STUDIES ON THE BIOLOGY AND CONTROL OF *LYGUS OBLINEATUS* (Say)

By

Zia-ud-Din

AN ABSTRACT

Submitted to the School of Graduate Studies of Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Department of Entomology

Year 1950

Approved Ray Hutson

Part 1

Studies on the biology of tarnished plant bug, _Lygus oblineatus_ (Say), were made because, in spite of low infestations, it causes considerable damage to crops.

"Lygus injury" varied with the crop and the part of the plant attacked, both in the test plants and in the field. Histological studies showed that necrosis started from the vascular bundles in the injured tissue.

The incubation period varied from eight to thirteen days at the mean temperatures ranging from 57.8 to 68.5° F. Nymphal development was affected similarly. The life-cycle was completed in 30 to 43 days. Females preferred chinese cabbage to beans for oviposition.

A record of variation in population of _L. oblineatus_ was compiled by counting insects per hundred sweeps every three days during the years 1949-1950. No adult was found on wing between November 25, 1949 and March 25, 1950. There was no heavy injury to fruit buds due to high mortality during hibernation. No insect survived storage at 35° F.

The infestation was at its peak during August and September but rapidly declined with the drop in temperature in October.

The ratio of males to females was four to six in June, one to one in August and September and one to nine in mid-October.

Part 2

I. Fourteen organic insecticides, at three concentrations were tested as contact sprays for the control of *L. oblineatus*. Ten insects were released on sprayed plants in each cage. Mortality counts were made every twenty-four hours. Maximum percent control is shown within parentheses in the following results.

i. Nicotine sulfate (42.9), nicotine sulfate + pyrethrum + sulfur (24.6), rotenone (6.6) and ryania (49.1) did not show satisfactory control.

ii. Methoxychlor (0.0), Pestox 3 (23.3), and allethrin (25.0) proved ineffective.

iii. DDT (85.7) and DDD (85.7) had a residual effect of six and five days respectively.

iv. Toxaphene (70) showed the effect after 48 hours.

v. Chlordane (100), lindane (100), TEPP (100) and parathion (100) had residual effect of 6, 12, 0 and 4 days respectively. TEPP hydrolized within three hours.

II. Field cage experiments were conducted for the control of *L. oblineatus* on celery. Three concentrations of lindane, four timings of sprays, and three intensities of infestation were used as variables. The harvested celery was analyzed on the basis of yield, percentage of injured stalks and number of punctures.

Four sprays increased the yield by 5.3 tons per acre over the check. This increase was reduced to 2.2 tons per acre with six sprays.

All three variables proved significant on the basis of percent injury and punctures. Four sprays of lindane at medium concentration gave satisfactory control. For better quality under high infestation six sprays were the best.

No off-flavor was detected in the treated celery.

III. Lindane, parathion, TEPP and a combination of nicotine sulfate, pyrethrum and sulfur were used in field trials for the control of *L. oblineatus* on chinese cabbage. The plots were laid out in randomized blocks replicated six times. Lindane gave significantly better control than the other three treatments.

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ACKNOWLEDGMENTS

The writer wishes to express his appreciation and most grateful thanks to Professor Ray Hutson, Head of the Department of Entomology, for his assistance and guidance in the conduct of this work and for his criticisms in the preparation of this manuscript.

The author is indebted also to a number of people for help during the progress of this work; to Dr. R. L. Carolus for providing storage facilities in the Horticulture Department; to Dr. J. F. Davis and his staff for constant help at the farm; to Dr. W. D. Baten for help in analyzing the data statistically; to Dr. H. L. King for reading the manuscript; and to the graduate students in the Entomology Department for cooperation during the course of these studies.

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PART 1

BIOLOGY OF *LYGUS OBLINEATUS* (Say)

INTRODUCTION

The tarnished plant bug, Lygus oblineatus (Say), is an important insect pest of cultivated crops. Since the early reports (Wier, 57; Riley, 35; Smith, 42; and others) of the injury to the nursery stock and garden crops by this native insect, the list of host plants has been increasing and it now includes truck crops, ornamental plants, fruit trees, forage crops, and many other cultivated and uncultivated plants.

It is not possible to figure out the exact loss due to L. oblineatus but there is no doubt that it is very extensive. In many instances the tarnished plant bug is not suspected as the insect responsible for the damage on certain plants because it does not breed on them. Moreover, by the time the injuries become apparent on the host plants, the tarnished plant bugs have moved to a more succulent crop. L. oblineatus inflicts injury not only by feeding and oviposition, which causes an upset in the development of the host plants by the introduction of phytotoxic substances, but has been suspected also as a vector of plant diseases, e.g., spindle-tuber in potato (Goss, 10) and spinach blight (McClintock and Smith, 26).

Crosby and Leonard (3) were the first to give a general description of the biology of the tarnished plant bug. It has been augmented by later workers such as Haseman (14) and Hughes (17) but in spite of it, practical control of *L. oblineatus* is still unsatisfactory.

An investigation of the biology of *L. oblineatus* was made under Michigan conditions in an attempt to find out an effective chemical control. Part 1 of this thesis is devoted to the description and discussion of the injury to the host plants, life-history, seasonal variation in the habits and the incidence of this pest. Part 2 deals with the control of *L. oblineatus* by organic insecticides.

NOMENCLATURE OF THE SPECIES

The tarnished plant bug was first described in 1746 by Linnaeus (23) as *Cimex griseus*, but was later changed by him to *Cimex pratensis*. The common name, tarnished plant bug, was first used by Riley (35) and subsequently became generally accepted in the English speaking countries of the world.

A number of different generic and specific names were given to tarnished plant bug by various systematists before Fieber (6) named it *Lygus pratensis*. Earlier, Say (37), while describing Heteroptera-Hemiptera, placed it in the genus Capsus and named it *Capsus oblineatus*. However, the tarnished plant bug has passed generally as *Lygus pratensis* (L.) in the American literature until 1941 when Knight (20) pointed out the confusion between the European species and the American species. He stated that the American species differed from the European species in the structure of the right genital clasper, darker coloration and definite stripes. He renamed *Capsus oblineatus* Say as *Lygus oblineatus* (Say).

Crosby and Leonard (3) incorporated an elaborate synonymical list for the species, *L. pratensis* (L.).

REVIEW OF LITERATURE

A survey of the previous literature on the tarnished plant bug reveals that the first comprehensive study was done by Crosby and Leonard (3). Earlier reports dealt with the depredations of this pest on various crops and brief description of the habits. Most of the workers gave an account of the injury and suggested plausible remedial measures.

Harris (13) referred to the color variability in the sexes as being non-specific in nature and also stated that there were only four distinct nymphal stages between the egg and the adult. Quaintance (33) concurred with Harris (13) in regard to the number of nymphal stages but gave diagrams of only three stages. About the effect of weather, Quaintance (33) mentioned that dry seasons favored the development of the tarnished plant bugs.

Garman (9) found tarnished plant bugs on strawberries. He considered that the extensive blackening of the part surrounding the feeding puncture was due to some fluid injected by the bug at the time of making the puncture. This was confirmed by the work of Smith (43) who showed that the saliva of the tarnished plant bug was very toxic and killed the cells with which it came in contact. Garman (9) also reported a fungus, Empusa sp. attacking tarnished plant bug and considered it to be the cause of the reduction in the numbers of the insect in damp weather.

Osborn and Gossard (28) described the injury to the expanding and the unopened buds of pears and apples. They found heavy infestations in non-weeded orchards. Patch (29 and 30) found similar injury on strawberries, pears and ornamental flowers. "Lygus injury" was so severe on asters and dahlias that no perfect flower could be obtained for sale. In 1907, Patch (31) reported his observations on the hibernation of the tarnished plant bug. In an area swarming with this insect the previous fall and apparently a very favorable place for hibernation, he could find only one live tarnished plant bug after hours of search.

Washburn (55) noticed a heavy infestation of the tarnished plant bugs on currants on May 7, but on May 16 nearly all the bugs had left the currants.

Taylor (54) gave an account of oviposition on the developing fruit of apples early in spring. No freshly laid eggs were found in any case after the apples were more than one-third of an inch in diameter and usually not later than the time of closing of the calyx.

Crosby and Leonard (3) compiled a report on the injury to forty-four cultivated plants from the descriptions given by earlier workers. They also worked out the life history of the tarnished plant bug although from the diagrams it appears that they were a little confused about the first three nymphal stages.

Haseman (14) investigated the peach nursery stock injury known as "stop-back." He worked out the life history of the tarnished plant bug and came to the conclusion that the main injury to the nursery stock was done by the overwintering adults.

Hughes (17) studied the tarnished plant bug in relation to alfalfa seed production. He described the injury to the alfalfa flowers on the basis of histological studies. In his studies on the biology, he took into consideration the environmental factors such as temperature and humidity.

The indirect injury caused by this insect has also been the subject of study by various workers. Forbes (7) observed fire-blight lesions associated with the feeding of the tarnished plant bug. This was confirmed about thirty years later by the experiments of Stewart (52 and 53).

McClintock and Smith (26) demonstrated that L. pratensis could carry the causal agent of spinach blight after feeding on the diseased plants.

Leach (22) came to the conclusion that some insects acted as vectors of heart rot of celery. Richardson

(34) conducted a series of experiments to show that the tarnished plant bug might serve as an agent of inoculation for celery heart rot. The insects were allowed to feed on celery plants that had been sprayed with a water suspension of *Erwinia carotovora* and incubated in high humidity. Within forty-eight hours infection appeared but the control remained healthy unless artificially wounded. Since plants sprayed with sterile water and subjected to insects remained healthy, he concluded that the tarnished plant bug would not be very effective as a vector.

Most of the recent literature on this pest is concerned with the chemical control, and is, therefore, discussed in part 2.

TECHNIQUE AND METHODS

Collection

An insect net, with a hoop twelve inches in diameter, was used for the collection of the tarnished plant bugs. The sweeping was done regularly in the clover fields for two years (1949-1950), at intervals of three days. A record of the seasonal variation in the population of *L. oblineatus* was kept by counting the number of insects per hundred sweeps. A sweep consisted of the movement of the net from one side to the other and then back again. The bugs were collected alive by sucking them into an aspirator tube direct from the net and then transferred to cardboard boxes with gauze tops.

Occasionally separate counts were made of the males and females to ascertain the variability in the sex ratio. A record of environmental conditions was kept.

Rearing

a. An attempt to rear the tarnished plant bugs on an artificial medium did not succeed. Small pieces, two inches by one inch, of sponge were soaked in a juice extracted from alfalfa. These were placed in petri dishes which were covered with cheese cloth. Tarnished plant bugs, five males and five females, were put in each petri dish.

The bugs lived on the juice but it was not possible to check the moulds with the equipment available at the time.

b. Cylindrical copper-gauze cages, one foot high and nine inches in diameter, were set up in the greenhouse. Most of the rearing experiments were done on chinese cabbage and bean pods. Some bugs were reared on celery and squash. Young plants of chinese cabbage were placed under the cages; five males and five females were released in each. After twenty-four hours the bugs were taken out and the number of eggs laid was counted. The eggs were observed at regular intervals during the hatching period. The nymphs were transferred to another type of cage. It consisted of a six-inch petri dish in which a smaller petri dish was placed. The small petri dish contained a piece of cotton soaked in potassium sulfate to avoid dessication. The small petri dish was covered with a very fine mesh gauze and on top of it were placed fresh bean pods. The pods were changed regularly in order to provide a fresh and succulent food for the nymphs. The big petri dish was covered with a coarse cloth to prevent the escape of the nymphs. The nymphs were examined at regular intervals and were changed to another cage after each ecdysis.

The trend of population in the field was observed carefully along with a record of the generations in the greenhouse.

Injury to Plants

a. In this series of experiments, four types of vegetables were used, viz., chinese cabbage, celery, squash and snap bean. The plants were grown in six-inch pots. They were covered with copper-gauze cages. In one series, twenty-five tarnished plant bugs were released for two days and in the second series, the same number of bugs were released for ten days. A few plants were kept without bugs to serve as control. The injury to the plants is shown in figures 1 to 5.

b. A histological study of the uninjured and the injured leaves of chinese cabbage was made. The injured leaves were taken from the plants which were exposed to the attack of the tarnished plant bugs for twenty-four hours and after that the injury was allowed to develop for seven days. The material was fixed in formol-acetic-alcohol and stained with Bismarck brown and methyl green.

Hibernation

a. A cage was set up in a protected place in the field on November 20, 1949. It covered a wooden flat which was filled with muck soil, dry leaves and hay. Three potted plants were put in it to provide food for the tarnished plant bugs until they hibernated. Two hundred and fifty insects were released in this cage.

A portion of the soil was brought into the laboratory in January, 1950 and was placed in a warm room.

Only one live female was recovered. The same procedure was repeated with the rest of the soil in February, 1950 but no live insect was found.

b. An attempt was made to store the insects in mailing tubes in refrigerated cabinets at 35° F. 78.8 percent of the bugs died within forty-eight hours; the rest of the bugs died in ninety-six hours.

