oxygen	276
Pakchoi	83, 119, 235, 409
Pale alyssum	395, 417
Pale ladysthumb	406, 421
Paleseed plantain	410, 421
Panicgrass	65, 128, 220–222, 409
Panicularia	387
Panicum	65, 127, 128, 220, 387
Panicum	220–222, 409
Pans, sample	14, 21
Pansy	409, 423
Papaver	387, 421
Paper toweling	88
Para grass	221, 409
Parentucellia	387
Parsley	80, 167, 409, 421
Parsley pests and injuries	295
Parsnip	80, 167, 409
Partial list of pests and injury conditions	293–296
Paspalum	58, 127, 222, 387, 388
Paspalum	222–223, 409
Pastinaca	80, 167, 388
Pathological considerations	284–296
Path rush	411, 420
Pea	73, 143, 243, 409
Pea, Austrian Winter	249
Pea pests and injuries	295
Pea, rough	74, 243, 411
Pea, sensitive	239, 412
Pea, Tangier	243, 413
Peach-leaved dock	402, 422
Peanut	73, 143, 409
Peanut pests and injuries	295
Pearl millet	62, 127, 223, 409
Peat moss	91
Peaweed	409
Pellett clover	250
Pelleted or coated seed	52, 105
Pennisetum	62, 128, 223, 388
Pennisetum	409
Pennycress	409, 423
Pennyroyal	409, 420
Pepper	80, 167, 409
Peppercress	235, 409
Peppergrass	409, 410, 420
Pepper pests and injuries	296
Perennial ground cherry	404, 421
Perennial mustard	237, 410
Perennial peppercress	409
Perennial ragweed	417
Perennial ryegrass	64, 127, 220, 411
Perennial sowthistle	412, 422
Perianth	263, 324
Pericarp	268–269
Persian clover	142, 250, 253
Persian ryegrass	220, 411
Pests and injury conditions:	
bean (*Phaseolus* spp.)	287, 294
beet	290, 294
broad or fava bean	294
cabbage and other Cruciferae	289, 294
carnation and other Caryophyllaceae	294
carrot	294
celery	291, 294
cereal or small grains	288, 294
China aster	294
clover and alfalfa	291, 295
corn (maize)	288, 295
cotton	290, 295
flax	290, 295
grass	295
parsley	295
pea	287, 295
peanut	295
pepper and tomato	296
rice	291, 296
soybeans	296
tree	296
vetch	296
Petri-dish tests	87, 92

Page

Petroselinum 80, 167, 388, 421
Pe-tsai 83, 119, 235, 410
Phacelia 388
Phalaris 60, 127, 223, 388
Phaseolus 73, 142, 248, 388
Phleum 66, 128, 388, 421
Physalis 80, 167, 388, 421
Physiologically unripe seed 279
Physiology of seeds 273–283
Picris 388, 421
Pimpernel 410, 417
Pimpinella 388, 421
Pimpinella 410, 421
Pinole clover 251, 254
Pinpoint clover 251, 254
Piptochaetium 388
Pisum 73, 143, 249, 388
Pitseed goosefoot 404, 418
Plagiobothrys 388, 421
Plains bluegrass 227, 397
Plains bristlegrass 397
Plains cheesemallow 399, 422
Plantago 388, 389, 421
Plantain 410, 421
Plant names 395–416
Plumeless thistle 410, 418
Poa 67, 127, 224, 389
Poison hemlock 410, 418
Poison ryegrass 410
Polygonaceae (knotweed family):
  dormancy treatments 167
  kinds of seed 167
  seedling interpretation 169
  substrata for tests 168
Polygonum 389, 421
Polypogon 389, 421
Ponyfoot 410, 419
Popcorn 62, 126, 410
Popcorn flower 410, 421
Poppy 410, 421
Portulaca 389, 421
Potassium nitrate and soil 102
Potentilla 389, 421
Poverty clover 251, 252
Poverty grass 204, 410
Poverty oatgrass 213, 409
Poverty sumpweed 413, 420
Poverty three-awn 410, 414
Povertyweed 410
Prairie burnet 398, 422
Prairie coneflower 410, 422
Prairie peppergrass 410, 420
Prairie-rocket 410
Prairie trefoil 245, 410
Predrying 103
Prickly lettuce 406, 420
Prickly mallow 407, 422
Prionopsis 389
Proso 65, 127, 222, 410
Prunella 389, 421
Psyllium plantain 410, 421
Pueraria 143, 249, 389
Puff dropseed 231, 402
Pumpkin 82, 124, 410
Puncturevine 410, 423
Purity determination 42–53

