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INFLUENCE OF TEMPERATURE ON THE EFFECTIVENESS OF DDT,
AND THE COMPARATIVE TOXICITY OF DDT AND LEAD ARSENATE
TO LARVAE OF THE JAPANESE BEETLE IN SOIL

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INTRODUCTION

Preliminary tests during the summer of 1943 showed that DDT (2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane) was very effective against larvae of the Japanese beetle (Popillia japonica Newman). In the fall an investigation was undertaken to establish the relationship between the temperature of the soil and the insecticidal action of DDT, and to compare the toxicity of this material with that of lead arsenate.

THE DDT

The DDT used in this investigation was the pure material. In order to facilitate mixing the material with soil, it was diluted with talc in the ratio of 1:9 by weight. This mixture was sufficiently fine to pass through a 100-mesh screen.

EFFECTIVENESS OF DDT AT DIFFERENT TEMPERATURES

The DDT was thoroughly mixed with sifted sassafras sandy loam at the rates of 0.416, 1.04, and 2.08 grams per cubic foot, which was equivalent to incorporating 10, 25, and 50 pounds of DDT with the upper 3 inches of an acre of soil. The soil and the chemical were mixed by being passed twice through a gyratory riddle. The soil was then placed in trays that were 18 inches square and 3-3/4 inches deep, about 1/3 cubic foot of soil being put into each tray. The soil was brought to optimum moisture, and grass seed was sown. Each experimental unit consisted of two or more trays of unpoisoned soil and two or more trays of each treatment with DDT.

Experimental units were placed in chambers, in which temperature was maintained with a variation of $\pm 1^{\circ}$ at 50° , 60° , 70° , and 80° F. A few days after an experimental unit had been placed in a chamber, 100 third instars were introduced into each treated and

untreated soil. The different batches of third instars, which varied in age and degree of development, were collected in the field. At intervals which varied with the temperature the larvae were removed from the soil for examination. A record was made of the number of dead and living individuals in each tray. After examination the living larvae were returned to the soil and each tray was reseeded and watered. The experiments were repeated from four to twelve times with different batches of larvae, a total of 10,400 being used in this investigation.

The mortality of larvae in soil containing DDT is the result of poisoning and, to some extent, other factors such as bacterial disease, nematodes, and injury. In order to estimate the net mortality that could be attributed to poisoning, the percentage of the larvae killed by each treatment was determined by the formula:

$$\text{Percent killed by poison} = \frac{\text{Number alive in untreated soil} - \text{Number alive in treated soil}}{\text{Number alive in untreated soil}} \times 100$$

Scatter diagrams of the relationship between the percentage killed and the number of days the larvae had been in the treated soil were prepared for the 10-, 25-, and 50-pound treatments at each temperature. The average time-mortality curves were then calculated from these data. These curves are presented in figure 1.

The deviation of each experimental value from the curve was determined. From these deviations, the average standard deviation of the 10-pound treatment was found to be 26.8 percent, of the 25-pound treatment 21.5 percent, and of the 50-pound treatment 18.3 percent. The individual experimental values were not entered in figure 1 because the number of them (862) tended to be confusing on the preliminary charts.

The experimental errors are somewhat higher than usually obtained in this type of work but may be attributed to the variability in the resistance of the different batches of larvae to poisoning and to the difficulty of incorporating such small quantities of a poison uniformly throughout a mass of soil. The smallest quantity of lead arsenate recommended for soil treatment against the Japanese beetle is 500 pounds per acre, or 1 part of lead arsenate to 1,600 parts of soil by weight. The DDT was mixed with soil at the rates of 1:16,000, 1:32,000, and 1:80,000.

As can be seen from figure 1, the effectiveness of DDT against the third instars was modified profoundly by the temperature. The 10-pound treatment required on the average something over 90 days at 50° F. to kill half of the larvae, 26.9 days at 60° F., 23.5 days at 70° F., and 11.7 days at 80° F. The 25-pound treatment accomplished this in 35.6 days at 50° F., in 19.5 days at 60° F., in 11.3 days at 70° F., and in 9.1 days at 80° F., and the 50-pound treatment in 26.5 days at 50° F., in 14.5 days at 60° F., in 10.2 days at 70° F., and in 6.3 days at 80° F.

RELATIVE VELOCITY OF POISONING AT DIFFERENT TEMPERATURES

There seemed to be a definite relationship between the temperature and the velocity of poisoning with a given treatment of DDT. As the reciprocals of the time required to obtain a definite level of mortality are a convenient measure of the relative velocity of poisoning, the data were converted to this form for further study.