HOST PLANTS AND THE NATURE OF INJURY

As stated earlier, the host plants of tarnished plant bug include vegetable crops, fruit trees, ornamental plants, forage crops, cotton, tobacco, wheat and many other cultivated and uncultivated plants. In this study, particular attention was paid to some vegetable crops. Greenhouse studies were supplemented by general field observations.

The extent of "Lygus injury" varies with the type of the crop and the part attacked. In their search for food the tarnished plant bugs puncture leaves, tender shoots, developing buds, flowers and fruits. The damage is enhanced by the punctures of oviposition. The nature of the injury inflicted on different crops may be the same but the resultant symptoms vary with the plant and the portion affected. In celery, the feeding punctures on the leaves produce brown wilted spots that are apparently due to the introduction of a phytotoxic substance into the tissue of the host. Similar feeding punctures on the leaves of snap beans do not produce brown or rusty wilted spots but instead cause white spotting.

In celery, if the feeding punctures are close together on the petiole, they form water-soaked areas (fig. 1) and result in a necrotic condition which spreads

FIG. 1 "LYGUS INJURY" ON CELERY (MAGNIFIED)

to the surrounding tissues. Later the stalks shrivel and bend at those places, giving a stunted appearance to the plant (fig. 2).

Beans constitute a major vegetable crop in Michigan. The tarnished plant bugs attack the tender shoots and puncture the developing pods, causing a cessation of their growth (fig. 3). In cage experiments it was found that when chinese cabbage plants were put in the same cage with the bean plants, typical feeding injury was observed on beans but no eggs were laid on them. The females seemed to have a preference for chinese cabbage for the purpose of oviposition. This may be the reason why the reduction in yield of beans, when it occurs, is not readily traceable to the activity of this pest. The cage experiments indicated that it might be a contributory factor in the damage to bean crop in some parts of the state.

Squash is fairly sensitive to the attack of the tarnished plant bug. The young shoots and leaves showed water-soaked areas and later a complete necrosis of the affected parts (fig. 4). The bug punctured the budding flowers and they withered away before opening. The punctures caused by oviposition were quite characteristic and were similar to those on chinese cabbage. A longitudinal slit was made with the ovipositor and the egg was laid in the tissue of the host plant. As growth proceeded and the wound healed, the slit acquired the shape of a narrow spindle.

FIG. 2 "LYGUS INJURY" ON CELERY

1. Control.
2. Plant exposed to tarnished plant bugs for two days.
3. Plant exposed to tarnished plant bugs for ten days.

FIG. 3 "LYGUS INJURY" ON SNAP BEANS

1. Control.
2. Plant exposed to tarnished plant bugs for two days.
3. Plant exposed to tarnished plant bugs for ten days.

FIG. 4 "LYGUS INJURY" ON SQUASH

1. Control.
2. Plant exposed to tarnished plant bugs for two days.
3. Plant exposed to tarnished plant bugs for ten days.

In chinese cabbage the feeding punctures were mostly made on the outer side of the mid rib of the leaves. This resulted in a necrosis of the area surrounding the punctures. As growth proceeded the cells on the inner surface of the mid rib being uninjured and necrosis having not spread to that extent, the injured leaves curled downwards (fig. 5) which prevented the formation of a compact cylindrical head. The mid rib of the leaves of chinese cabbage remained succulent throughout the growing season. The insect, therefore, attacked the outer leaves as they were successively exposed after the injured leaves had curled down. The feeding punctures on the leaf lamina resulted in rusty spots as in the case of celery.

A histological study of the leaves of chinese cabbage showed that the aim of the piercing-sucking mouth parts was to reach the vascular bundles. The vascular bundles, which were pierced by the mouth parts of the bug, disintegrated (fig. 6b), apparently due to the introduction of a phytotoxic substance. The injury spread to the cortex and eventually caused a complete necrosis of the tissues surrounding the punctured tissue.

FIG. 5 "LYGUS INJURY" ON CHINESE CABBAGE

1. Control.
2. Plant exposed to tarnished plant bugs for two days.
3. Plant exposed to tarnished plant bugs for ten days.

FIG. 6a. TRANSVERSE SECTION OF THE LEAF OF CHINESE CABBAGE SHOWING UNINJURED VASCULAR BUNDLES

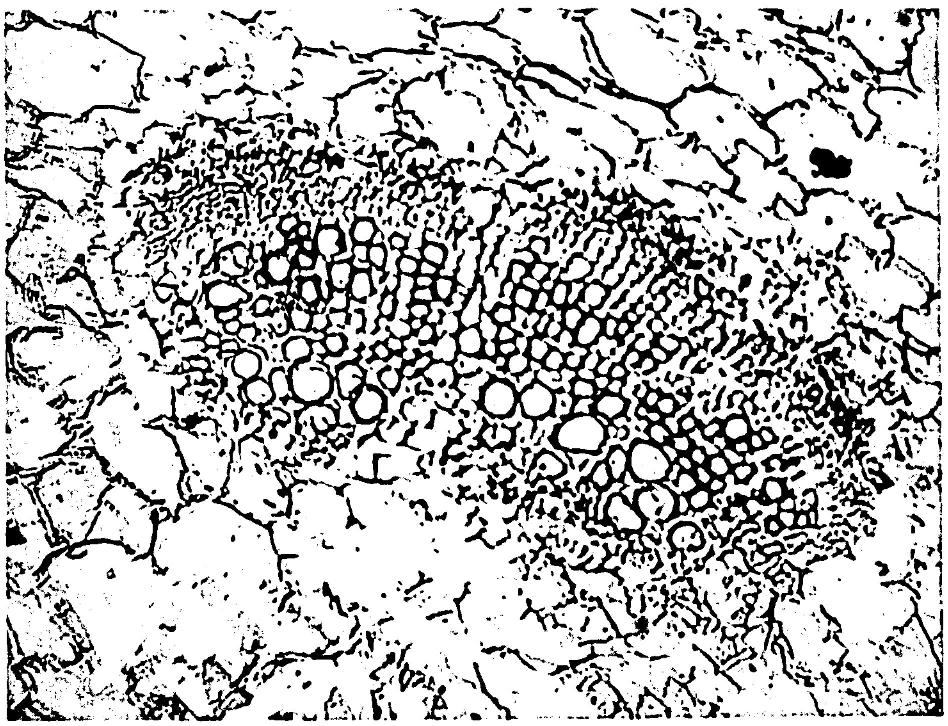
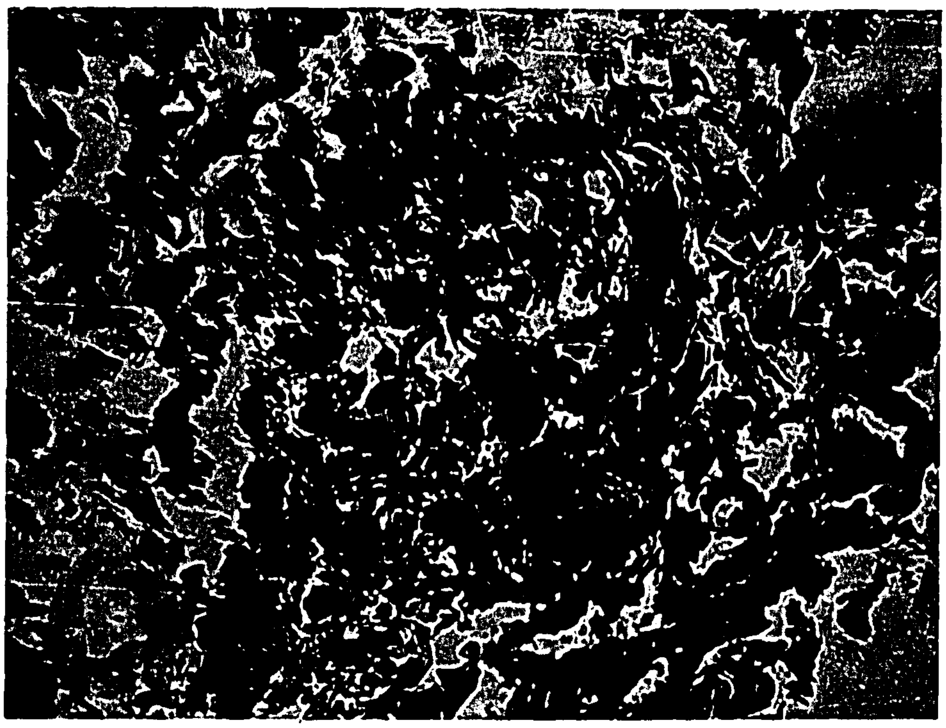


FIG. 6b. TRANSVERSE SECTION OF THE LEAF OF CHINESE CABBAGE SHOWING NECROSIS IN THE INJURED VASCULAR BUNDLES AND THE SURROUNDING TISSUE



LIFE HISTORY AND DESCRIPTION OF STAGES

Oviposition

L. oblineatus females were observed in the act of oviposition in cages set up for the purpose in the greenhouse. Young plants of chinese cabbage were used in this study. The females engaged in a series of manipulations before laying an egg on a particular spot. The preoviposition activities sometimes extended to a period of fifteen minutes. The female appeared restless; the movements of the antennae and the beak indicated that a general survey of the plant was under way. In chinese cabbage, the female always selected some part of the mid rib. The author never observed an egg being laid on the lamina of the leaf.

The female used the beak as a sort of anchor and slowly arched the abdomen before inserting the ovipositor into the tissue of the host plant. This was followed by movements similar to sawing which lasted for about one-half minute. Usually the egg was laid singly or in a row of two or three but in one instance, a female was seen to lay twelve eggs in a row, one after the other, within a period of ten minutes. The eggs were not laid straight down with the egg cap facing upwards but were laid at an angle. Normally the egg caps did not protrude out of the tissue just after oviposition. The eggs were not laid all at one time.

A number of females were dissected to determine the approximate number of eggs (Table I). The maximum number was found to be 72 and the minimum was 13.

TABLE I

EGGS DISSECTED FROM L. OBLINEATUS GRAVID FEMALES

Date	Females Dissected	Eggs Per Female (Mean)
April 4, 1950	3	18.6
June 1, 1950	8	47.9
July 27, 1950	8	62.4
September 7, 1950	7	63.4

Incubation

The incubation period varied from eight to thirteen days (Table II).

In group 1, the eye-spots developed in six to eight days after oviposition whereas in group 2 and 3, they developed in five to seven days. In group 2 and 3, the period of incubation after the development of eye-spots was shorter than in group 1.

By the time the eye-spots developed, the egg was pushed outwards due to the drying up of the punctured

TABLE II

INCUBATION STUDIES OF L. OBLINEATUS

Group	Developmental Period	Eggs Laid	Nymphs Hatched	Incubation Period		Average Mean Temperature °F
				Range Days	Mean Days	
1	May 5 to May 24, 1950	78	56	10-13	12.5	57.8
2	June 15 to June 29, 1950	85	69	9-12	11.4	67.0
3	July 28 to August 19, 1950	90	82	8-12	11.1	68.5

tissue and at this stage the developing eggs appeared as small papillae on the mid rib of the leaves of chinese cabbage and could be seen with the naked eye.

In the cage experiments, 81.8 percent eggs hatched.

Egg

The freshly laid egg has a protoplasmic transparency but during the incubation period it becomes translucent and is very pale yellow in color. It is sac-like (fig. 7a), a little broader towards the end away from the micropyle. The egg is convex on one side but on the opposite side it is curved inwards just posterior to the egg cap. The egg cap appears concave in a lateral view. The chorion is sculptured with polygonal to round markings which in some cases coalesce. The size of the egg varies

FIG. 7a. EGG OF L. OBLINEATUS

from 0.91 to 0.97 millimeter in length and 0.30 to 0.34 millimeter in width.

Nymphal Development

It was found that just before ecdysis the nymphs were not very active. At the time of moulting the head capsule was cast off first and then the nymph wriggled out of the loosened cuticle. The nymphal development was completed in an average period of 24.1 to 28.0 days (Table III).

First Nymphal Stage

The young nymph is pale yellowish in color. The body is cylindrical and averages 0.93 millimeter in length and 0.32 millimeter in breadth (fig. 7b). The first three antennal segments are pale with a brownish tinge; the fourth segment is pinkish in color. The lengths of the four antennal segments average 0.09, 0.23, 0.21 and 0.31 millimeter. The central facets of the eye are deep purple but the periphery is light in color. The beak is sooty to dark at the tip but is pale towards the base. The anterior and the posterior margins of the thoracic segments are parallel. The wing pads are not developed. There is a reddish spot at the base of the tibia. The dorsal gland is light purple in color.