Page

Purity procedures for specific groups 54–85
Purity testing equipment:
  diaphanoscope 14
  forceps and spatula 13
  lamps 20
  magnifiers 13
  microscope 13
  scales and balances 13
  sample pans 14
  seed blowers 15
  seed containers 14
  seed herbarium 20
  sieves 14
  workboard 12
Purple bluets 397, 420
Purple coneflower 401, 418
Purple-flowered groundcherry 404, 421
Purple star-thistle 413, 418
Purpletop 410, 423
Purple vetch 79, 143, 255, 257, 415
Pursh seepweed 410
Purslane 410, 421
Purslane speedwell 412, 423
Pycnanthemum 389, 421

Quackgrass 410
Queen Anne's-lace 410
Queensland beardgrass 202, 396
Quincula 389

Rabbitfoot clover 251, 253, 400
Rabbitfoot grass 410, 421
Radish 83, 119, 410, 422
Ragi 410
Ragweed 410, 417
Ragweed seed, naked 51
Ragwort 411, 422
Raimannia 390
Random cups method 39
Ranier fescue 217
Ranunculus 390, 421, 422
Rape 83, 119, 234, 411
Raphanus 83, 119, 390, 422
Rapistrum 390, 422
Ratibida 390, 422
Rattail fescue 217, 403
Rattlebox 240, 411
Record cards, sample 369, 370
Record, sampling 38
Records and reports 191–193
Red campion 232, 398
Red clover 77, 142, 250, 253, 400
Red fescue 127, 403
Red goosefoot 404, 418
Red hempnettle 405, 419
Red oat 207, 408
Red orach 409, 417
Redroot amaranth 395, 417
Redscale 411
Red-seeded dandelion 402, 423
Redseed plantain 410, 421
Redtop 55, 128, 197, 411
Reducing the sample 39
Reed canary grass 60, 127, 223, 399
Ree wheatgrass 199, 201, 415
Rescue grass 59, 128, 210, 411
Reseda 390, 422

