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RUSSIAN-THISTLE AS A SUMMER HOST PLANT OF
THE BEET LEAFHOPPER IN THE SAN JOAQUIN VALLEY,
CALIFORNIA, AND METHODS OF REDUCING ITS ACREAGE

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INTRODUCTION

The beet leafhopper (Eutettix tenellus (Bak.)) is the only known vector of the virus of curly top, a disease which causes losses to sugar beets, tomatoes, beans, and other crops throughout that portion of the United States west of the Rocky Mountains.

Russian-thistle (Salsola pestifer A. Nels.) is a very important host plant of the beet leafhopper in a large portion of the insect's range, and in the San Joaquin Valley of California it is the most important host plant of this insect during the summer months from May to October. The purpose of this circular is to summarize the accumulated information regarding the habits and characteristics of Russian-thistle, its relations to the beet leafhopper, and possible control measures in California. 1/

1/ The information on weed host plants contained in this circular, aside from the relation of these plants to the beet leafhopper, is largely abstracted from the manuscript for a technical bulletin of the U. S. Department of Agriculture (not yet published) entitled "The Ecology of the Principal Summer Hosts of the Beet Leafhopper in the San Joaquin Valley, California," by F. R. Lawson and R. L. Piemeisel. In addition, much of the information presented is based upon the work of Piemeisel and Lawson in California, "Types of Vegetation in the San Joaquin Valley of California and Their Relation to the Beet Leafhopper." U. S. Dept. Agr. Tech. Bul. No. 557, 29 pp., 1937; and on the work of Piemeisel in Idaho, "Changes in Weedy Plant Cover on Cleared Sagebrush Land and Their Possible Causes." U. S. Dept. Agr. Tech. Bul. No. 654, 45 pp., 1938.

THE BEET LEAFHOPPER AND ITS HOST PLANTS

The life history of the beet leafhopper in California will be briefly described before its host-plant relationships are discussed.

For its reproduction this insect depends upon two sets of host plants, namely, winter annuals, which are the chief constituents of the vegetation on grazing lands of the western plains and lower foothills, and summer annuals, which are abundant on idle, intermittently farmed lands in the valley proper and to some extent also on deteriorated grazing land. In winter the adult females of the beet leafhopper live on the winter annuals and toward spring they deposit their eggs. The brood that hatches from these eggs leaves the ripening winter annuals in April or May and scatters widely. Many individuals reach the summer host plants and breed on these throughout the summer, ordinarily producing three generations. When the summer hosts die the insects are again forced to move, and large numbers again reach the winter annuals--the spring breeding grounds. In the years when winter annuals have not yet germinated because of inadequate fall rains, the leafhoppers exist on any green vegetation until germination takes place and winter annuals are available as food. Thus the annual cycle is completed.

During the spring movements, and to a lesser extent in the late summer or fall movements, beet leafhoppers temporarily infest practically all plants in the San Joaquin Valley and establish populations on favorable hosts. In most years this infestation extends into the Sacramento Valley and also into the Salinas Valley, as well as other districts along the coast. Throughout the infested areas those plants that are susceptible to the disease are infected, and if leafhoppers are sufficiently numerous, serious losses occur in susceptible crops.

Surveys have shown that the acreages of summer hosts are much smaller than the acreages of the winter annuals that serve as winter and spring hosts, and as a means of leafhopper control it would be easier to reduce the acreage of summer hosts. Although the leafhopper has many summer host plants, most of these are either very poor hosts or are so restricted in distribution or abundance that they are not of practical importance. Only four are important. Three are weeds, bractscale (Atriplex seranana A. Nels.), fogweed (Atriplex expansa (S. Wats.)), and Russian-thistle, and one is a crop plant, the sugar beet. The sugar beets often support high populations of the beet leafhopper during the summer, but in the San Joaquin Valley most of the crop is usually harvested before the middle of August, and insects from these fields must find other summer hosts in order to survive until the winter hosts germinate.

Bractscale is a very good host and is abundant, but in many areas it dies early in the season, and the leafhoppers from this source, like those from beets, must find other summer hosts to survive until the winter annuals come up in the fall.

Fogweed also dies early and, moreover, is usually a very poor host. Large numbers of leafhoppers may be produced on this plant, but in most years and in most areas populations are very low if compared with those of other hosts.