TABLE III

TIME REQUIRED FOR NYMPHAL DEVELOPMENT OF *L. OBLINEATUS*

Group	Developmental Period	Instar	Nymphs	Nymphal Period		Mean Average Temperature ° F
				Range Days	Mean Days	
1	May 16 to May 31, 1950	First	56	5-8	6.1	61.0
	May 22 to June 5, 1950	Second	41	3-6	4.3	63.5
	May 27 to June 11, 1950	Third	40	3-6	4.1	64.1
	May 31 to June 16, 1950	Fourth	32	4-6	5.3	66.2
	June 5 to June 24, 1950	Fifth	30	6-9	8.2	67.5
2	June 25 to July 7, 1950	First	69	5-8	5.7	65.7
	July 1 to July 11, 1950	Second	45	2-5	4.0	67.7
	July 4 to July 16, 1950	Third	43	3-6	3.5	69.5
	July 8 to July 21, 1950	Fourth	35	3-5	3.8	68.9
	July 12 to July 30, 1950	Fifth	35	5-9	7.1	69.2
3	August 6 to Aug. 26, 1950	First	90	3-8	5.6	67.0
	August 10 to Aug. 31, 1950	Second	58	2-5	4.0	67.2
	August 13 to Sep. 4, 1950	Third	49	3-5	3.6	66.6
	August 17 to Sep. 9, 1950	Fourth	49	3-6	4.0	65.3
	August 21 to Sep. 17, 1950	Fifth	47	7-10	8.8	64.3

FIG. 7b. FIRST NYMPHAL STAGE OF L. OBLINEATUS

Second Nymphal Stage

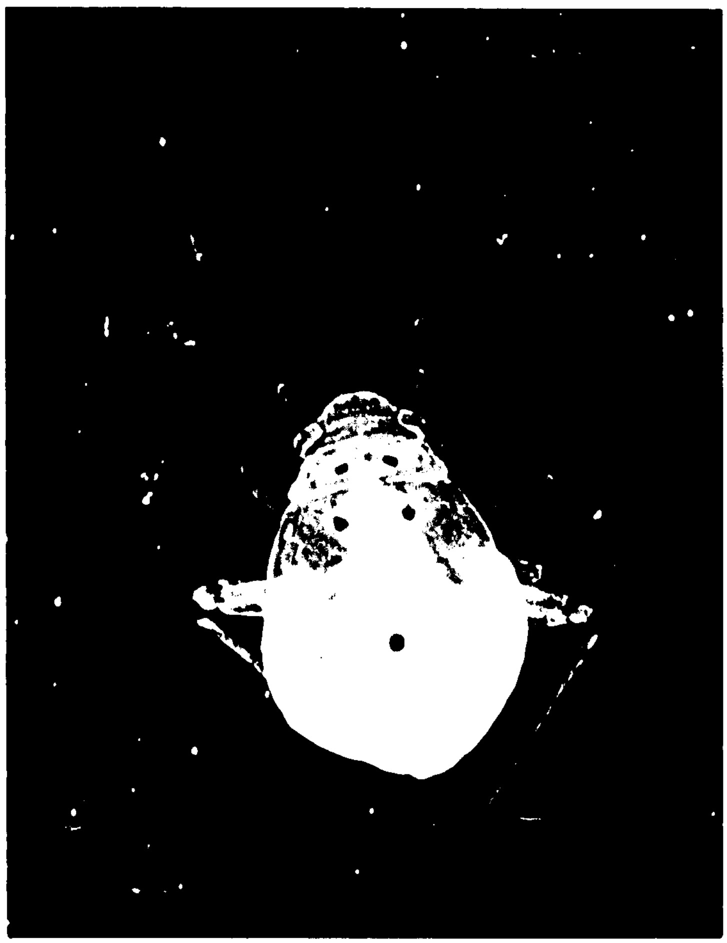
The color becomes yellowish green. The body is elongate but the abdomen is slightly broader as compared to first nymphal stage. It averages 1.54 millimeter in length and 0.62 millimeter in breadth (fig. 7c). The first and the third segments of the antennae are red, the second segment has a yellowish band in the center, and the fourth segment is dark red. The lengths of the antennal segments average 0.11, 0.54, 0.30 and 0.40 millimeter. The eyes are dark purple in color. There are no special markings on the thoracic segments and the wing pads are not yet visible. The color of the legs is yellowish-brown. A red spot appears at the distal end of the femur similar to the spot on the proximal end of the tibia. The dorsal gland is red in color.

Third Nymphal Stage

The color is light green with brownish blotching. The body is now obovate in shape and the abdomen looks very plump. The body averages 2.09 millimeters in length and 1.2 millimeter in breadth (fig. 7d). The antennal segments are brown with a reddish tinge. They average 0.19, 0.76, 0.59 and 0.47 millimeter in length. The tip of the beak is sooty but the rest of it is pale. The eyes are deep purple in color. The thoracic segments have become concave on the posterior side and there are four reddish purple spots on the dorsal side.

FIG. 7c. SECOND NYMPHAL STAGE OF L. OBLINEATUS

FIG. 7d. THIRD NYMPHAL STAGE OF L. OBLINEATUS



A beginning of the wing pads is visible. There is an incomplete red band on the tip of the femur and the beginning of another band close to it. The dorsal gland is darker in the center.

Fourth Nymphal Stage

The following description concurs in all essentials with the description given by Haseman (14). The color is very variable at this stage and the body is blotched with red and brown. The males are generally more colorful than the females. The body averages 2.41 millimeters in length and 1.32 millimeter in breadth (fig. 7e). The antennal segments are reddish brown in color and have lighter central portion. The lengths of the antennal segments average 0.36, 0.92, 0.68 and 0.63 millimeter. The eyes are very dark in color. The four thoracic spots are very prominent. The wing pads reach the third abdominal segment. Red transverse bands are seen on the thoracic and the abdominal segments. The legs and the ventral surface of the body is blotched with red. There are two red bands near the base of tibia, two bands towards the tip of the femur and a large blotch towards the base of the femur. The dorsal gland is dark in the center and has a light red periphery.

FIG. 7e. FOURTH NYMPHAL STAGE OF L. OBLINEATUS

Fifth Nymphal Stage

The coloration is similar to the fourth nymphal stage. The body averages 3.65 millimeters in length and 1.87 millimeter in breadth (fig. 7f). The first antennal segment is dark in color, the second has a pale central band and the third and fourth segments are reddish brown. The lengths of the antennal segments average 0.44, 1.30, 0.81 and 0.67 millimeter. The eyes are blackish in color and the beak is dark at the tip. There is a Y-shaped yellowish area behind the two posterior thoracic spots. The wing pads reach the sixth abdominal segment. There are two complete brownish bands on the distal end of the femur and two bands towards the proximal side of the tibia. Reddish brown blotches are present towards the base of the femur. The dorsal gland is deep purple in color. The genitalia are visible through the sheath.

The Adult

The general color is variable. It is generally yellowish brown with a reddish or pinkish tinge. It is marked with reddish brown, dusky and fuscous areas. A Y-shaped yellowish area on the dark scutellum is characteristic of *L. oblineatus* (fig. 7g). The hemelytra are finely pubescent and their general color is pinkish yellow with brown blotches towards the distal side of the corium and in the middle of the clavus. The apex of the

FIG. 7f. FIFTH NYMPHAL STAGE OF L. OBLINEATUS

FIG. 7g. DORSAL VIEW OF THE ADULT OF L. OBLINEATUS

cuneus is dark brown and the inner basal angle is reddish. The antennal segments average 0.56, 1.56, 0.95 and 0.78 millimeter in length.

The males and females are almost of the same size, when measured to the wing tips. The mean size of the females is 5.48 millimeters and the males 5.44 milimeters in length. The length of the body in the males is 0.60 millimeter shorter than the females (figs. 7h and 7i). The males are darker in color than the females.

FIG. 7h. VENTRAL VIEW OF THE ABDOMEN (MALE) OF

L. OBLINEATUS

FIG. 71. VENTRAL VIEW OF THE ABDOMEN (FEMALE) OF

<u>L. OBLINEATUS</u>

SEASONAL VARIATION AND HABITS

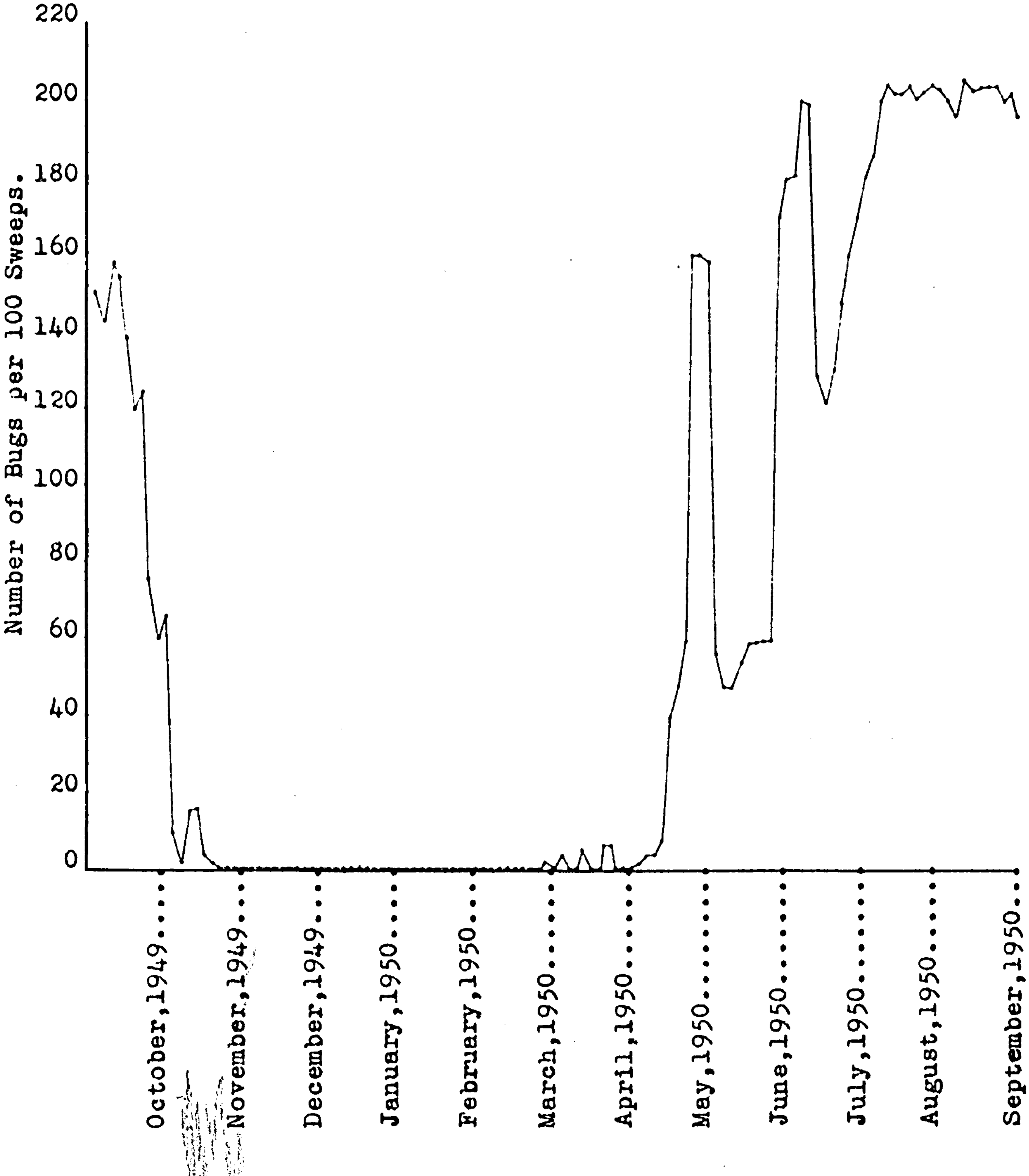
The seasonal variation in the population of *L. oblineatus* (fig. 8) was recorded from October 1, 1949 to September 30, 1950. October, 1949, was one of the warmest Octobers since 1864. The highest mean temperature was 73° F. on October 9, 1949. The infestation of the bugs remained fairly high until October 25 when it suddenly started to decline and by November 25, 1949 no adult was found on wing. March 26, 1950 was the first day when the overwintering adults were found on the wing again. The number of insects collected in the clover fields was never more than ten per hundred sweeps until the middle of May, 1950. The peak of the population was reached on May 25 when most of the adults from the first brood were active on the host plants. There was a sudden fall in the intensity of the population from May 31 to June 3. This decline may have been caused by the following factors:

1. The overwintering adults oviposited in clover fields, mainly on the weeds. The adults from the first brood, after emergence, disseminated from their breeding places to the adjoining crops.

2. The sudden drop in temperature accompanied by a precipitation of 2.30 inches and hail on June 2, 1950 may have caused an abnormal mortality.

FIG. 8. SEASONAL VARIATION IN THE POPULATION OF

L. OBLINEATUS.



After June 4, 1950 the temperature remained consistently high and the humidity was low for the rest of the month. The peak of the second brood was observed on July 12, 1950. There was a small drop in the intensity of infestation for the following few days but that was probably due to the dissemination of the bugs to other crops. The population record showed an overlapping of the various stages of the first and the second generations but this overlapping reached its maximum during the months of August and September, when due to a consistently high level of infestation, the insects had spread uniformly all over the fields.

As a result of an occasional count of insects according to sex, it was found that the ratio of males to females varied in different parts of the season. No significance was attached to the ratio of the sexes in the overwintering insects because the number of insects collected was very small. After the adults of the first brood had emerged, the ratio of males to females was approximately four to six. In the second generation the ratio was almost one to one. This ratio kept up during the months of July, August and September. However, the ratio of males to females was one to nine in the collection made after October 10, 1950.