From the average curves given in figure 1 the number of days required to kill 30, 40, 50, 60, and 70 percent of the larvae were determined, then the reciprocals of these values were obtained. For each level of poisoning the reciprocals were plotted against the corresponding temperatures. An approximate straight-line relationship seemed to exist between the relative velocity of poisoning and the temperature. The slopes of these lines were determined by the method of least squares. The curves for the 30-, 50-, and 70-percent levels of poisoning are presented in figure 2. The curves for the 40- and 60-percent levels were omitted because of the lack of space.

The velocity of poisoning increased progressively with the increment in the temperature. At 60° F. the velocity of poisoning was usually double that at 50° F.; at 70° F. it was tripled, and at 80° F. it was quadrupled. The velocity of poisoning with lead arsenate has been found to increase with temperature in the same manner(2).1/

THRESHOLD TEMPERATURE OF POISONING

The minimum temperature at which larvae are sufficiently active to ingest DDT in the soil is an important factor in that it limits the period of insecticidal action in the fall and in the spring. The threshold temperature above which the larvae begin to ingest perceptible amounts of food has not been determined experimentally.

It may not be possible to determine experimentally the temperature above which poisoning will be perceptible but it is possible to obtain from the reciprocal curves given in figure 2 an empirical estimate of this temperature. When the curves for the 25- and the 50-pound treatments of DDT were extended below 50° F. they intersected the X axis at points between 39.3° and 43.6° F. A temperature of 40° F. has been accepted tentatively as the approximate threshold of poisoning of larvae by DDT. These results are similar to those obtained with lead arsenate.

1/ Underscored numbers in parentheses refer to Literature Cited, p. 6.

POISONING AND THERMAL SUMMATION

With 40° F. as the threshold, it was found with the 10-, 25-, and 50-pound treatments that the products of the number of days and the number of degrees above the threshold were practically constant values for each level of poisoning. It was evident that the rate of poisoning was closely correlated with the summation of the day-degree units above the threshold.

The mortalities obtained with the 10-, 25-, and 50-pound treatments at temperatures of 50°, 60°, 70°, and 80° F. were plotted against the summations of the day-degree units above the empirical threshold. The scatter diagrams showing this relationship are presented in figure 3. The average curves were then calculated and the average standard deviations were determined. The average standard deviations are indicated on the charts as broken lines above and below each curve.

The standard errors of the thermal unit-mortality curves for the 25- and the 50-pound treatments were practically the same as those of the time-mortality curves for these treatments. The standard error for the 10-pound treatment was slightly larger.

This study of the data tends to demonstrate that, as with lead arsenate, the level of mortality obtained with a treatment of DDT is dependent upon the number of day-degree units accumulated after the larvae came into contact with the poison. With these data, it is possible to estimate the possible effectiveness of the 10-, 25-, and the 50-pound treatments from a summation of the thermal units following the application of the treatment.

DDT VS LEAD ARSENATE

Lead arsenate has been used for the control of larvae of the Japanese beetle in soil for many years. It is of great interest therefore to compare the relative effectiveness of lead arsenate and DDT in poisoning the larvae.

A study was made of the relative velocities of poisoning of the larvae by DDT and lead arsenate. The reciprocals of the time required to poison half of the larvae with 500 and 1,000 pounds of lead arsenate and with 10, 25, and 50 pounds of DDT were plotted against the corresponding temperatures. These curves are shown in figure 4. In this case the height of each curve above the X axis was adjusted slightly so that all of the intercepts would be at 40° F.

It was found that the velocity of poisoning with the 500-pound lead arsenate treatment was half the rate with the 1,000-pound treatment. The velocity of poisoning with 10 pounds of DDT per acre was not significantly different from the rate with 1,000 pounds of lead arsenate.

The rates with the 25- and the 50-pound treatments of DDT were significantly greater than that of 1,000 pounds of lead arsenate. The velocity of poisoning with the 25-pound treatment was 28 percent faster and the velocity with the 50-pound treatment 76 percent faster than the rate with 1,000 pounds of lead arsenate.