	Page
Respiration	274
Rheum	81, 167, 390
Rhodes grass	66, 128, 212, 411
Rhubarb	81, 167, 411
Rhynchospora	390, 422
Ribbed paspalum	223, 409
Ribgrass	411
Rice	62, 126, 411, 421
Ricegrass	65, 128, 411, 421
Rice pests and injuries	296
Ringwing	411, 419
Ripgut grass	211, 411
Riverbank wild-rye	215, 416
Roemeria	390, 422
Roemeria poppy	411, 422
Rorippa	83, 119, 237, 390
Rosa	390, 422
Rose	411, 422
Rose clover	250, 254, 400
Roubieva	390, 422
Rough blistercress	411, 419
Rough bluegrass	67, 127, 225, 397
Rough buttonweed	398, 419
Rough hawkbit	405, 420
Rough pea	74, 143, 243, 411
Rough pigweed	411, 417
Rough sumpweed	413, 420
Roundleaf thoroughwax	414, 418
Roundleaf toadflax	414, 420
Rubus	390, 422
Ruby milkvetch	239, 407
Rudbeckia	390, 422
Rudimentary embryo	50, 280
Rules for testing seeds:	
development	2
germination	341
history	2
in foreign countries	2
nature	2
official	328–368
purity	329
sampling	328
tolerances	356
Rumex	81, 167, 390, 422
Runner bean	73, 142, 395
Running mallow	407, 420
Rush	411, 420
Rushgrass	411
Rushpea	241, 411
Russian pigweed	411, 418
Russian thistle	411, 418, 422
Rutabaga	83, 119, 234, 411
Rye	62, 126, 411, 422
Ryegrass	64, 127, 220, 411
Ryegrass, fluorescence test	103
Safflower	411, 418
Sage	411, 422
Sainfoin	74, 143, 248, 411
Salad-rocket	236, 411
Salsify	84, 113, 411
Salsola	390, 422
Saltbush	411
Saltgrass	214, 411
Salt heliotrope	405, 420
Salvia	390, 422
Sample, drawing of	37
Sample pans	14, 21
Samplers	5, 6
Samples awaiting test	40
Samples, filing	40
Samples, size	38
Sampling	37–39, 328–329
Sand and soil	89
Sand bluestem	57, 127, 203, 397
Sandberg bluegrass	227, 397
Sandbrier	411
Sandbur	211, 411
Sand dropseed	66, 127, 231, 402
Sand lovegrass	216, 407
Sand oat	208, 408
Sandvine	411
Sandwort	411, 417
Sanguisorba	390, 422
Sanitary conditions of equipment and supplies	95
Saponaria	390, 422
Sarson	234
Satureja	390, 422
Savory	411, 422
Sawdust	92
Saxifrage pimpernella	410, 421
Scabiosa	390, 422
Scabiosa	411, 412, 422
Scabiosa star-thistle	413, 418
Scales and balances	13, 44
Scaleweed	412
Scarlet gaura	404, 419
Scarlet globemallow	404, 423
Scarlet pimpernel	410, 417
Scented gaura	404, 419
Schedonnardus	390, 422
Scirpus	390, 422
Scleranthus	390, 422
Sclerotia and nematode galls	49
Scorpion crownvetch	240, 401
Scorpionweed	412, 417
Scratch dropseed	231, 402
Scrophularia	391, 422
Sea-blite	412, 423
Sea-poppy	412, 420
Seashore saltgrass	214, 411
Seaside clover	251, 253, 400
Secale	62, 126, 391, 422
Sedge	412, 418
Seed blower	15, 46
Seedbox	412, 420
Seed-coat modification	103
Seed coats	268, 267–270
Seed containers	14, 43
Seed counters	22
Seed dividers	43
Seed herbarium	20
Seed identification	194–261
Seed in interstate commerce	3
Seed laboratories:	
commercial	4
Federal	4
State	4
Seed morphology	263–272
Seed physiology	273–283
Seed sampling	37–41
Seed testing, primary objective	1
Seed-testing rules	328–368