Although the tarnished plant bug does not rank as a major pest in Michigan, its infestation may be fairly high in certain local areas. It was at such places that an attempt was made to study the mode of hibernation in this insect. Thorough search of the trash in the clover fields, alongside the hedges, and under loose bark of dead trees was made. Throughout the winter period, (1949-1950), only sixteen adults were found out of which thirteen were females. Eggs or nymphal stages were not found. This confirms the idea that the tarnished plant bugs overwinter in the adult stage in this part of the country. It is also apparent that the cold winters of Michigan cause a heavy mortality in the overwintering adults and that is why the fruit growers do not have to reckon with the serious "Lygus injury" early in the spring, as is so common in the southern states. The heavy rate of mortality during hibernation was also borne out by the cage experiment already described.

L. oblineatus is capable of long flights but normally it does not take recourse to flight when disturbed. It usually shifts from one plant to the next. For a large collection of insects in comparatively short time, the plots of clover were first swept along the borders and then through the center. By sweeping along the borders, all the bugs concentrated on the central rows. This habit of the tarnished plant bug was further manifested when a portion of an infested field was cut. The bugs concentrated along the uncut edge rows and it took a few days before they were again dispersed over the entire field. However, if the tarnished plant bugs were kept in a cage for an hour and then released in the same field from which they were collected, they fly away.

The tarnished plant bugs were more active in the afternoon than in the cooler hours of the day. Many times they simulated death, when disturbed, by dropping on the ground or into the leaves of the host plants.

Throughout the course of this study, extending over two years, only once did a tarnished plant bug insert its beak into the palm of the writer. It caused an irritation which lasted for two and a half hours.

The tarnished plant bugs gave an unpleasant odor especially if they were more than fifty in the aspirator tube. It caused an irritation of the throat and a cough.

When the insects were released on caged plants, it was observed that the bugs did not insert their beaks immediately into the tissue of the plant. They first cleaned the right antenna and then the left antenna with the pair of prothoracic legs. Then they swept the tissue with the antennae and the beak after which they inserted the piercing-sucking mouth parts into the tissue of the plant. The feeding lasted from one-half minute to ten minutes. In many plants it was observed that the bugs preferred to feed at the nodes of the shoots.

SUMMARY

1. The apparent symptoms of feeding injury by tarnished plant bug vary according to the nature of the host plant. The feeding punctures cause brown or rusty spots on celery and the leaf lamina of chinese cabbage, but in snap beans leaves are speckled with whitish spots.
2. Heavy "Lygus injury" causes stunting in celery, prevents head formation in chinese cabbage, checks pod setting in beans and blasts the blossoms of squash.
3. The females of L. oblineatus show a preference for chinese cabbage for oviposition.
4. Histological studies of the uninjured and the injured leaves of chinese cabbage show that the tarnished plant bug punctures the tissue of the host plant and sucks the sap from the vascular bundles. Necrosis starts from the vascular bundles and spreads to the surrounding cortex.
5. L. oblineatus overwinters in the adult stage in East Lansing and its vicinity.
6. The percentage of mortality is very high in the overwintering tarnished plant bugs.

7. Adults were not found on wing between November 25, 1949 to March 25, 1950.
8. The overwintering females lay eggs on weeds and clover in the spring.
9. The peak of infestation of L. oblineatus is during the months of August and September.
10. The ratio of males to females is approximately 4 to 6 in June, 1 to 1 in August and September and 1 to 9 in the middle of October.
11. Feeding lasts from one-half minute to ten minutes at one time.
12. The eggs are either laid singly or in rows.
13. The eggs are laid at an angle in the tissue of the host.
14. The maximum number of eggs dissected from a gravid female is 72 and the minimum 13.
15. The incubation period varies from 8 to 13 days according to the temperature.
16. The life-cycle is completed in 30 to 43 days at East Lansing.
17. There are apparently three complete generations in a year at East Lansing.

PART 2

CONTROL OF *LYGUS OBLINEATUS* (Say)

By

ORGANIC INSECTICIDES

INTRODUCTION

The economic importance of the tarnished plant bug, *Lygus oblineatus* (Say), has increased greatly during the last fifty years because of the rapid increase in the areas put under cultivation, and a gradual change in cultural practices. However, until the modern era of synthetic organic insecticides, none of the chemical treatments gave a satisfactory control. Haseman's statement (14), "Preventive measures prove more effective," still held true in 1940.

The advent of modern organic insecticides gave a fresh impetus to the study of the control of tarnished plant bug. A number of insecticides have been tested during this period by various workers but no comprehensive work has been reported so far on the subject. Some preliminary reports suggested the effectiveness of benzene hexachloride (BHC) but it could not be recommended as a control measure on many crops because it imparted an off-flavor to them.

The work reported in this part of the thesis was designed to investigate the effect of the more common organic insecticides on the control of tarnished plant bug. Fourteen insecticides were tested in the greenhouse experiments and five of them were tested in the field.

Lindane showed very favorable results in the greenhouse and had the highest residual effect. An elaborate field experiment was, therefore, conducted to test the effectiveness of lindane under conditions approximating very closely the field conditions. Artificial infestations of tarnished plant bugs were maintained by covering the plots with large cloth cages similar to those used in raising asters.

Some of the natural organic insecticides were tested to investigate any possibility of their use in the control of tarnished plant bugs in Asiatic countries, especially Pakistan, where pyrethrum, derris and tobacco plants are widely cultivated but where synthetic organic insecticides must be imported from foreign countries.

REVIEW OF LITERATURE

Riley (35) is probably the first worker to mention any experimental work on the use of contact insecticide for the control of tarnished plant bug. Kerosene emulsion was used in thoroughly wetting the bugs under captivity with very indifferent results. Forbes (7 & 8), Davis (4), Stedman (50) and others in the same period also recommended kerosene emulsion but laid more emphasis on clean culture and some mechanical devices of control.

Pyrethrum and tobacco decoction gave quite favorable results in the laboratory experiments (Forbes; 7a) but did not stand up under field conditions. Smith and Scales (46) used various mixtures of pyrethrum, Paris green and sulfur but obtained only 36 percent control whereas they reported 80 percent control with pyrethrum (.76 pyrethrins). Smith et al (46) obtained 85 percent control with pyrethrum (0.71% pyrethrins). Sorensen (48) tried two combinations of pyrethrum and sulfur and concluded that neither was significantly better than the control. Shull and Fisher (41) used a dry stabilized pyrethrum-rotenone bearing dust at the rate of 30 to 40 pounds per acre and noticed an initial reduction of 80 to 90 percent in the population of bugs in treated plots but within a few days there was no difference in the populations found in treated and untreated plots.

Early workers like Webster (56) and Schöyen (39) had unsuccessfully used tobacco decoction in field trials. Stedman (50) reported fairly good results by the use of "Rose Leaf Insecticides" (nicotine) on strawberries. Britton and Zappe (2) working on "stop-back" in pears, apples, and other flowering plants suggested heavy spraying with nicotine sulfate and soap. Haseman (15) applied nicotine spray to check "buttoning" in strawberries. However, Hill (16) showed that nicotine preparations did not prevent injury to celery due to the feeding and oviposition of tarnished plant bug.

Many workers have tried different inorganic insecticides and repellents, e.g., cryolite, sulfur, Paris green, calcium arsenates, hydrated lime, slate dust, and sodium arsenate, etc., with varying results. Medlar and O'Neal (27) reported 87.5 percent control with unconditioned sulfur (98-100%, 325 mesh). Hill (16a) got 92.67 percent control with 75 to 100 pounds per acre of sulfur dust on celery. In combination with hydrated lime the percentage of control increased to 94 to 98 percent. However, no account is given of the intensity of infestation or the prevalent temperatures during the period of the experiment. Smith et al (47) in a series of experiments got only three to thirteen percent control with sulfur and 29 to 30 percent control with micronized sulfur. Only 10 to 22 percent control was obtained with different grades of cryolite. Medlar and O'Neal (27) got one hundred percent control with calcium arsenate and conditioned dusting sulfur. Smith et al (47) obtained only 29 to 45 percent control with calcium arsenate 4347 plus sulfur.

Rotenone has also been used alone or in combination with sulfur. It has not been shown to give more than 49 percent control under laboratory conditions and the percentage of control fell down even with a very high dosage under field conditions (Shull, 40 & Smith, 44).

Since 1943 DDT has been tried for the control of tarnished plant bugs with only a fair degree of success. Granovsky (11) used 2.5 percent and one percent DDT dust and observed that at the end of six days after dusting he was able to get about 85 percent control.

Lange (21) used vapo-sprays with 1.2, 2.4, and 3.6 percent DDT against Lygus bugs directly and also on truck crops on which bugs were released immediately after spray. The time required to kill did not show any appreciable difference with the various concentrations used. Dustan (5) obtained almost complete control on chrysanthemums with 16 ounces of DDT (in Velsicol emulsion) and eliminated the infestation within four or five days. However, Perron (32) showed that DDT provided good, but not perfect protection from feeding injury on asters. Romney (36) recorded that although 2.5 percent DDT gave a good control of Lygus bugs at the time of application but did not show enough residual effect for the nymphs which hatched four days after the application. Ivy and Ewing (18) got 100 percent mortality from one to five days with 4.6 percent active ingredient of DDT and sulfur on cotton but no mention is made of the residual effect after five days. Woodside (58) found that DDT (two pounds of 50 percent wettable powder per hundred gallons of water) reduced catfacing in peaches to 3 percent against 8.2 percent in check.

Scales and Smith (1948) working with _L. oblineatus_ on cotton gave an account of the comparative toxicity of toxaphene, BHC and chlordane. They reported that twenty percent toxaphene dust was equal to two percent parathion dust, superior to twenty percent chlordane dust and inferior to five percent BHC dust. In another series of tests ten percent toxaphene dust was inferior to a 2.5 percent parathion dust and three percent gamma BHC dust but superior to a ten percent chlordane dust. Woodside (58) found that four pounds of 25 percent toxaphene wettable powder per one hundred gallons of water applied at petal fall resulted in five percent of the peaches being scarred as compared to 8.2 percent in the check.

Ivy and Ewing (18) working on cotton insects tried five concentrations of BHC as dust at the rate of 16 pounds per acre. With a concentration of 1.25, 2.5, 5 and 10 percent of the active ingredient, they got 100 percent mortality on the third and fifth day but with 0.62 percent it was reduced to 85 percent and 92 percent respectively. The nymphs were shown to be slightly more resistant. Stevenson and Sheets (51) working on cotton insects in which Lygus hesperus predominated showed that after three days of the application of 5 percent gamma isomer of BHC, the mortality was 100 percent.

Marshall (24) investigated the effect of chlordane on Lygus insects causing catfacing in peaches. He reduced catfaced peaches to five to seven percent by one spray of chlordane, three pounds, plus lead arsenate, two pounds, plus zinc sulfate, four pounds, plus lime, six pounds.

Gyrisco and Marshall (12) reported that BHC, parathion, DDT and DDD proved effective for the control of the tarnished plant bug on alfalfa and red clover. However, they found that none of these insecticides persisted in toxicity much over a week. Parathion and BHC gave up to 90 percent control of the tarnished plant bugs for about a week.

It may be noted that except for an occasional mention of the burning effect of high dosages of arsenates on the leaves of host plants, no correlation has been worked out between the insecticidal and phytotoxic effects of various insecticides which show promise for the control of *L. oblineatus*.

EQUIPMENT AND METHODS USED

Laboratory Experiments with Contact Sprays for the Control of *L. oblineatus*

A spray chamber was constructed in the Entomology greenhouse in which plants could be sprayed at a relatively constant temperature and a uniform deposit of spray material could be obtained on all plants. The chamber was open at the front and was furnished with an exhaust fan at one side near the back to carry fumes and spray fog outside the building. A turntable which rotated at a speed of about fourteen revolutions per minute was placed in the center of the chamber. The spray fluid was applied from an atomizer type spray-gun maintained by a DeVilbiss pressure regulator valve at twenty pounds pressure. During operation the plant to be sprayed was put at the center of the rotating turntable and the spray nozzle kept at a distance of about thirty inches from the plant.

Tarnished plant bugs were kept in cages in the greenhouse. Test plants (chinese cabbage, *Brassica pekinensis* var. Michihli) were grown in three-inch pots in the greenhouse. The spray solutions were made in 150 milliliter Erlenmeyer flasks and were kept agitated by a magnetic mixer. One end of the metallic tube attached to the lower side of the spray gun was dipped in the spray solution during the spraying operation. The spray gun was flushed with water after each treatment. Each plant was sprayed for forty-five seconds. It was then set aside for half an hour before it was put under a wire-gauze cage and ten tarnished plant bugs were released into the cage. Water sprays were included to serve as checks. After every twenty-four hour period counts of live and dead tarnished plant bugs were made. All results were corrected according to Abbot's formula (1), giving the final comparisons in terms of percent control.

Fourteen insecticides at three concentrations (Table IV) were tested for the control of *L. oblineatus*. Each test was replicated three times. This experiment was carried out twice. In case of 100 percent kill more bugs were added at the end of the corresponding twenty-four hour period. The results of this work are indicated in Tables III to XVI and Figures 9 to 21.