This leaves Russian-thistle as the only summer host which normally has high populations of the insect and which usually survives until late in the season. On large areas of this weed the usual fall population is from 25 to 50 beet leafhoppers per square foot and in some years it is even higher. For instance, in the fall of 1934 a block of several thousand acres averaged over 500 leafhoppers per square foot, and one large field had over 1,000 per square foot.

Russian-thistle is also important in another way. Besides being a very good host, a larger proportion of its acreage occurs on the west side of the valley and near the spring breeding grounds. Studies of the fall movements have indicated that only a small percentage of the insects bred in the middle and eastern portions of the valley ever reach the spring breeding grounds, and only those originating near the western foothills have a fair chance of survival.

ABUNDANCE OF SUMMER HOST PLANTS

The possibility of reducing the acreage of the summer host plants of the beet leafhopper depends to a large extent upon the area occupied. The three important weed hosts, particularly Russian-thistle, are widely distributed and infest much of the farm land in the San Joaquin Valley. However, most of this infestation is so light that it is of very little importance as a source of beet leafhopper populations. For instance, a strip of weeds $4\frac{1}{8}$ feet wide and 2 miles long by the side of the road is very conspicuous but actually contains only 1 acre. In estimating the abundance of weed hosts it is necessary to draw a more or less arbitrary line between stands which shall be included and those which shall be ignored. In making the estimates of weed-host acreages that follow, dense patches, if small, as in barnyards, have been ignored, and so have large areas if the stand was sparse and under 10 percent.

Comparative acreages of the three important weed hosts of the beet leafhopper for a period of several years are given in table 1. The figures do not include San Joaquin, Stanislaus, and Merced Counties, which were surveyed only 3 years, from 1933 to 1935. These three counties contained from 2,000 to 8,000 acres of Russian-thistle, 1,000 to 5,000 acres of bractscale, and 200 to 1,000 acres of fogweed.

A better conception of the magnitude of weed-host areas can be obtained by a comparison with the acreages of the crops affected. Figures for sugar beets and tomatoes, which are the two most important crops affected by the leafhopper in this area, are given in table 2.

Table 1.--Comparative acreages of the three important summer host plants of the beet leafhopper in the San Joaquin Valley

(These figures are estimates based on partial surveys, and only large variations are considered significant.)

East and central portions of the valley							
	1931	1932	1933	1934	1935	1936	1937
Russian-thistle:	97,000	55,600	47,600	30,300	6,000	6,500	
Bractscale	114,000	44,300	36,700	16,200	5,700	7,500	
Fogweed	163,700	74,000	50,000	63,100	23,800	39,700	
West portion of the valley							
Russian-thistle:	27,500	11,300		39,200	50,400	30,000	32,400
Fogweed		1,500	400	4,700	2,300	1,800	900

Table 2.--Total acreage of sugar beets and tomatoes in the principal areas affected by leafhoppers from the San Joaquin Valley*

Location	1931	1932	1933	1934	1935	1936	1937
San Joaquin Valley:	7,513	7,260	7,931	14,114	21,036	31,816	31,575
Sacramento and Salinas Valleys	73,032	80,413	85,586	89,216	101,022	137,942	130,731
Total	80,545	87,673	93,517	103,330	122,058	169,758	162,306

*Figures obtained from the California Cooperative Crop Reporting Service.

In the San Joaquin Valley the losses from curly top are moderate to heavy. In the Sacramento and Salinas Valleys losses are light to moderate, although in some years they have been severe.

Since Russian-thistle is the only summer host found in abundance near the overwintering areas of the leafhopper, it is reasonable to assume that if this weed were greatly reduced in area in this district, a proportional reduction in beet leafhopper populations would be effected (excepting possibly Kern County, in which the movements of the insect in relation to the host areas have not been sufficiently studied). This does not mean that either Russian-thistle or the beet leafhopper would be completely eliminated as pests, but that the acreages of Russian-thistle, populations of the insect, and crop losses from curly top would be greatly reduced.

CHARACTERISTICS OF RUSSIAN-THISTLE

It is obvious that if measures designed to reduce the acreage of Russian-thistle are to be undertaken, careful consideration should be given to the characteristics of the plant in order to discover the best methods of attacking the problem.