The poisoning of larvae in the soil is a joint function of the amount of poison in the soil and the accumulated thermal units. The joint functional relation with the 10-, 25-, and 50-pound treatments of DDT was determined according to the procedure outlined by Ezekiel (1). The joint functional relation for the lead arsenate treatments has been determined previously (2). The average mortalities obtained with the 10-, 25-, and 50-pound treatments of DDT and with the 200-, 500-, and 1,000-pound treatments of lead arsenate with thermal units from 100 to 1,000 are presented in figure 5.

The 200-pound treatment of lead arsenate was relatively ineffective, the mortality not reaching 20 percent with 1,000 day-degree units. With the 500-pound arsenical treatment, a mortality in excess of 50 percent was obtained with 800 thermal units. This level of mortality was obtained with the 1,000-pound arsenical treatment with 500 thermal units. With DDT a mortality of 50 percent or greater was obtained with the 10-pound treatment and 500 thermal units and with the 25-pound treatment and 400 thermal units. The mortality with the 50-pound treatment approached 50 percent with 300 thermal units. Within this range of thermal units none of the lead arsenate treatments poisoned more than 90 percent of the larvae. Mortalities in excess of 95 percent were obtained with the 25- and the 50-pound treatments of DDT.

The molecular weight of lead arsenate is 347.17; that of DDT is 354.35. As 10 pounds of DDT is very close in effectiveness to 1,000 pounds of lead arsenate in sassafras sandy loam, it is evident that, pound for pound, or molecule for molecule, DDT is about 100 times as toxic to the larvae as is lead arsenate.

SUMMARY

An investigation was carried on to establish the influence of temperature on the effectiveness of DDT against third instars of the Japanese beetle and to compare the relative toxicities of DDT and lead arsenate in the soil.

The velocity of poisoning of the larvae with DDT increased progressively with the increment in the temperature. At 60° F. the velocity was double that at 50° F., it was tripled at 70° F., and quadrupled at 80° F. The velocity of poisoning with lead arsenate has been found to increase in the same manner.

The empirical threshold of poisoning appeared to be about 40° F., as with lead arsenate. There was found to be a close correlation between the poisoning of the larvae and the summation of the day-thermal units above this threshold.

The velocity of poisoning with DDT at the rate of 10 pounds per acre was not significantly different from the rate with 1,000 pounds of lead arsenate. The velocity with the 25-pound treatment was 28 percent faster and with the 50-pound treatment 76 percent faster than that with 1,000 pounds of lead arsenate.

Pound for pound, or molecule for molecule, DDT appears to be 100 times as toxic to the larvae in the soil as is lead arsenate.

LITERATURE CITED

- (1) Ezekiel, M.
1930. Methods of correlation analysis. 427 pp. New York.
- (2) Fleming, W. E., and W. W. Maines
Influence of temperature on effectiveness of lead arsenate against larvae of the Japanese beetle in the soil. U. S. Dept. Agr., Bur. Ent. and Plant Quar. E-622.