Field Experiments

Split plot experiment for the control of L. oblineatus on celery by lindane as contact spray. This experiment was set up at the Michigan State College Muck Experimental Farm. The design of the experiment is shown in Table VI. Lindane was used at three concentrations, i.e., high, medium, and low. Three intensities of infestation of tarnished plant bugs were maintained and the number of applications of the sprays, from the time of transplanting to harvest, were 0, 2, 4, and 6. Each replicate series comprised an area of 20 by 30 feet divided into nine plots. A plot had four rows with ten plants of celery in each row. Planting distance was thirty inches between rows and seven inches between plants in a row. A cage, 30 by 20 by 6 feet, was set up to cover all the nine plots in a replicate series and was covered with aster cloth. This was partitioned by cheesecloth into nine sub-cages each enclosing a single plot.

The whole experiment was repeated three times. Celery (*Apium graveolens*, variety Cornell 19) was planted in flats on May 17, 1950, and was transplanted under the cages on June 10, 1950. The plots were irrigated only once, on July 12, 1950, due to frequent rainfall after that day. As a precautionary measure against disease, Dithane was dusted once on July 31, 1950. The insecticide was sprayed according to the following schedule:

(i) Schedule for 6 sprays

1. June 29, 1950
2. July 12, 1950
3. July 26, 1950
4. August 9, 1950

5. August 23, 1950

6. September 7, 1950

(ii) Schedule for 4 sprays

1. June 29, 1950

2. July 18, 1950

3. August 7, 1950

4. August 27, 1950

(iii) Schedule for 2 sprays

1. June 29, 1950

2. August 7, 1950

Twenty-five percent lindane wettable powder was used at the rate of 32 ounces per 100 gallons for high concentration, 16 ounces per 100 gallons for medium concentration and 8 ounces per 100 gallons for low concentration. The sprays were applied with a three-gallon compressed air sprayer. Tarnished plant bugs were released in four batches on the following dates respectively:

1. June 30, 1950

2. July 19, 1950

3. August 8, 1950

4. August 28, 1950

In all two hundred tarnished plant bugs were released in each cage marked for A intensity of infestation; 400 in B; and 800 in C. On August 16, 1950, one plant was pulled out at random from each row and injury to the plants was recorded.

The crop was harvested on September 15, 1950. All the nine plants in each row were weighed for total weight and the trimmed weight (i.e., the weight of the stalks of celery which are normally marketable). Three plants were picked at random from each row. Total number of stalks in the three selected plants, the number of injured stalks due to feeding punctures of L. oblineatus, and the total number of punctures were recorded. The entire data and their analyses appear in Tables VII to XXV.

Randomized block experiment for the control of L. oblineatus on chinese cabbage by various insecticides. This experiment was set up at the Muck Experimental Farm. A plot, 30 by 22 feet, was divided into seven sub-plots. The sub-plots had two rows of chinese cabbage, each row having 17 plants. The distance was 25 inches between rows and 15 inches between plants in the row. The following seven treatments were applied after randomly selecting the sub-plots.

1. So Untreated.
2. S_1T_1 Lindane 25% at 16 ounces per 100 gallons, 4 applications.
3. S_1T_2 Lindane 25% at 16 ounces per 100 gallons, 6 applications.
4. S_2T_1 Parathion 15% at 24 ounces per 100 gallons, 4 applications.
5. S_2T_2 Parathion 15% at 24 ounces per 100 gallons, 6 applications.

6. S_3 TEPP at 16 ounces per 100 gallons, 6 applications.

7. S_4 Nicotine sulfate at 12 ounces, plus Pyrethrum at 16 ounces, plus Sulfur at 48 ounces per 100 gallons, 6 applications.

This was replicated six times and was completely randomized. The plan of experiment is given in Table XXVI.

Chinese cabbage was planted on July 1, 1950 and the spraying schedule was tentatively arranged as follows:

1. July 16, 1950
2. July 26, 1950
3. August 5, 1950
4. August 15, 1950
5. August 25, 1950
6. September 4, 1950

The spray was applied to the chinese cabbage crop with a three-gallon compressed air sprayer.

On August 6, 1950, four plants were pulled from each sub-plot at random and the total number of feeding punctures was recorded. These data with their analyses are given in Tables XXVIII and XXIX.

On August 7, 1950, a hail storm completely ruined the chinese cabbage crop, and this experiment had to be abandoned.

TABLE IV

CONCENTRATIONS OF INSECTICIDES USED AS CONTACT SPRAYS FOR THE CONTROL OF L. OBLINEATUS

Number	Insecticides	Ounces per 100 Gallons		
		High Concentration	Medium Concentration	Low Concentration
1	Nicotine Sulfate 40%	32	16	8
2	a. Nicotine Sulfate 40%	24	12	6
	b. Pyrethrum 18%	32	16	8
	c. Sulfur 95%	96	48	24
3	Rotenone 4%	160	80	40
4	Ryania 40%	480	240	120
5	Methoxychlor 50%	64	32	16
6	DDT 50%	64	32	16
7	DDD 50%	64	32	16
8	Toxaphene 40%	64	32	16
9	Chlordane 40%	64	32	16
10	Lindane 25%	32	16	8
11	Parathion 15%	32	16	8
12	TEPP 50%	32	16	8
13	Pestox 3	32	16	8
14	Allethrin 4%	32	16	8

The insecticides were obtained from the following firms:

No. 1 - Tobacco By-Products & Chemical Corp., Richmond, Virginia.
No. 2b & 14 - McLaughlin Gormley King Co., Minneapolis 4, Minnesota.
No. 2c - Stauffer Chemical Co., New York 17, N. Y.
No. 3 & 4 - S. B. Penick & Co., New York 7, N. Y.
No. 5 - E. I. du Pont de Nemours & Co., Wilmington 98, Delaware.
No. 6, 10 & 13 - Dow Chemical Co., Midland, Michigan.
No. 7 - Rohm & Haas Co., Philadelphia 5, Pennsylvania.
No. 8 & 11 - American Cyanamid Co., New York 20, N. Y.
No. 9 - Julius Hyman & Co., Denver, Colorado.
No. 12 - California Spray Chemical Corp., Richmond, California.

TABLE V

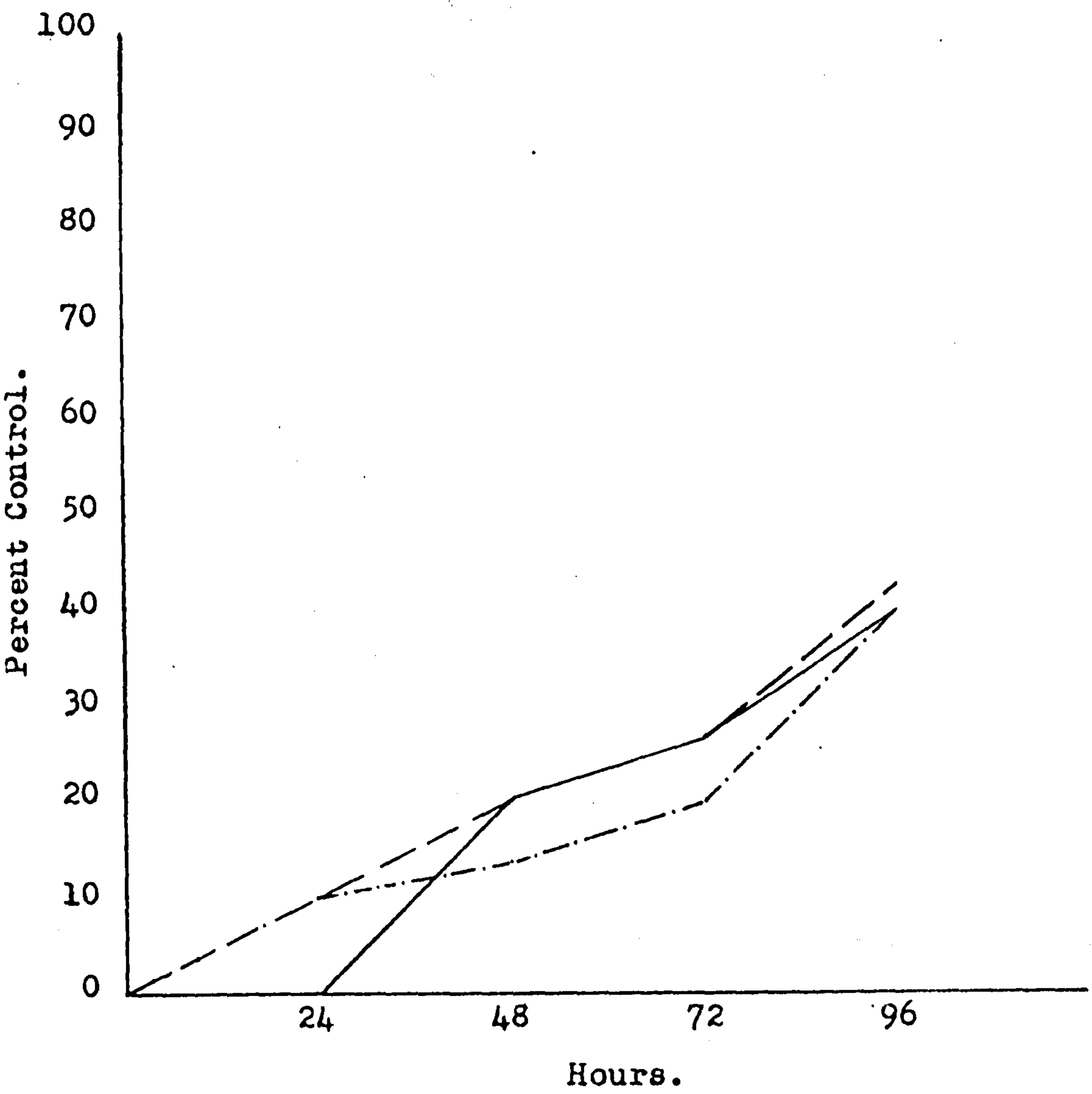
PERCENT CONTROL BY VARIOUS INSECTICIDES AS CONTACT SPRAY AGAINST _L. OBLINEATUS_*

Insecticides	High Concentration				Medium Concentration				Low Concentration			
	Hours After Spray				Hours After Spray				Hours After Spray			
	24	48	72	96	24	48	72	96	24	48	72	96
Nicotine Sulfate	6.7	20.0	26.7	42.9	0.0	20.0	26.7	40.0	6.7	13.3	20.0	40.0
Nicotine Sulfate + Pyrethrum + Sulfur	0.0	15.0	23.3	24.6	0.0	8.3	8.3	8.8	0.0	0.0	5.0	7.1
Rotenone	0.0	0.0	0.0	5.3	0.0	0.0	6.6	6.6	0.0	0.0	3.3	6.6
Ryania	0.0	16.6	45.0	49.1	0.0	6.6	15.0	19.3	0.0	0.0	11.6	12.2
Methoxychlor	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DDT	13.7	26.3	75.4	82.1	17.2	43.8	71.9	85.7	8.3	29.7	59.1	66.0
DDD	63.9	69.7	83.9	85.7	46.6	53.4	64.6	73.2	35.2	43.1	55.3	55.3
Toxaphene	0.0	0.0	55.0	70.0	0.0	0.0	60.0	70.0	0.0	0.0	20.0	40.0
Chlordane	93.0	100.0	-	-	100.0	-	-	-	50.0	78.2	81.9	90.9
Lindane	96.6	100.0	-	-	96.6	100.0	-	-	100.0	-	-	-
Parathion	78.3	91.6	100.0	-	90.0	100.0	-	-	53.3	56.6	-	-
TEPP	100.0	-	-	-	91.6	-	-	-	55.0	-	-	-
Pestox 3	0.0	6.6	15.0	23.3	0.0	8.3	13.3	13.3	0.0	0.0	0.0	0.0
Allethrin	0.0	0.0	20.0	25.0	0.0	0.0	13.3	15.0	0.0	0.0	0.0	0.0

*All figures for percent control are corrected against the untreated series using "Abbot's formula" (1).

60 tarnished plant bugs were used in each test.

FIG.9. MORTALITY CURVE SHOWING THE EFFECT OF NICOTINE SULFATE.