Russian-thistle is strictly an annual growing from seed each year. It normally germinates in the spring in March or April but grows rather slowly until the coming of warm weather in May or June. Seed may be set as early as the first of July, but if sufficient moisture is present in the soil, growth and seed production will continue until frost. If there is not sufficient moisture, death may occur any time between germination in the spring and freezing weather in the fall.

Russian-thistle, like all other wild plants, is often forced to engage in a struggle for existence with other species. In the San Joaquin Valley its principal competitors are winter annuals, which germinate in the fall and grow during the winter. Since Russian-thistle does not germinate until spring, it is at a serious disadvantage. In this region very little, if any, rain falls in the summer months from July to September. Consequently, Russian-thistle on unirrigated land must depend for its greatest growth on moisture stored in the soil. If winter annuals are present, they have first chance at the water supply, and if they are sufficiently abundant, they will use up the soil moisture so that none is left for Russian-thistle. As a result, Russian-thistle, except under special circumstances, can grow only where the winter annual cover has been destroyed or greatly reduced. Such conditions are found in the cultivated districts on plowed land. But where a crop is planted the weed is usually destroyed by tillage, so that the only places where it can become abundant are on fallow fields, on abandoned land, or in thin stands of grain. This type of land is common in the poorer districts where there is excessive alkali or inadequate irrigation water, and in years when the prices of farm products are low many fields lie idle and large acreages of Russian-thistle are produced. But even here the species leads a precarious existence. Fallow or abandoned fields are usually plowed again within 1 or 2 years, or, if they are not plowed, the winter annuals come in so quickly that they crowd out Russian-thistle. Records kept of a number of fields which were not plowed and which contained heavy stands of the weed showed that only 36 percent survived 2 years in succession. This means that, if Russian-thistle is to hold its own and maintain a stable acreage in agricultural districts, there must be a continuous succession of idle lands available, and seed must be carried to these new areas.

In years when farm prices are high, very little land is permitted to lie idle, and the only place where Russian-thistle can grow in abundance is on deteriorated grazing lands. It is on this sort of deteriorated land that most of the Russian-thistle acreage in the western portion of the valley is found at present. Throughout this portion there is generally a fairly good cover of winter annuals, and the struggle for existence is usually severe.

Under these conditions the weed can survive only in those years when additional moisture is received after the winter annuals have died. This is provided by late rains or floods, which enable the seedlings that had come up earlier in the season to survive and continue to grow. In this region such rains are very irregular in distribution and time of occurrence. They usually are local showers over a comparatively restricted area and may not occur in the same place two years in succession.

Thus, on grazing land, as in the cultivated district, places suitable for the growth of Russian-thistle are continually shifting in location, and widespread seed dissemination is necessary for the weed to maintain a stable or increasing acreage. Such dissemination is dependent on plants that are well spaced, grow to be rounded in shape, and have an abundance of seed, and not on the crowded plants that become slender in shape and produce little seed. After the round-shaped individuals have died they break loose at the soil level and roll before the wind as typical tumbleweeds, scattering seed as they go. However, the slender or small plants either are entangled and are not broken off or, if broken off, do not roll extensively.

Wide distribution of seed is somewhat limited by the tendency of rolling plants to drop the bulk of their seed in the first 2 or 3 miles, although the empty bushes may travel long distances. Also, even the rounded plants are not broken off immediately after death but tend to remain in place until after the first rains have fallen. Thus there is an interval when the dry plants can be easily burned before the seed has been widely scattered.

POSSIBLE METHODS OF REDUCING THE ABUNDANCE OF RUSSIAN-THISTLE

In the San Joaquin Valley large sums of money have been spent and much effort has been expended in attempts to eradicate Russian-thistle locally. It should be emphasized that this circular does not deal primarily with this type of control. The stands which are ordinarily present in farm land and which cause expense and considerable trouble to farmers are usually too thin and scattered to be of much importance as leafhopper breeding areas. Most of the measures which will be considered in this paper are useful only for reducing large acreages of heavy stands and preventing increases.