	Page
Seedling classification	96–97
Seedling interpretation(s):	
Aizoaceae	109
Chenopodiaceae	109
Compositae	114
Cruciferae	120
Cucurbitaceae	125
Gramineae	131
Leguminosae	146
Liliaceae	160
Linaceae	162
Malvaceae	165
Polygonaceae	169
Solanaceae	169
Umbelliferae	169
Seepweed	412
Selfheal	412
Senecio	391, 422
Sensitive pea	239, 412
Sericea lespedeza	74, 143, 243, 406
Serradella	248, 412
Sesame	412, 422
Sesamum	391, 422
Sesbania	74, 143, 249, 391
Sesbania	74, 143, 249, 412
Setaria	65, 127, 227, 391
Shaftal clover	250
Sheep fescue	61, 127, 217, 403
Sheep sorrel	412, 422
Shepherds-purse	237
Sherardia	391, 422
Short-awn foxtail	202, 404
Showy crotalaria	240, 401
Showy vetch	256, 257, 415
Shriveled seeds of buckhorn	51
Siberian kale	234, 406
Siberian lespedeza	74, 143, 243, 244, 406
Siberian millet	229
Sicklepod	239, 412
Sickleweed	412, 419
Sida	391, 422
Sida	412
Sidalcea	391, 422
Sidalcea	412
Side-oats grama	57, 127, 209, 404
Sideritis	391, 422
Sidopsis	391, 422
Sieves	14
Silene	232, 391
Silky bluestem	203, 397
Silver hairgrass	201, 405
Silver-leaf nightshade	408, 422
Silversheath knotweed	406, 421
Singletary pea	412
Sisymbrium	237, 391, 422
Sisyrinchium	391, 422
Sixweeks fescue	217
Size of samples	38
Skeletonleaf bur-sage	398, 419
Skeletonweed	412, 418
Skunkweed	412, 421
Sleepy catchfly	233, 399
Slender chloris	212, 399
Slender crabgrass	401, 419
Slender foxtail	202, 404
Slenderleaf crotalaria	240, 401
Slender oat	207, 408
Slender paspalum	222, 409
Slender plantain	410, 421
Slenderpod deervetch	245, 402
Slender spikerush	412, 419
Slender vetchling	243, 415
Slender wheatgrass	55, 127, 415
Slimweed bur-sage	398, 419
Sloughgrass	208, 412
Small cranesbill	401, 419
Smallflower Erysimum	402, 419
Small-flowered buttercup	398, 422
Small-flowered morning-glory	259, 408
Small-headed clover	251, 254, 400
Small hop clover	143, 250, 252, 400
Smartweed	412, 421
Smilo	65, 128, 412, 421
Smooth brome	127, 210, 397
Smooth crabgrass	401, 419
Smooth hawksbeard	405, 418
Smooth-seeded wild bean	249, 395
Smooth vetch	255
Snowberry	412, 423
Snow-on-the-mountain	412, 419
Soft chess	211, 399
Soft grass	412
Soil and sand boxes	21
Soil and sand sterilizers	22
Soil divider	5, 7
Soja	391
Solanaceae (nightshade family):	
dormancy treatments	167
kinds of seed	167
seedling interpretation	169
substrata for tests	168
Solanum	80, 167, 391, 422
Sonchus	391, 392, 422
Sorghastrum	57, 127, 392
Sorghum	70, 127, 230, 392
Sorghum	70, 127, 229, 412
Sorghum-Sudan hybrids	230, 412
Sorrel	81, 167, 412, 422
Source of seeds for germination test	92
Sourclover	75, 143, 247, 400
Southern bur-clover	246, 400
Southern curled mustard	119
Southern oat	207, 408
Sowthistle	412, 422
Soybean	73, 143, 241, 412
Soybean pests and injuries	296
Spacing the seeds	93
Spatula	13
Spatulate fog-fruit	412, 420
Special tests	53
Specularia	392, 422
Speedwell	412, 423
Spelt	62
Spergula	392, 422
Sphaeralcea	392, 423
Spiderling	412, 418
Spiderwort	412, 423
Spike bentgrass	198, 396
Spike redtop	412
Spikerush	412, 419
Spikeweed	412, 418
Spinacia	84, 107, 392
Spinach	84, 107, 412
Spinach mustard	83, 119, 235, 408

Page

Spiny sowthistle 412, 422
Sporobolus 66, 127, 231, 392
Spotted bur clover 77, 142, 246, 398
Spotted cats-ear 399, 420
Spotted knapweed 406, 418
Spotted spurge 413, 419
Spotted water-hemlock 415, 418
Spreading dogbone 402, 417
Spreading pigweed 413, 417
Spring savory 411, 422
Sprinkling devices 22
Spurge 413, 419
Spurry 413, 422
Squash 82, 124, 413
Stachys 392, 423
Standard crested wheatgrass 55, 127, 415
Star-thistle 413, 418
Starwort 413, 423
Steeping in water 103
Sterilizers, soil and sand 22
Stellaria 392, 423
Stickseed 413, 420
Stinkgrass 216, 413
Stinkweed 413
Stipa 392, 423
Stizolobium 73, 142, 249, 392
St. Johnswort 413, 420
Stinging nettle 408, 423
Stone cells 392, 413
Strawberry clover 77, 143, 250, 253, 400
Strawberryweed 413, 421
Striate clover 250, 253, 400
Striate crotalaria 240, 401
Striate lespedeza 243, 244
Stricta Boisduvalia 418
Strophostyles 249, 392
Structure of seeds 263–271
Suaeda 392, 423
Sub clover 143, 250, 254, 400
Substrata, germination:
- Aizoaceae 108
- Chenopodiaceae 108
- Compositae 113
- Cruciferae 120
- Cucurbitaceae 125
- Gramineae 130
- Leguminosae 144
- Liliaceae 160
- Linaceae 162
- Malvaceae 164
- Polygonaceae 168
- Solanaceae 168
- Umbelliferae 168