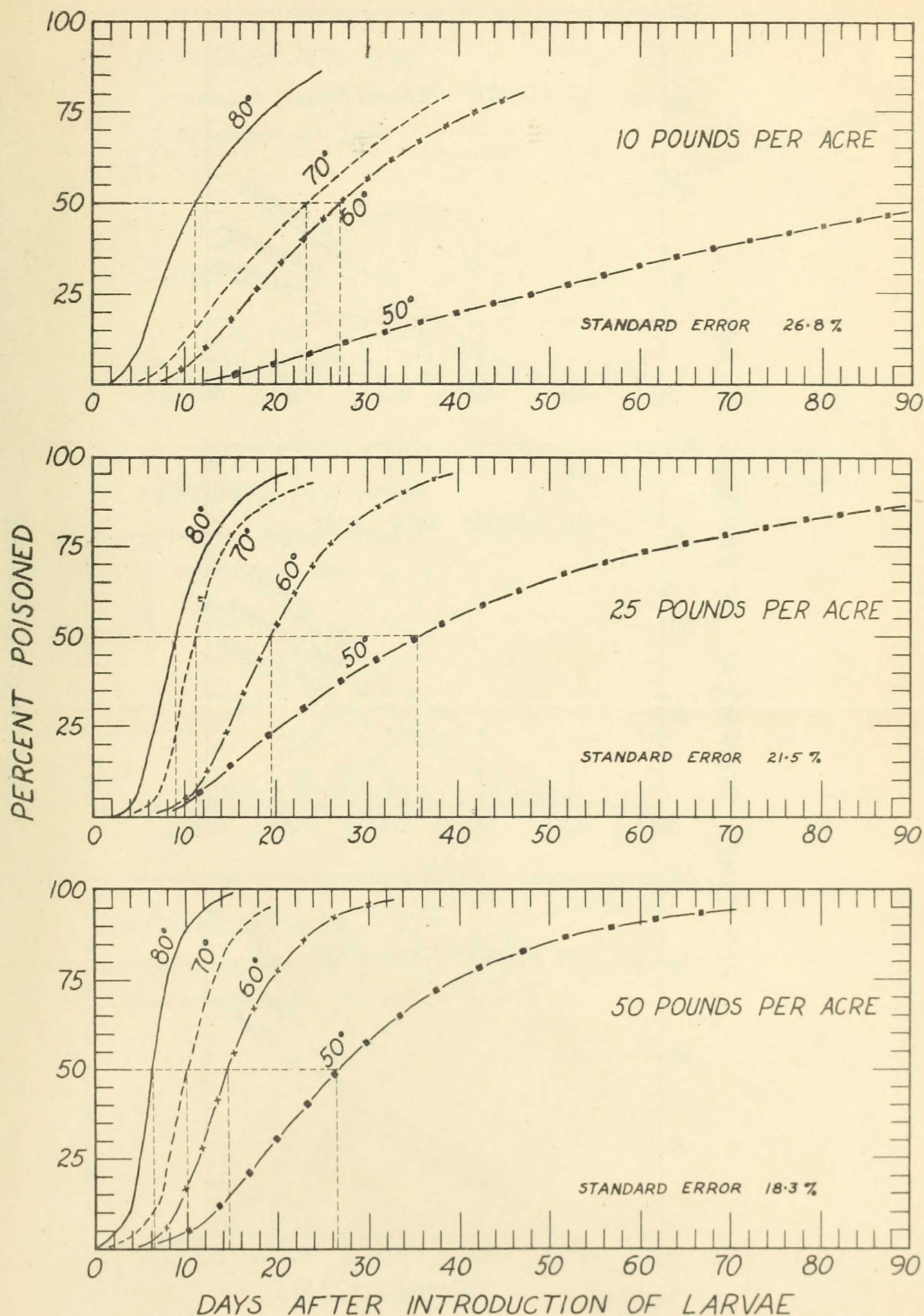


Figure 1. -- Effectiveness of the 10-, 25-, and 50-pound treatments with DDT against third-instar larvae at constant temperatures from 50° to 80° F.