Since the winter annual cover of much of the San Joaquin Valley is of such great importance is restricting the area occupied by Russian-thistle, any method used in control must not destroy this cover, otherwise the measures applied will do more harm than good. This is true for the permanent grazing lands only, since in the cultivated district, where the fields occupied by the weed are plowed every year or two anyway, this consideration is a minor one. Here any measure can be used which effectively destroys the weed and does not impair the productivity of the soil.

Reduction of Russian-thistle Acreage in Cultivated Land

Within the cultivated district Russian-thistle acreage can be reduced by destruction of the growing plants and seeds or by the prevention of seed dissemination.

Destruction of plants and seeds

Like most annual weeds, Russian-thistle will die if cut off at or near the surface of the ground below the first branches. The roots are not extensive, and any cultivating tool which pulls up or cuts off the plants will destroy them.

The best time to destroy a stand of Russian-thistle would be before the plants have produced seed, that is, about July 1. However, on large-scale experiments in heavily infested sections it would be more practicable to wait until later in the season, even though it is necessary to gather and burn the plants to destroy the seeds. Many fields of the weed which appear to be green and succulent in the spring will die without producing seed before the middle of the summer. This premature drying is usually a result of competition with other species, although very often Russian-thistle grows so thickly that it dries prematurely. Whether a given field will die before seed is produced cannot be definitely foretold early in the season, since a late rain may make the difference between survival and death. In years when rain falls in June, many fields survive that would otherwise have perished.

Destruction of plants and seeds is continually practiced by farmers in infested localities to eliminate Russian-thistle as a weed in crops. In newly infested districts county and State authorities have carried out extensive campaigns intended to prevent further spread. The sugar-processing companies that are directly affected by damage from the curly top disease have destroyed stands of the weed on considerable acreages in strategic locations where high populations of the beet leafhopper were present.

The cost of destroying Russian-thistle by tillage depends upon local wages paid to labor and the price of fuel oil and other materials. A very cheap and effective method was devised by ranchers in the Carrizo Plain where Russian-thistle was invading dry-land grain fields. A 10-foot weeder blade was mounted on wheels to run about an inch below the surface of the soil. An ordinary hay rake was hitched behind each blade, and three of these devices were pulled behind a tractor, so that a 30-foot swath of weeds was cut and piled in windrows in one operation preparatory to burning. The cost ranged from 25 to 35 cents per acre. This weeder can be used only where the soil is level and not too compact.

Another relatively cheap method has been used by farmers in the Mendota section and to some extent by the sugar companies. This consists in dragging and piling the weeds with a railroad rail drawn behind a tractor.

This method is not effective except in stands of large, nearly mature plants. Even in such stands many small plants will be missed by the drag. The method will prevent the scattering of seed to other fields if the large plants are burned, but it does not effectively destroy the local supply of seed. It costs about 75 cents per acre and has been used primarily to clear fields for plowing.

The prevention of seed dissemination

The methods listed under this heading are intended primarily to prevent the infestation of new fields of Russian-thistle and not to reduce local ones. As pointed out above, the large acreages of Russian-thistle can be maintained only if new fields are constantly infested. If extensive seed dissemination is prevented, very few new fields will be seeded, and existing infested acreages will be reduced partly by replowing and partly by the replacement of Russian-thistle by winter annuals.

It has also been noted that Russian-thistle plants do not break loose and roll immediately after death but remain in place for some time after the first rains. During this period the plants are dry enough to burn and can be cheaply destroyed. Trials of burning were made in three counties of the San Joaquin Valley in 1933 and 1934, relief labor being used. The work was carried out satisfactorily only in Stanislaus County. Gangs of men were employed to burn all of the Russian-thistle plants that could be found in certain portions of this county. In spite of the fact that only hand labor was used and the work could not be completed until after the rainy season had begun, there was a marked reduction in Russian-thistle acreage as a result of the program. It was found that heavy stands could be burned in place early in the season by careful tending and resetting of fires. Where there were thin stands, piling the plants was necessary, and later in the season during wet weather piling was necessary in all kinds of stands. Piles of the weed would burn readily even when wet if the fire was started with a hot flame, such as that of a blow torch.