Substratum:
- blotters 87
- cotton 90
- creped cellulose paper wadding 91
- filter paper 90
- Kimpak 91
- mica 92
- paper toweling 88
- peat moss 91
- Petri-dish test 92
- sand and soil 89
- sawdust 92

Page

Suckling clover 77, 143, 250, 252, 400
Sudan grass 70, 127, 229, 230, 413
Sugar beet 84, 107, 396
Sulla 241, 413
Summer cypress 413, 420
Summer rape 234, 411
Sumpweed 413, 420
Sunflower 84, 113, 413, 420
Sunn crotalaria 240, 401
Sun spurge 413, 419
Swainsonia 250, 392
Sweetclover 75, 143, 247, 413
Sweet corn 62, 126, 401
Sweet sorghum 127, 230
Sweet Sudan grass 229, 413
Sweet vernalgrass 66, 128, 204, 414
Swine-cress 413
Swiss chard 84, 107, 399, 413
Switchgrass 65, 128, 222, 413
Symphoricarpos 392, 423

Tables and desks 42
Tall buttercup 398, 421
Tall fescue 61, 127, 218, 403
Tall hedge mustard 413
Tall indigo 413
Tall lettuce 407, 420
Tall oatgrass 66, 128, 205, 409
Tanacetum 292, 423
Tangier pea 243, 413
Tansy 413, 423
Tansy mustard 237, 413
Tansy ragwort 411, 413, 422
Taperleaf groundcherry 404, 421
Taraxacum 84, 113, 392, 423
Tarweed 413, 420
Tassel grape-hyacinth 404, 421
Teasel 413, 419
Teasel clover 251, 252, 400
Teesdalia 392, 423
Teff 216, 413
Temperature effects on seed 281
Temperature, germination 94, 101, 102, 275
Test result calculations 191–193
Tests, field 179
Tests, special 53
Tetragonia 84, 107, 392
Teucrium 392, 423
Texas bluegrass 67, 127, 226, 397
Texas blueweed 397, 420
Texas millet 221, 413
Thalictrum 392, 423
Thelesperma 392, 423
Thermometers 25
Thimble clover 251, 254, 400
Thistle 413, 414, 418
Thlaspi 392, 423
Thorn-apple 414
Thoroughwax 414, 418
Three-awn 204, 414
Three-seeded mercury 414, 417
Thymeleaf sandwort 411, 417
Ticklegrass 198, 414
Tickseed 414, 418
Tievine 414
Tift Sudan grass 229, 413