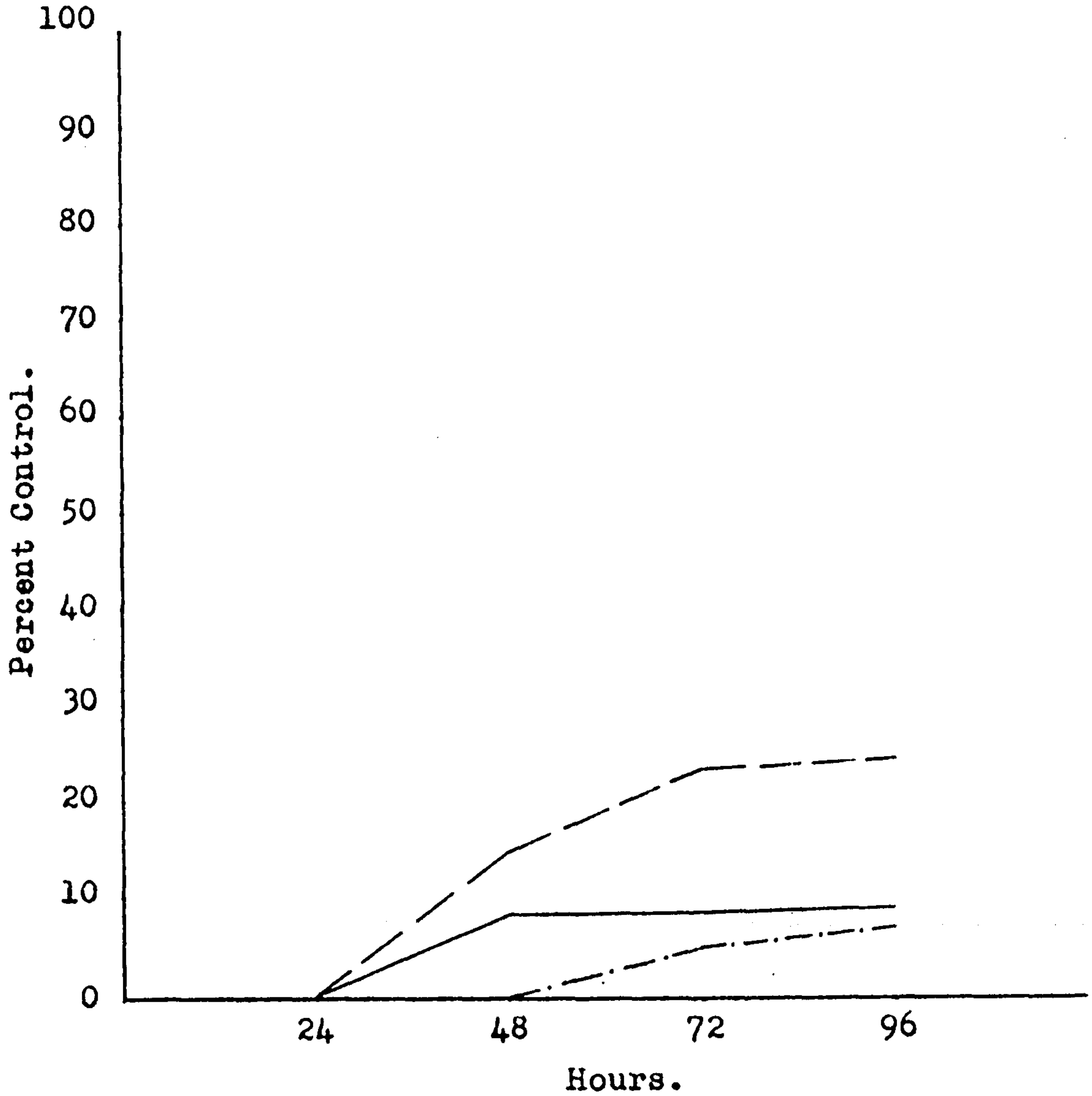


---- High Concentration.

____ Medium Concentration.

-.-. Low Concentration.

FIG. 10. MORTALITY CURVE SHOWING THE EFFECT OF NICOTINE SULFATE, PYRETHRUM & SULFUR.

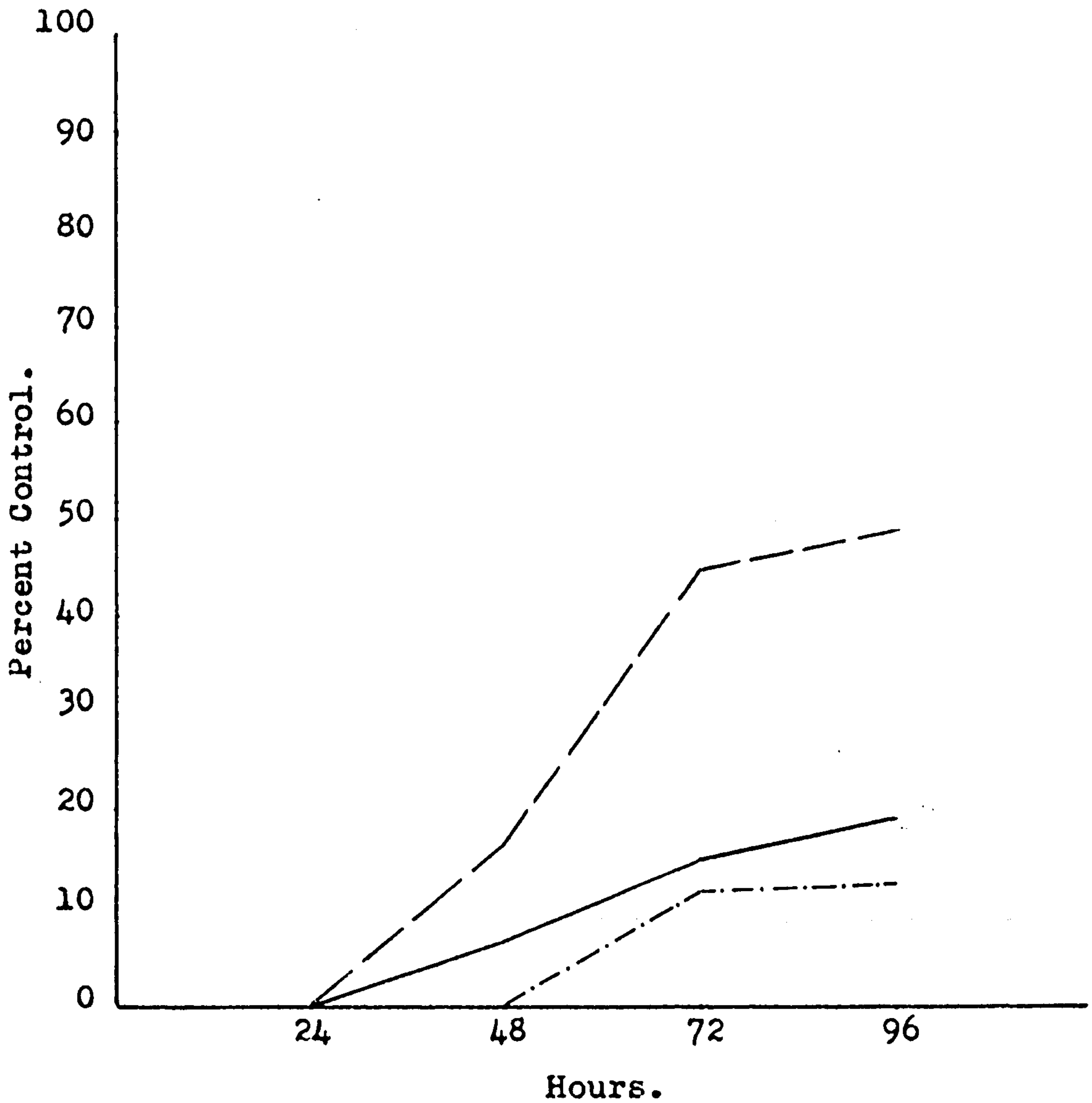


---- High Concentration.

____ Medium Concentration.

-.-. Low Concentration.

FIG. 11. MORTALITY CURVE SHOWING THE EFFECT OF RYANIA.

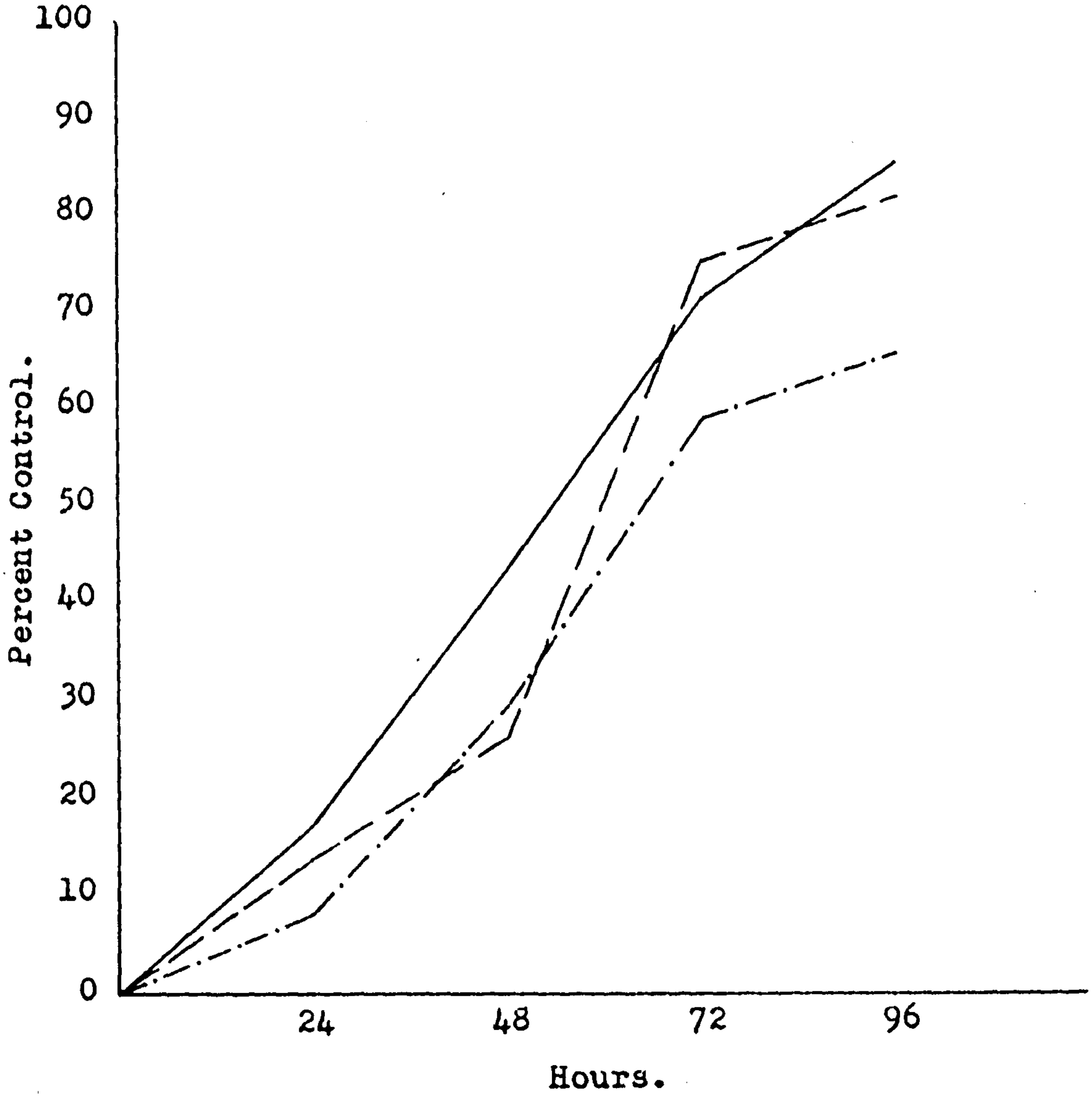


---- High Concentration.

____ Medium Concentration.

-.-. Low Concentration.

FIG. 12. MORTALITY CURVE SHOWING THE EFFECT OF DDT.

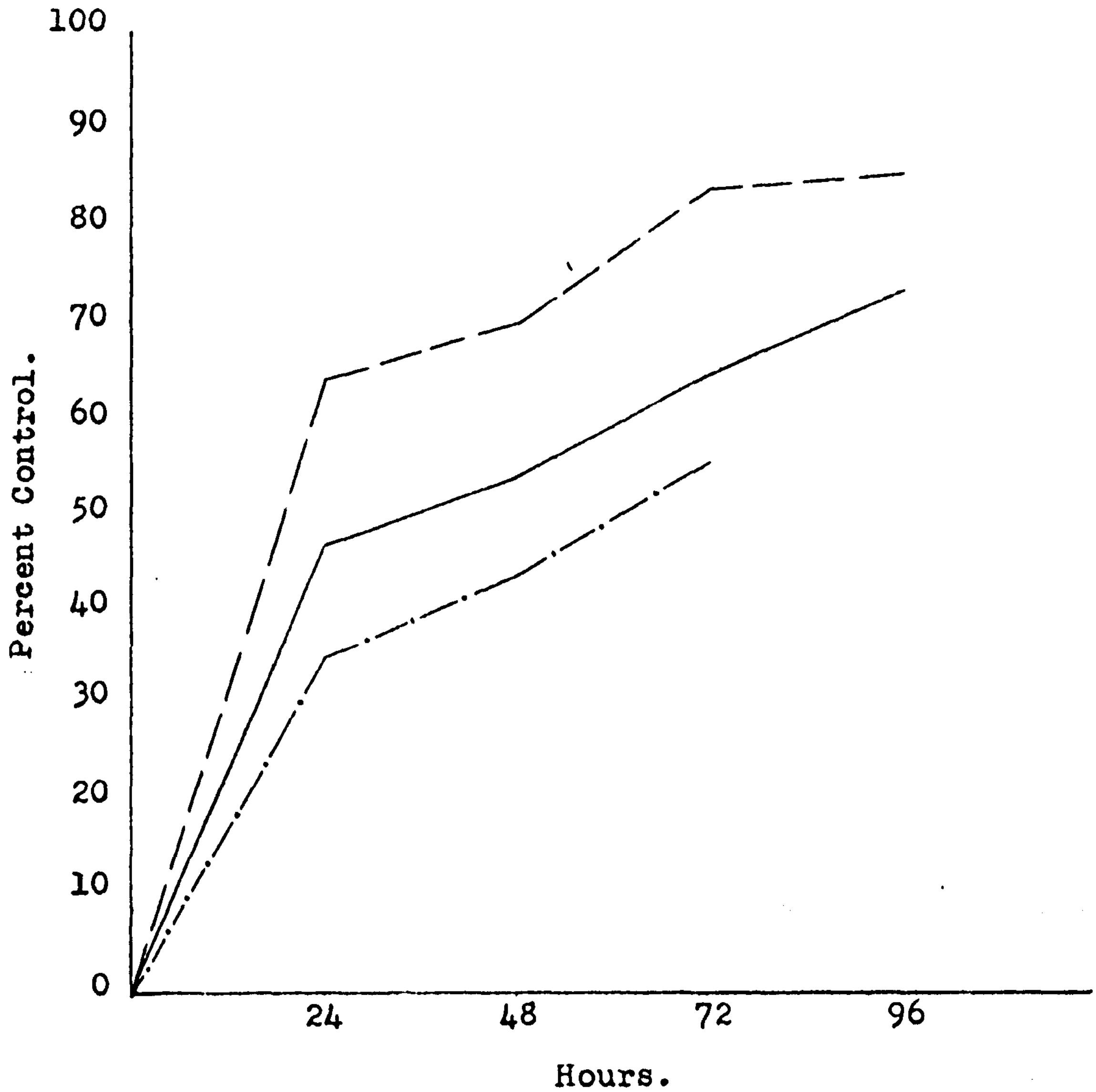


---- High Concentration.