In 1933 Russian-thistle was destroyed within a 41-square-mile area in Stanislaus County. In this year there were 1,736 acres of the weed in fields of 5 acres or more and in stands of 10 percent or greater density. The following year there were only 556 acres in such stands, a decrease of 68 percent. In an adjacent area of 73 square miles, partly in Stanislaus and partly in Merced County, where no burning was done, there were 2,222 acres in 1933 and 3,410 acres in 1934, an increase of 53 percent. The experiment was repeated in the fall of 1934 with the inclusion of some additional territory, and there was a reduction of 75 percent, from 931 acres in 1934 to 234 acres in 1935. In the check section there was a reduction of 63 percent, from 3,035 acres to 1,129 acres. Taking the changes in the checks into consideration, there was a reduction in the experimental section of 80 percent from 1933 to 1934 and 32 percent from 1934 to 1935.

When dry plants are handled as they were in this experiment, an adequate supply of seed is dropped locally, so the benefits derived do not result from the reduction of infestations already present, but are due largely to the destruction of seed available for the infestation of new areas.

Another method of preventing seed dissemination is by the erection of fences to catch wind-blown plants. This method was used in the Carrizo Plain infestation to supplement more direct measures. It is necessary to patrol the fence at intervals and burn the collected plants. Otherwise, when the infestation is heavy, weeds will pile up against the fence in such numbers that they mash it down or they may be rolled over the top of the pile. The fence should be at least 5 or 6 feet high, and burning can be more conveniently done if the fence is made of metal posts and wire.

Any of the above methods can be applied to Russian-thistle growing in cultivated sections. In large-scale programs probably a combination of methods would be most effective. On permanently abandoned land the most effective measure is the prevention of further destruction of the developing winter annual cover. If unimpeded, winter annuals will replace Russian-thistle in 1 or 2 years, but cultivation, excessive grazing, or fire may retard or reverse the process.

A further possibility of reducing the area of Russian-thistle on cultivated land would be through the application of land-improvement measures designed to eliminate intermittent farming. The maintenance of large acreages of the weed is dependent upon the temporary abandonment year after year of considerable areas of land. Any measure which decreases the extent of this practice, such as the improvement of the water supply or the permanent abandonment of the poorer sections, would result in a proportional reduction in the acreage of leafhopper host plants.

Reduction of Russian-thistle Acreage in Grazing Land

On grazing land the possible methods of reducing the abundance of Russian-thistle are limited by the necessity of considering the cover of winter annual forage plants. In order to show more clearly how the present vegetational cover affects Russian-thistle the diagram in figure 1 has been included. There are two things which must be present for Russian-thistle to grow. These are seed and soil moisture during the growing season. Seed supply is dependent upon the amount and distribution of the production of the preceding year. Since these lands are not irrigated, soil moisture comes directly from rain or from floods. Most of the rain falls during the winter. Winter rains are general throughout the valley and are a reliable source of soil moisture, but spring rains are uncertain, local in character, and may be intense, so as to cause flash floods. The outer large circle in the diagram (fig. 1) represents the general winter conditions in the valley, but, since on grazing land a good cover of winter annuals is ordinarily present, these plants use up the moisture from the winter rains before Russian-thistle can get a good start. As a result it is normally restricted to bare soil or to those areas where the cover of winter annuals has been greatly reduced. But if rain falls late in the spring after the winter annuals have died, soil moisture is available even where a good cover of these plants is present, and Russian-thistle can continue to grow and produce seed. The interaction of these factors is illustrated by the overlapping of the small circles in the diagram.

The undependable nature of the late spring rains and the restricted area they usually cover has been mentioned. Thus, if the western plains of the valley were evenly covered by a stand of winter annuals so that Russian-thistle would be entirely dependent on spring rains as a source of soil moisture, it could not grow in most years. Since most of the seed in the soil is germinated the first year by the winter rains, one or two unfavorable seasons without spring rain would so deplete the seed supply that the establishment of heavy stands would be impossible even in the most favorable years. Under present conditions, however, where the winter annual cover is broken by bare or nearly bare spots, Russian-thistle on these spots is able to produce a seed supply sufficient for a rapid increase when conditions become favorable.

There are two possible methods of reducing Russian-thistle acreage on grazing land. The most obvious is a direct attack on the seed supply by the destruction of growing plants and seed or by the prevention of seed dissemination. The second method involves an indirect attack by improvement of the present winter annual cover to the point where Russian-thistle cannot compete successfully.