Page

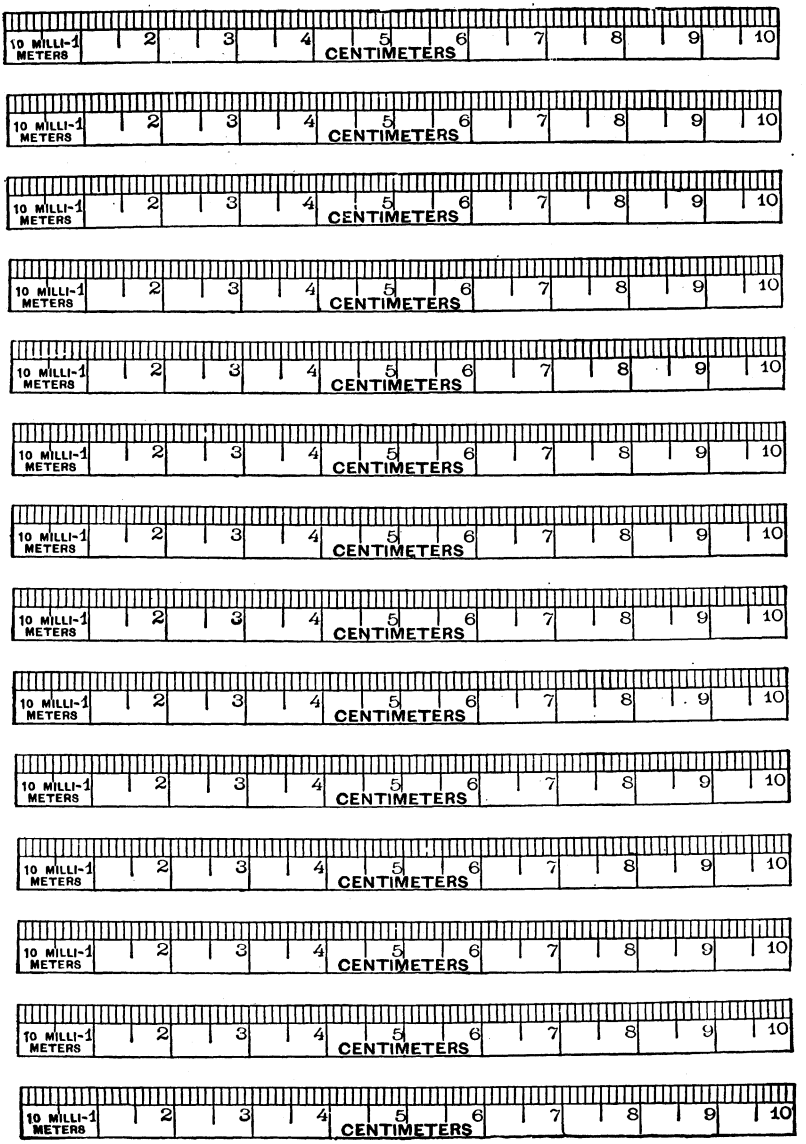
Timothy 66, 128, 414, 421
Timothy canary grass 224, 399
Tiny vetch 256, 257, 415
Tipton-weed 414
Toadflax 414, 420
Tocalote 414
Tolerances 187–190, 356–368
Toluene distillation method 185
Tomato 80, 167, 414
Tomato pests and injuries 296
Tomcat clover 251, 253, 400
Toothed bur-clover 246
Toothed cornsalad 401, 423
Toothed spurge 413, 419
Toothpick plant 414, 417
Torilis 392, 393, 423
Towermustard 414, 417
Tradescantia 393, 423
Tragopogon 84, 113, 393, 423
Trays, germination 30
Treacle-mustard 414, 419
Tree pests and injuries 296
Trefoil 75, 143, 245, 414
Trianthema 393, 423
Tribulus 393, 423
Trichostema 393, 423
Tridens 393, 423
Triers, seed 5, 6
Trifolium 77, 142, 250, 393
Trigonella 254, 393
Trigonella 254–255, 414
Trinius bluegrass 397
Triodia 393
Trisetum 393, 423
Trisetum 414, 423
Triticum 62, 126, 394, 423
Trompillo 414
Tualatin oatgrass 205
Tufted hairgrass 213, 405
Tumblegrass 414, 422
Tumblemustard 414, 422
Tumbling pigweed 414
Turkestan bluestem 202
Turkey mullein 414, 419
Turkistan thistle 414
Turnip 83, 119, 235, 414
Turnip rape 83, 119, 235, 414
Tussack grass 414

Ultraviolet lamp 32
Umbelliferae (carrot family):
  dormancy treatments 167
  kinds of seed 167
  seedling interpretation 169
  substrata for tests 168
Urtica 394, 423

Vaccaria 394
Vacuum-oven method 184
Valerianaceae (valerian family):
  dormancy treatments 167
  kinds of seed 167
  seedling interpretation 169
  subtrata for tests 168
Valerianella 80, 167, 394, 423
Variety identification 52
Variety testing 178–182
Vasey grass 58, 128, 222, 414
Vegetable mustard 83
Vegetable soybean 143
Veiny dock 402, 422
Velvetbean 73, 142, 249, 414
Velvet bentgrass 55, 127, 197, 198, 396
Velvet grass 66, 128, 411, 420
Velvet-leaf 414
Venus's-looking-glass 414, 422
Verbascum 394, 423
Verbena 394, 423
Vernalgrass 203, 414
Veronica 394, 423
Vervain 414, 423
Vetch 79, 143, 255, 415
Vetch pests and injuries 296
Vetchling 242, 415
Viability, determination 105
Vicia 79, 143, 255, 394
Vigna 73, 143, 257, 394
Vinegar bluecurls 396, 423
Vine-mesquite 222, 415
Viola 394, 423
Virginia buttonweed 398, 419
Virginia spiderwort 412, 423
Virginia wild-rye 215, 416