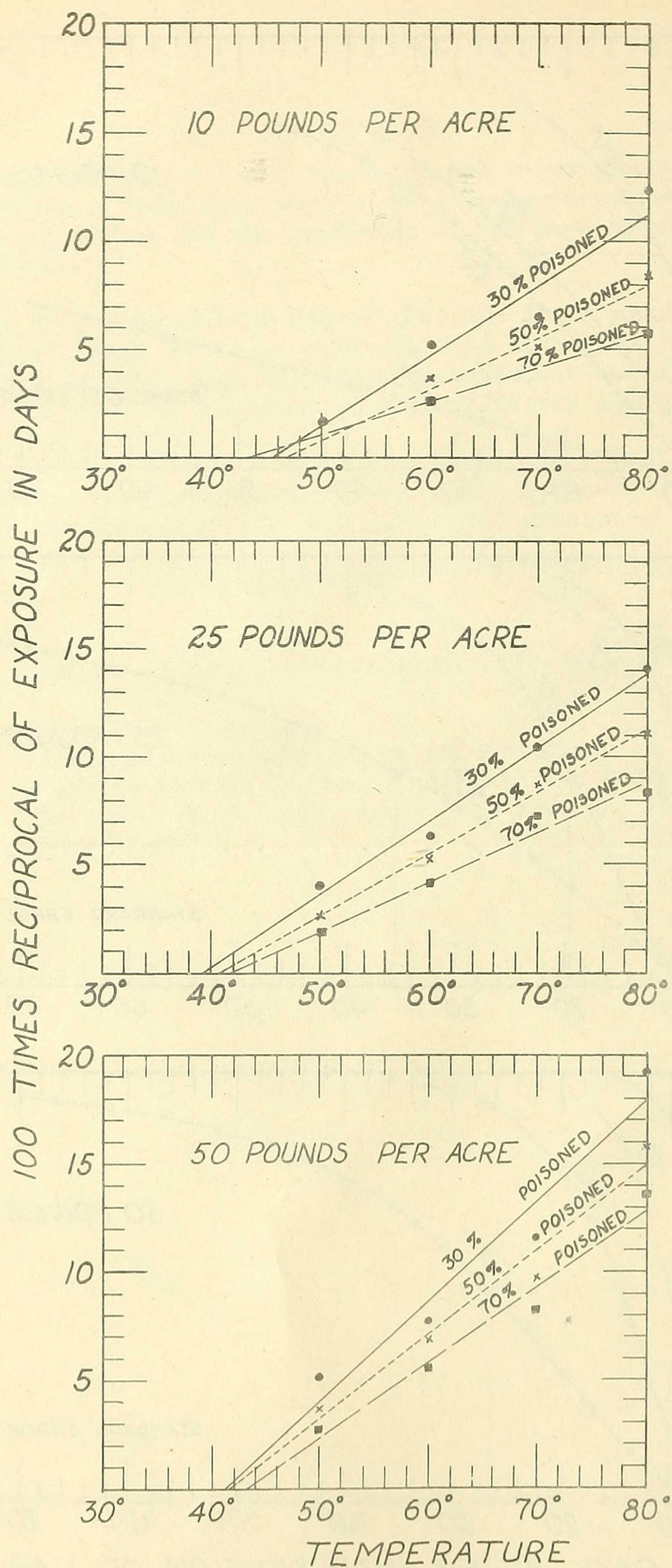


Figure 2. -- Relative velocity of poisoning of third-instar larvae with the 10-, 25-, and 50-pound treatments of DDT at temperatures of 50°, 60°, 70°, and 80° F., and the empirical threshold of poisoning.