Direct methods

Destructive methods such as cultivation or burning, which remove the natural cover of the soil, make a more favorable situation for Russian-thistle the next year, and, although if rigorously applied they might reduce the area occupied by weeds, it would be necessary to continue these measures indefinitely unless complete eradication could be effected. This seems a remote possibility in view of the large area infested. Such a program, even if effective, would be very expensive, not only in funds actually expended in control measures, but also in the loss of forage and in injury to livestock ranges.

There are some direct or mechanical means of Russian-thistle reduction that might be applicable to grazing land. For instance, in some sections fencing could be used to stop wind-blown plants. However, if the piles along the fences were destroyed by burning, precautions would need to be taken to prevent the fire from spreading and burning off the forage on the adjacent range.

It is probable that other direct means of reducing Russian-thistle areas on these plains can be found. It seems likely that some machine could be used to collect the plants of the weed without seriously disturbing the cover of winter annuals. This would prevent seed dissemination and, if carried on for several years, might greatly reduce the present infestations. Research and experiment might show that methods such as burning or disking, if applied under specific conditions, would reduce the acreage of the weed without seriously injuring the future growth of the winter annual cover.

It should be pointed out, however, that while some direct measures may not injure the cover, neither are they likely to improve it. The present

areas of Russian-thistle might be reduced, but if nothing is done to improve the present stand of winter annuals and thereby decrease the area where the weed can grow, constant vigilance will be necessary to prevent a rein-festation.

Indirect methods

On the basis of present information the most effective means of reducing Russian-thistle areas on these plains would be through an improvement of the present cover of winter annuals.

This can be done most effectively by a decrease in the present rate of removal of forage. Any area of grazing land produces each year a certain amount of forage. Part of this can be removed without injury to the productive capacity of the range. But if all or nearly all the more palatable plants are removed, those that remain are not able to compete with less palatable species and eventually die out. This decline continues through a series of less and less palatable plants until only a few scattered weeds remain on the soil. During this process of deterioration the productive capacity of the land steadily decreases, but if the rate of removal of vegetation is decreased to a point below the immediate productive capacity, the process is reversed and the capacity of the range increases. Any agency which destroys vegetation, whether it is livestock, rodents, fire, or plowing, will cause deterioration if the sum total of its effect added to that of the others is greater than the current productive capacity of the land. In a series of wet years temporary improvement may occur if productive capacity increases faster than the range load, but such gains are usually wiped out very quickly when a return to a cycle of normal or below-normal rainfall occurs.

The grazing lands of the San Joaquin Valley over a long period of years have been gradually deteriorating as a result of excessive use. There are numerous indications of this, the most obvious of which include the presence of unpalatable range weeds, the absence of the formerly abundant perennial forage plants, and the presence of bare spots. Excessive grazing by livestock is probably the chief cause of deterioration, although in some areas rodents may be an important factor.

The unfavorable results of overgrazing, such as excessive soil erosion, the loss of range capacity, the silting of reservoirs, and the destruction of wildlife, have been dealt with by numerous range investigators. Here it should be emphasized that unless overgrazing is checked in the San Joaquin Valley, Russian-thistle will in the future become much more abundant than it is at present, with a consequent increase in damaging numbers of the beet leafhopper.

A program of range rehabilitation would not only reduce Russian-thistle acreages but over a period of years would pay for itself by increasing the forage value of the ranges.

SUMMARY

Russian-thistle, because of its suitability as food and its abundance in areas immediately adjacent to the spring breeding grounds, is the most important host plant of the beet leafhopper in the San Joaquin Valley during the summer months from May to October.

Estimates of the abundance of this weed from 1931 to 1937 are given. For beet leafhopper populations the most important areas of the weed are found at present in grazing land on the west side of the valley.

Russian-thistle is a summer annual incapable of competing successfully with the typical winter annual vegetation of this region. In consequence, important stands are restricted to grainfields and fallow or abandoned land in the cultivated district, and to deteriorated grazing land.

Russian-thistle is a typical tumbleweed in its habits of seed distribution.

On cultivated land it can be reduced in area by methods which destroy growing plants and seed or which prevent seed dissemination.

On grazing land such direct methods of reduction are limited by the necessity of preserving the winter annual cover of vegetation, which at present limits the acreage and distribution of the weed.