Wall barley 219
Wallflower 415
Wart-cress 236, 415
Water foxtail 202, 404
Water-hemlock 415, 418
Watermelon 82, 124, 415
Water-oven method 184
Wavyleaved gaura 404, 419
Wedgescale orach 409, 417
Weed and crop seed illustrations 262
Weed seed, interpretation 49
Weed seeds devoid of seed coats 51
Weeping lovegrass 66, 127, 216, 407
Weights of working samples 330–336
Weingaertneria 394
Western bluestem 397, 415
Western dock 402, 422
Western snowberry 412, 423
Western stickseed 413, 420
Western wheatgrass 55, 127, 415
Westernvolth ryegrass 219
Wheat 62, 126, 415, 423
Wheatgrass 55, 127, 198, 415
White bedstraw 396, 419
White blossom sweetclover 75, 400, 413
White clover 77, 143, 250, 253, 400
White cockle 232, 400, 415
White horehound 405, 415, 421
White horsenettle 405, 415
White-leaved povertyweed 416
White lupine 73, 143, 245, 246, 407
White mustard 83, 119, 234, 408
White-seeded yellow lupine 246
Whitestem mentzelia 407, 421
White sweetclover 247, 400
Whitetip clover 251, 253, 400
Whitetop 416
White vervain 414, 423
White Wonder millet 229, 407
Whorled milkweed 407, 417

	Page
Wild bean	395
Wild carrot	399, 419
Wild celery	399, 417
Wild chervil	416, 417
Wild flax	416
Wild four-o'clock	416, 421
Wild garlic	404, 417
Wild madder	416
Wild oat	207, 409
Wild onion and wild garlic bulblets	52
Wild pansy	409, 423
Wild potato vine	416
Wild radish	410, 422
Wild rose	422
Wild-rye	55, 128, 214, 416
Wild sunflower	420
Wild teasel	413, 419
Willow-herb	416
Willow-leaved dock	402, 422
Wimmera ryegrass	103, 219, 411
Windgrass	204, 416
Windmill grass	212, 416
Winged pigweed	416
Wingseed spurry	413, 422
Winter bentgrass	198, 396
Wintercress	416, 418
Winter rape	83, 119, 234, 411
Wiregrass	416
Witchgrass	219, 416
Wolfberry	416
Wood bluegrass	67, 127, 226, 397
Woodland flax	403, 420
Wood meadow grass	416
Woodrush	416, 420
Wood sorrel	416
Woollypod vetch	79, 143, 255, 257, 415
Workboard	12, 42
Wormseed mustard	416
Woundwort	416
Xeranthemum	394, 423
Yardlong bean	396
Yarrow	416, 417
Yellow beardgrass	203, 396
Yellow blossom sweetclover	75, 400
Yellow bluestem	202
Yellow chamomile	399, 417
Yellow clover	400
Yellowcress	237, 416
Yellow false-mallow	403, 422
Yellow fieldcress	237, 403
Yellow foxtail	229, 416
Yellow hop-clover	416
Yellow Indian grass	127, 405
Yellow lupine	73, 143, 245, 246, 407
Yellow melilot	248
Yellow nutgrass	408, 419
Yellow oxalis	409, 421
Yellow pea	416
Yellow rocket	416
Yellow star-thistle	413, 418
Yellow sweetclover	247, 413
Yellow trefoil	416
Yellow trisetum	414, 423
Yellow vetch	255, 256, 415
Yellow vetchling	242, 415
Yorkshire fog	416
Zea	62, 126, 394
Zigzag clover	250, 254, 400
Zoysia	65, 127, 231, 394
Zoysia	231, 416



Rulers to be cut out and used for measuring seeds.