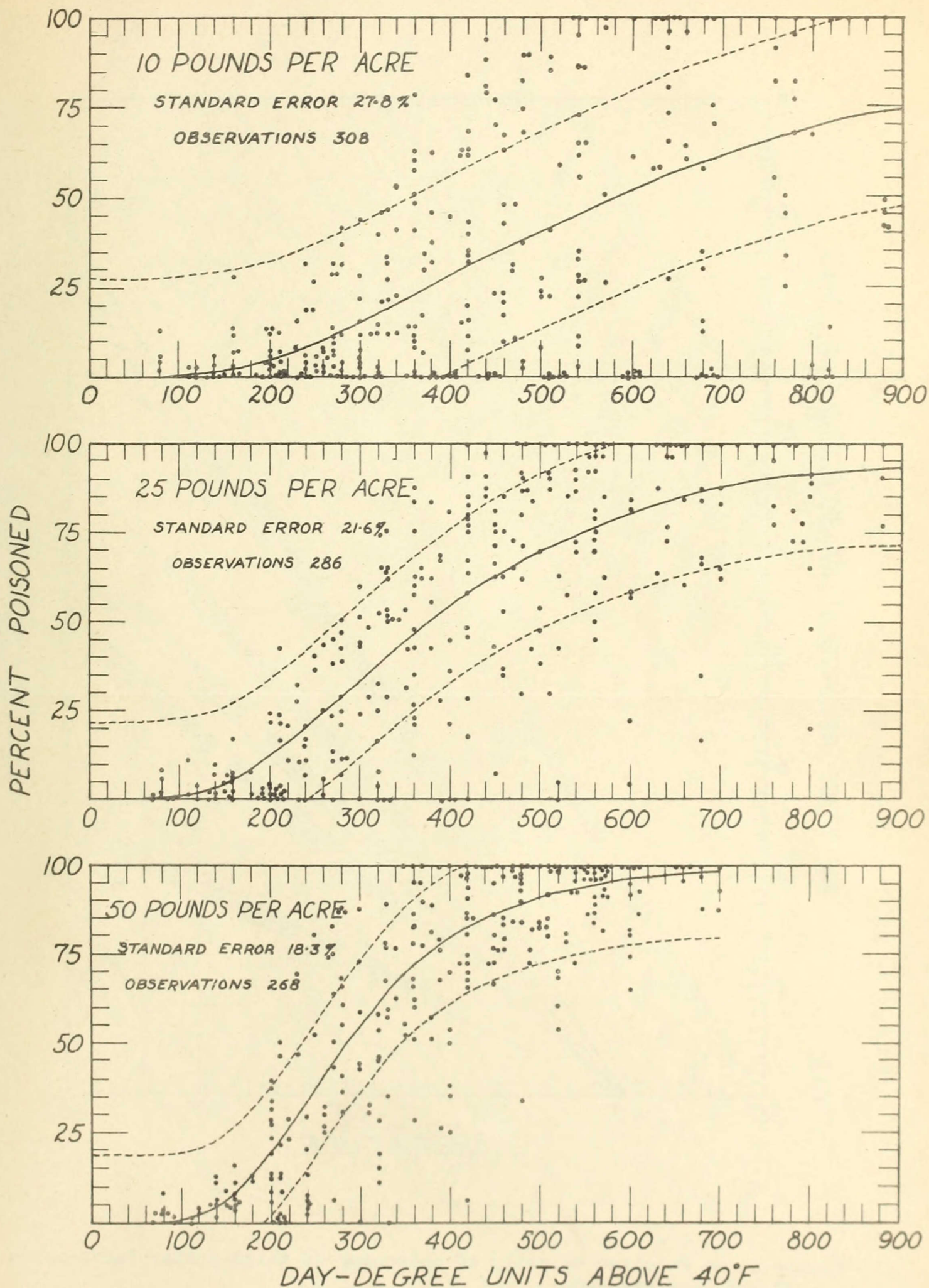


Figure 3. - Relation between the poisoning of third-instar larvae with the 10-, 25-, and 50-pound DDT treatments and accumulated thermal units above the empirical threshold.