____ Medium Concentration.

-.-. Low Concentration.

FIG. 13. MORTALITY CURVE SHOWING THE EFFECT OF DDD.

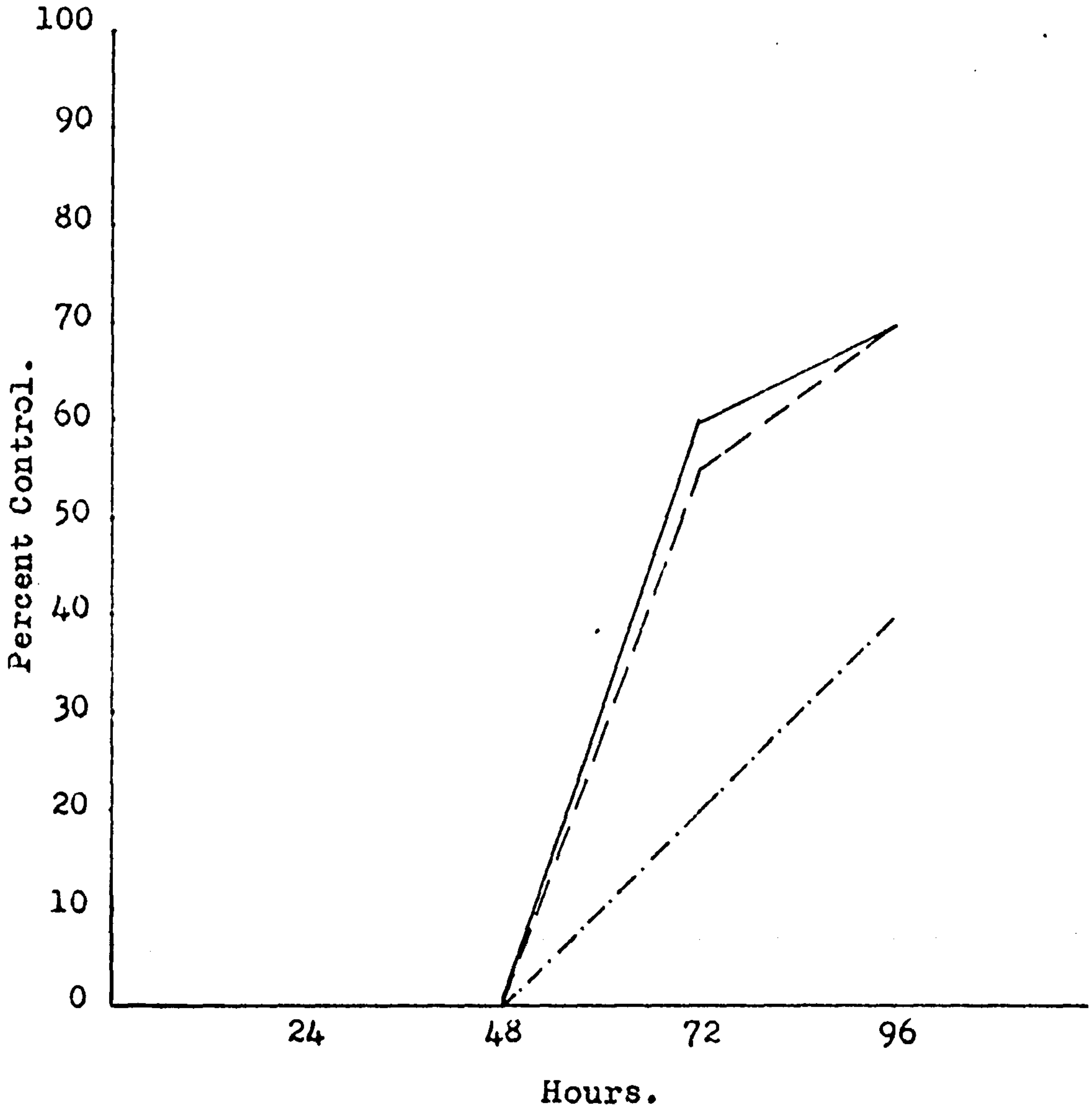


---- High Concentration.

____ Medium Concentration.

-.-. Low Concentration.

FIG. 14. MORTALITY CURVE SHOWING THE EFFECT OF TOXAPHENE.

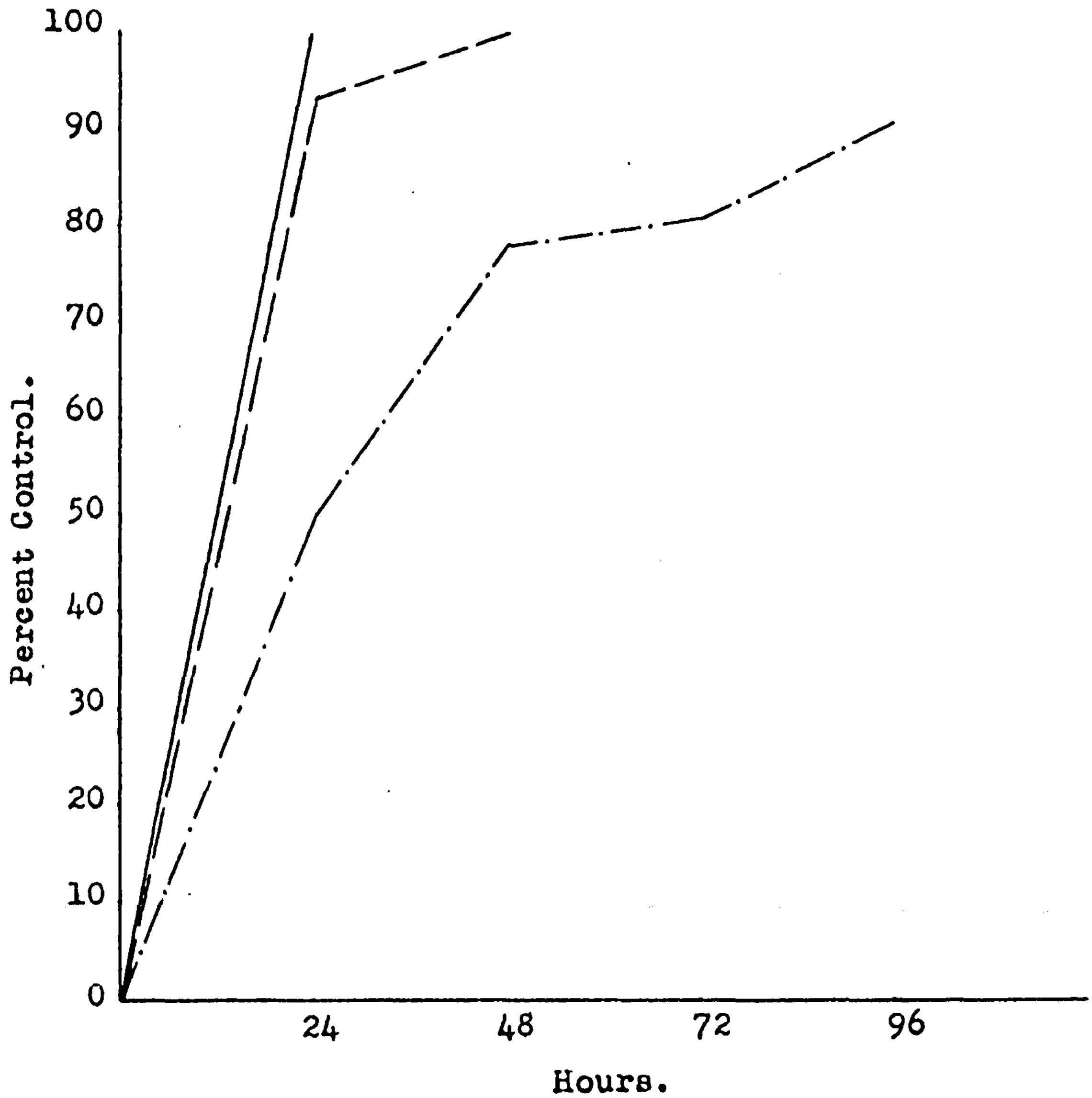


---- High Concentration.

____ Medium Concentration.

-.-. Low Concentration.

FIG.15. MORTALITY CURVE SHOWING THE EFFECT OF CHLORDANE.

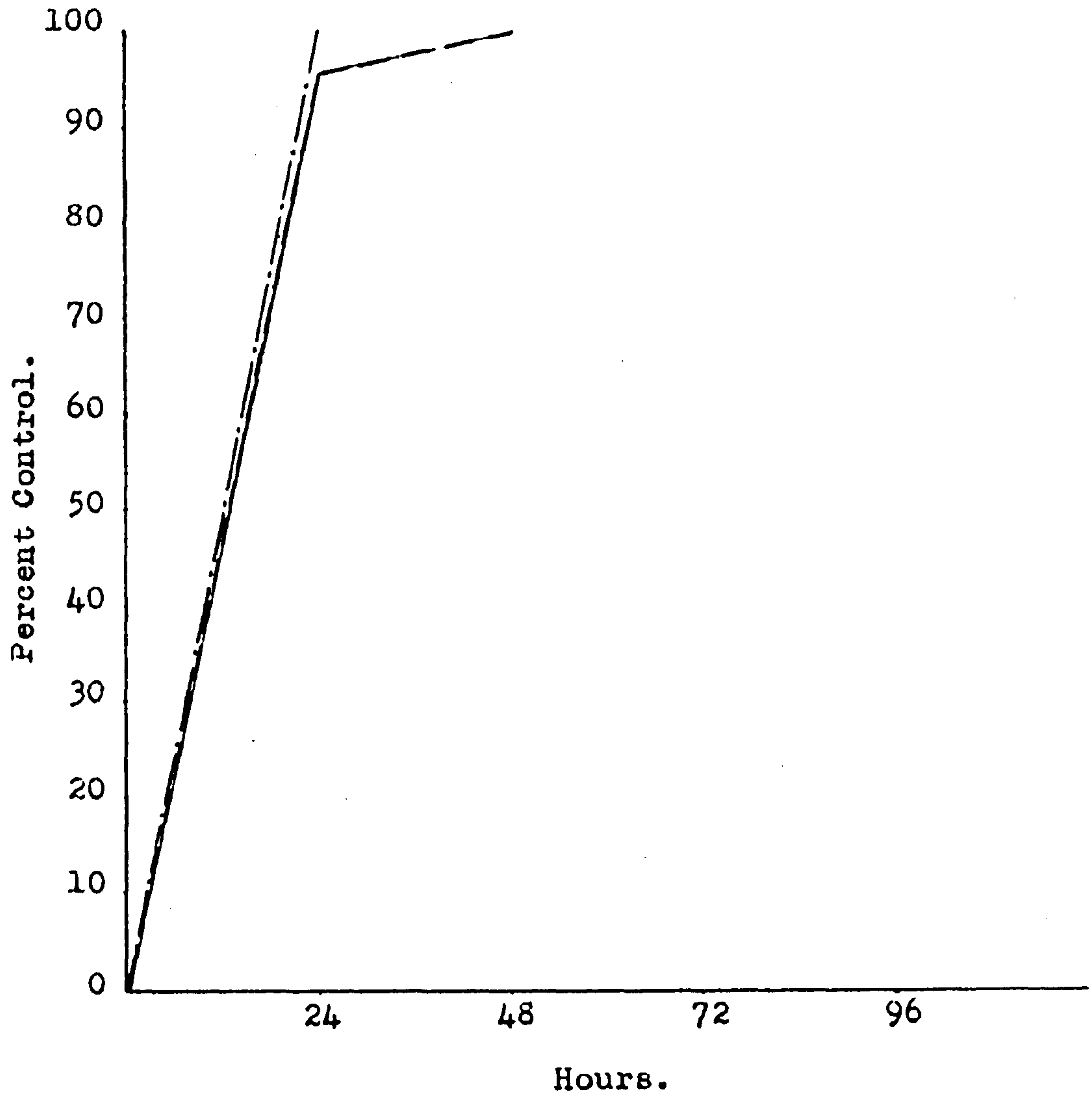


---- High Concentration.