On the basis of present information the most effective method of reducing Russian-thistle acreage in grazing land would be through an improvement in the present cover of winter annuals. This can be done by a reduction in the present rate of forage removal.

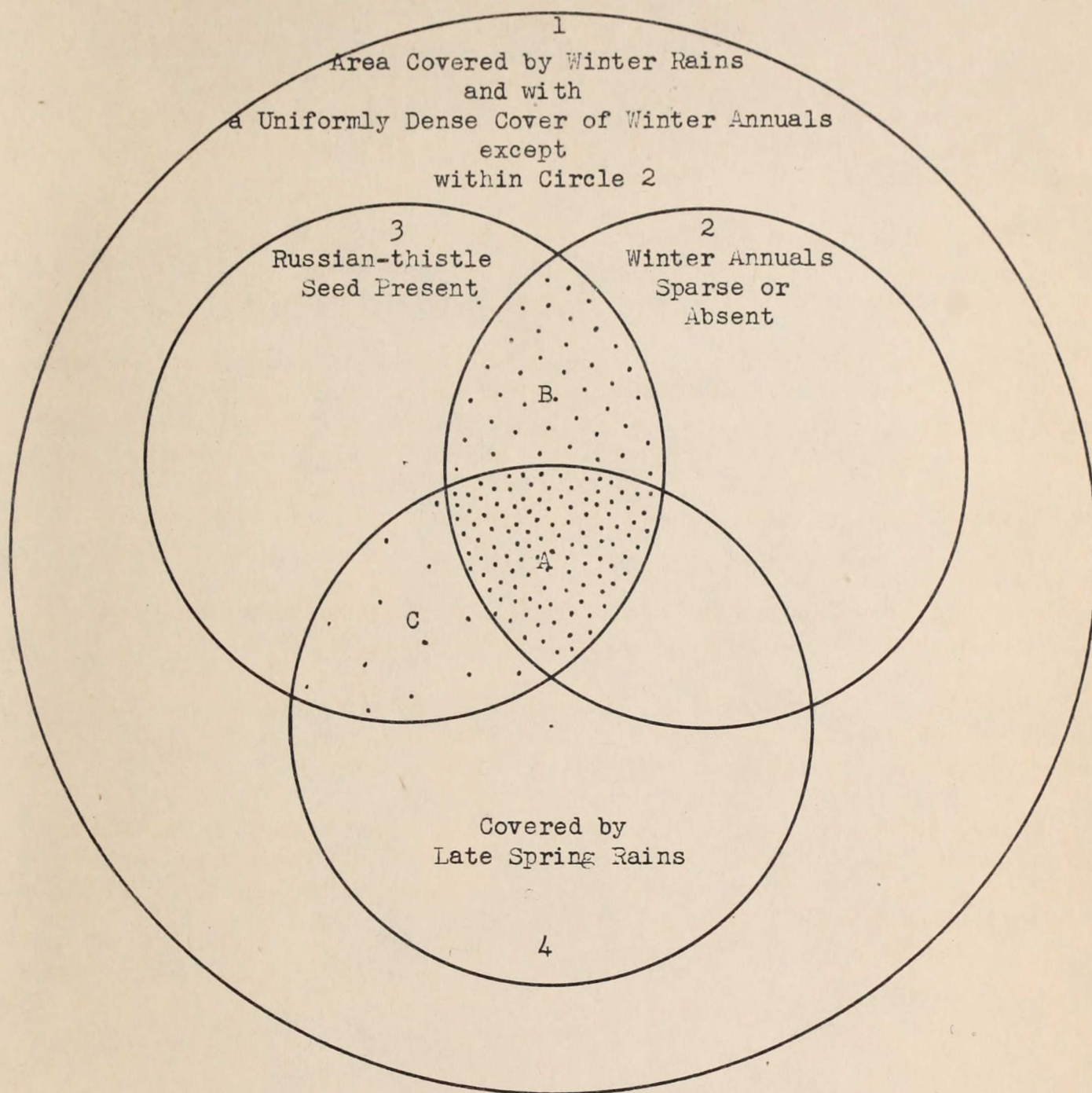
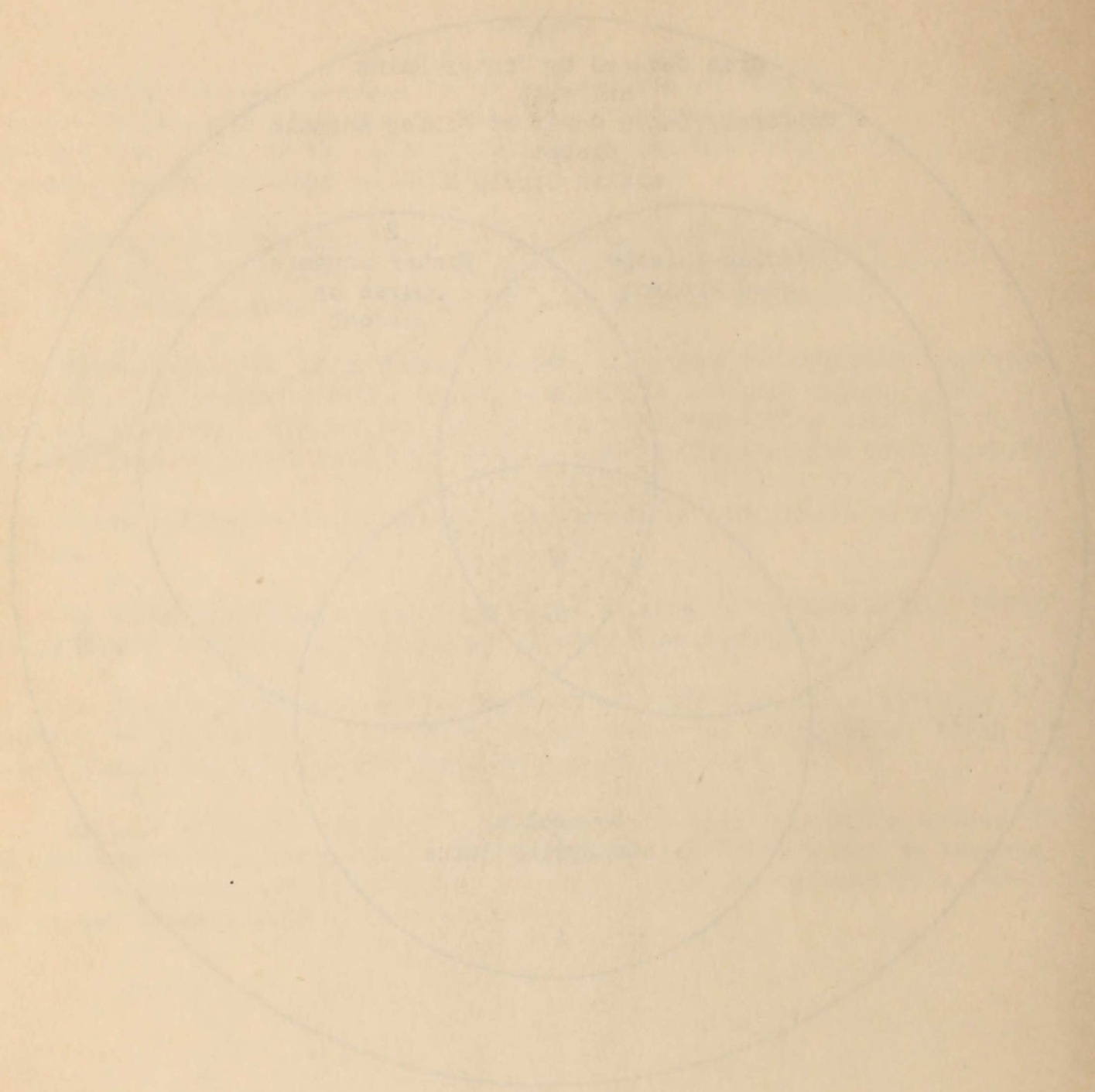


Figure 1.--Diagram of the effects of rainfall, seed supply, competition, and the interaction of these factors on the growth of Russian-thistle. A, Area where Russian-thistle almost certainly will grow and mature; B, area where Russian-thistle will grow but will die prematurely if the stand is dense; C, area where Russian-thistle will not survive except in years when late spring rains are unusually heavy.



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