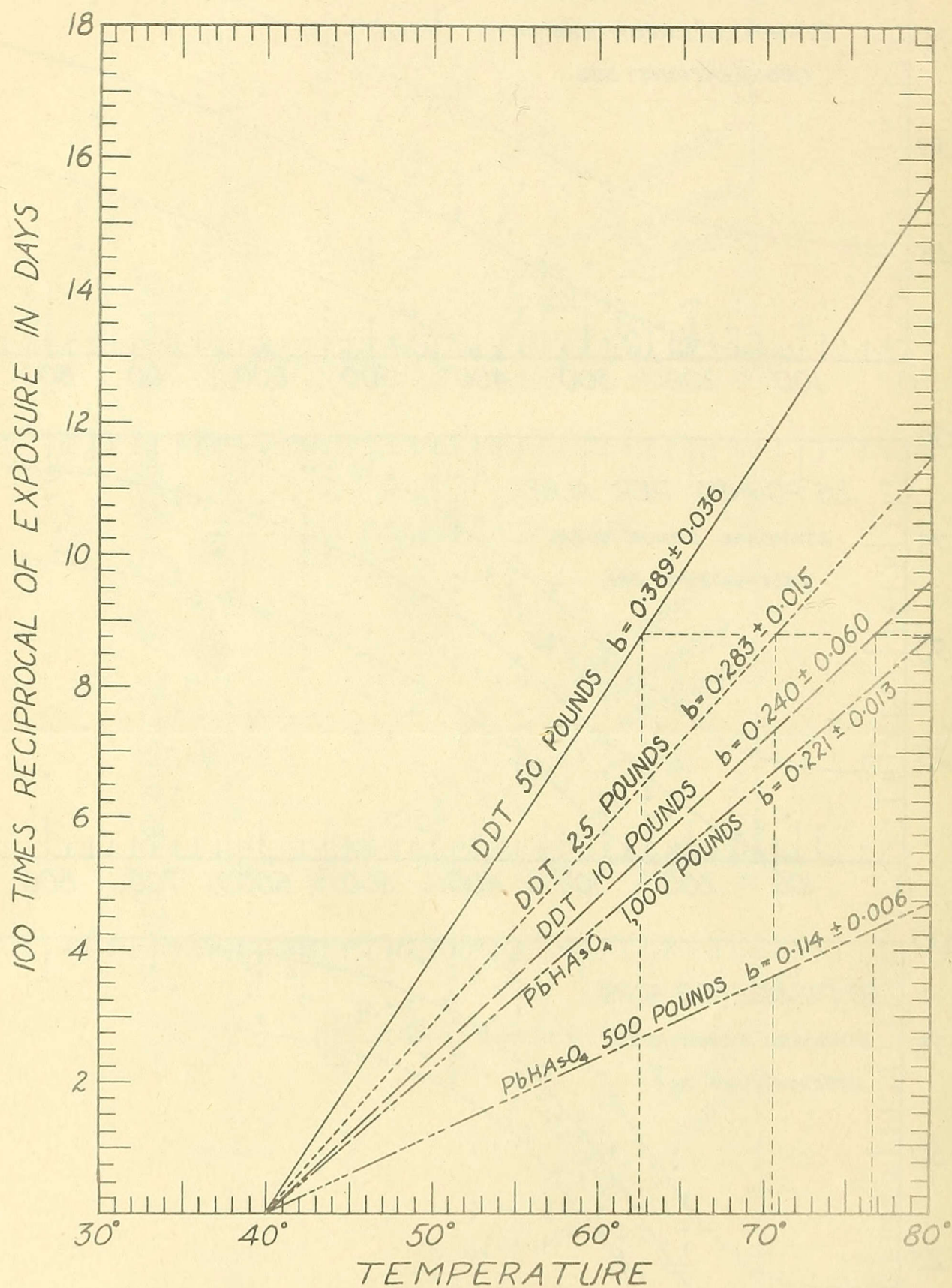
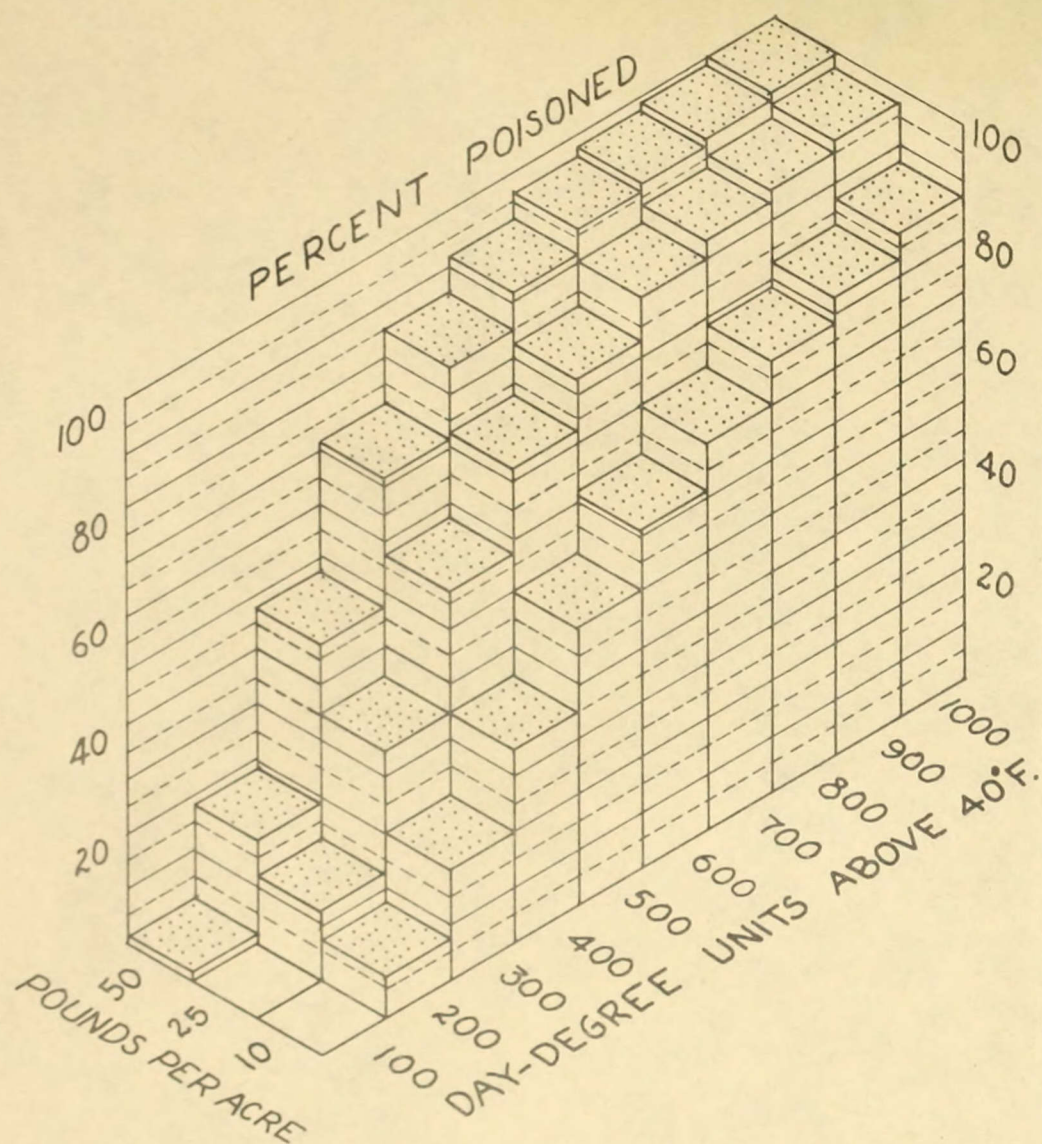
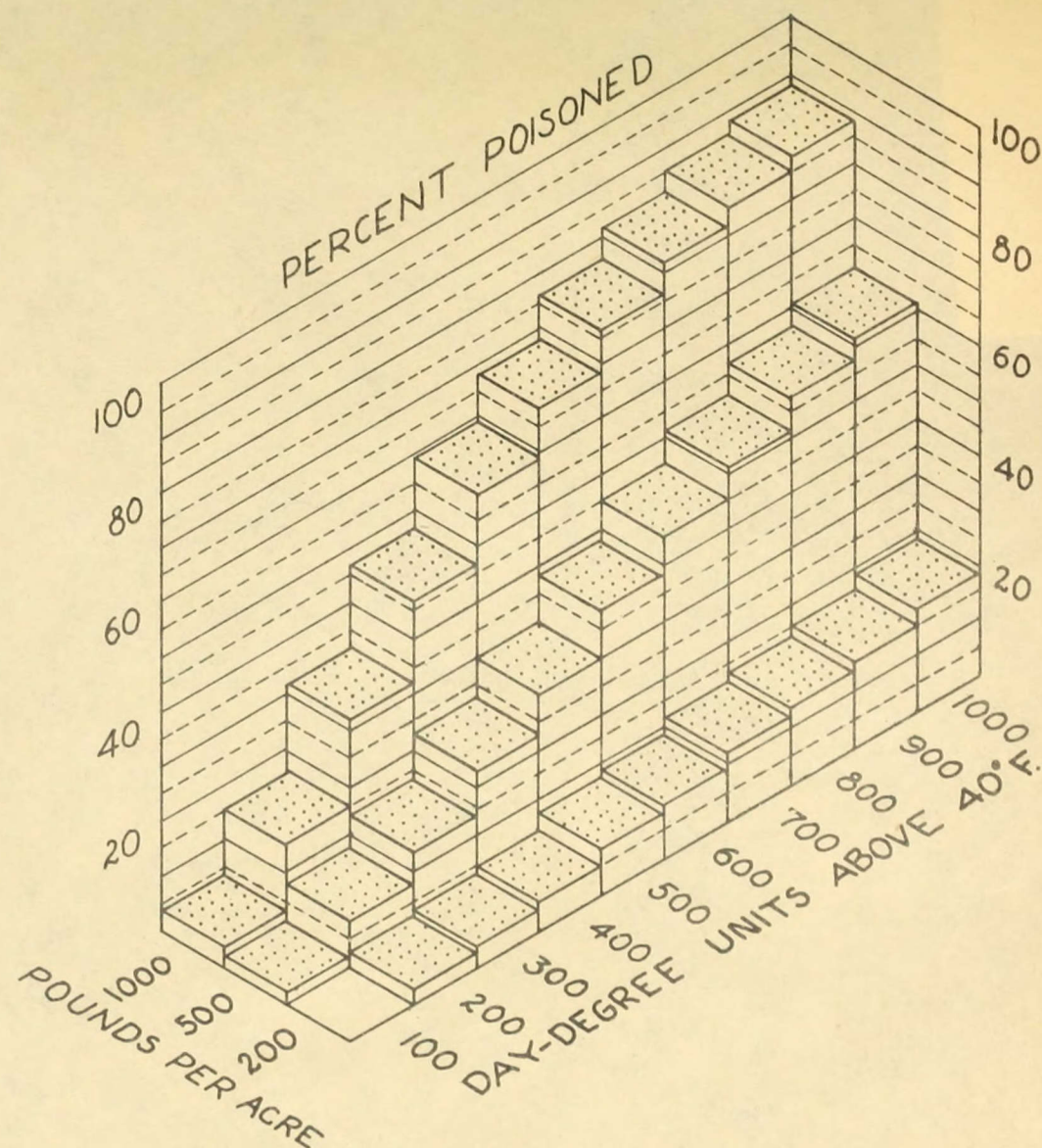


Figure 4. -- Relative velocity of poisoning of third-instar larvae with DDT and lead arsenate.



DDT



LEAD ARSENATE

Figure 5. -- The joint functional relation between the percent of the larvae poisoned, the accumulated thermal units above the empirical threshold, and the quantities of DDT and lead arsenate in soil.

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