____ Medium Concentration.

-.-. Low Concentration.

FIG. 16. MORTALITY CURVE SHOWING THE EFFECT OF LINDANE.

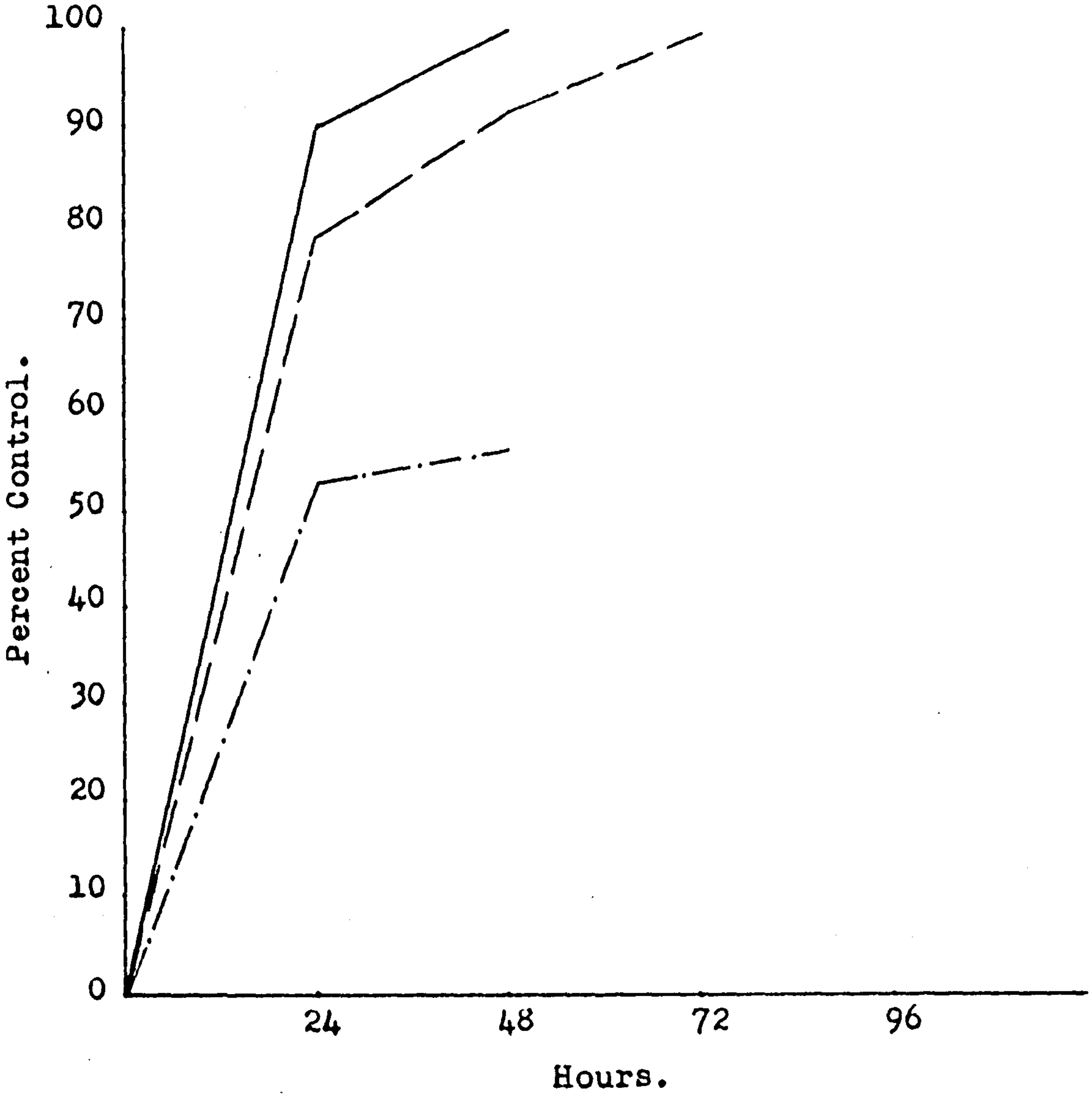


---- High Concentration.

____ Medium Concentration.

-.-. Low Concentration.

FIG. 17. MORTALITY CURVE SHOWING THE EFFECT OF PARATHION.

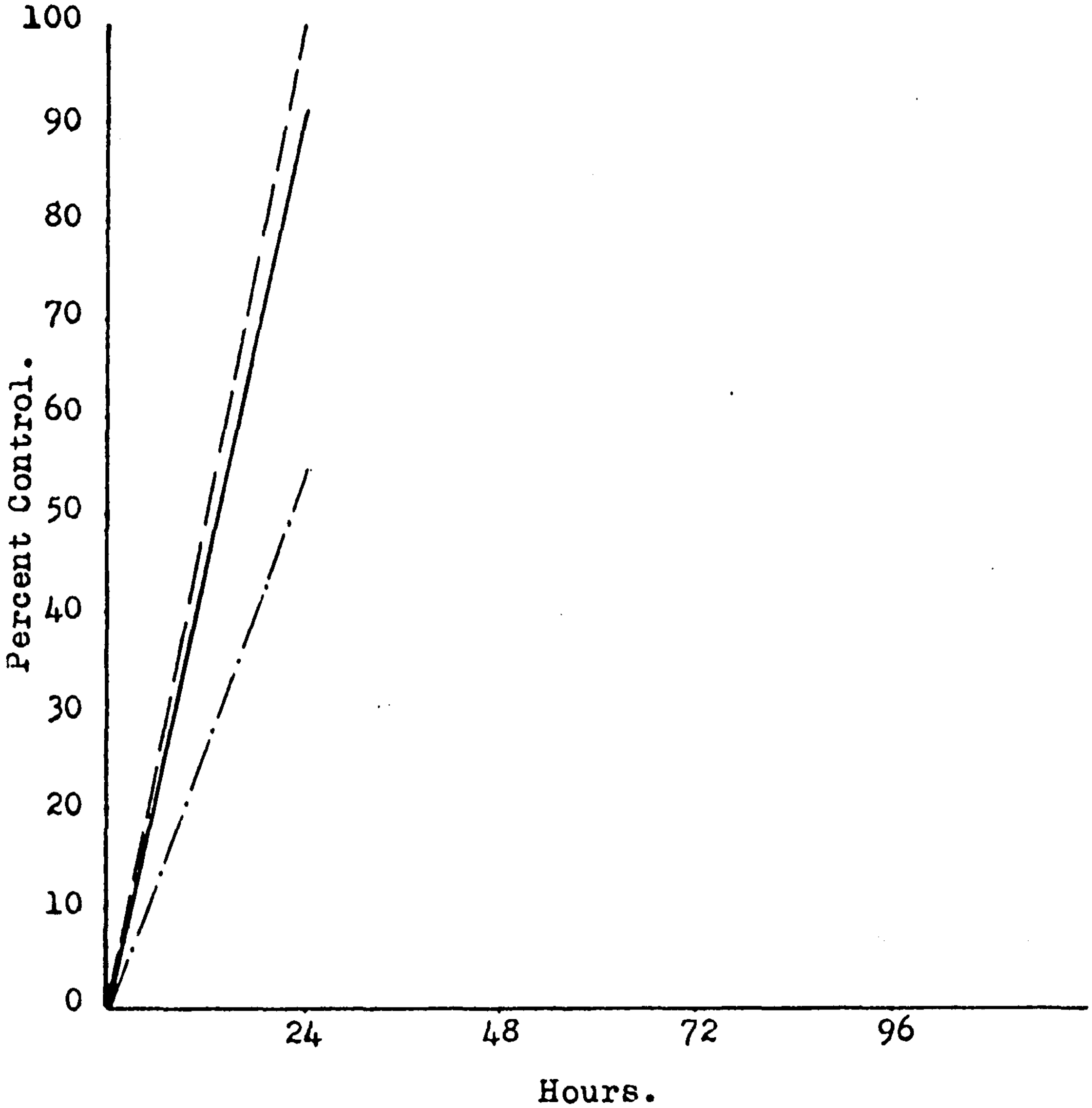


---- High Concentration.

____ Medium Concentration.

-.-. Low Concentration.

FIG. 18. MORTALITY CURVE SHOWING THE EFFECT OF T E P P.

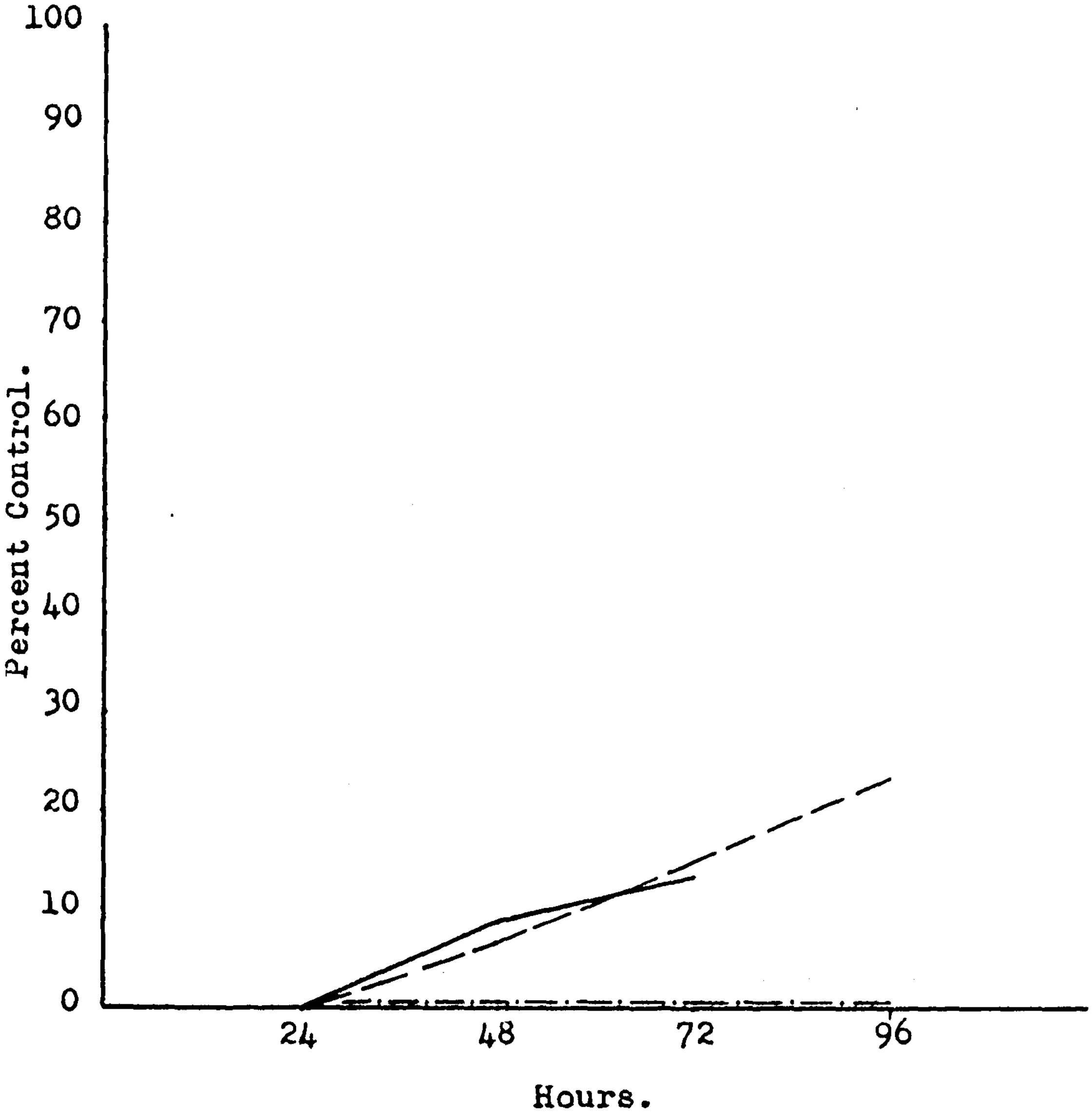


---- High Concentration.

____ Medium Concentration.

-.-. Low Concentration.

FIG. 19. MORTALITY CURVE SHOWING THE EFFECT OF PESTOX 3.



---- High Concentration.

____ Medium Concentration.

-.-. Low Concentration.

FIG. 20. CONTROL OF L. OBLINEATUS BY VARIOUS INSECTICIDES AT MEDIUM CONCENTRATION.

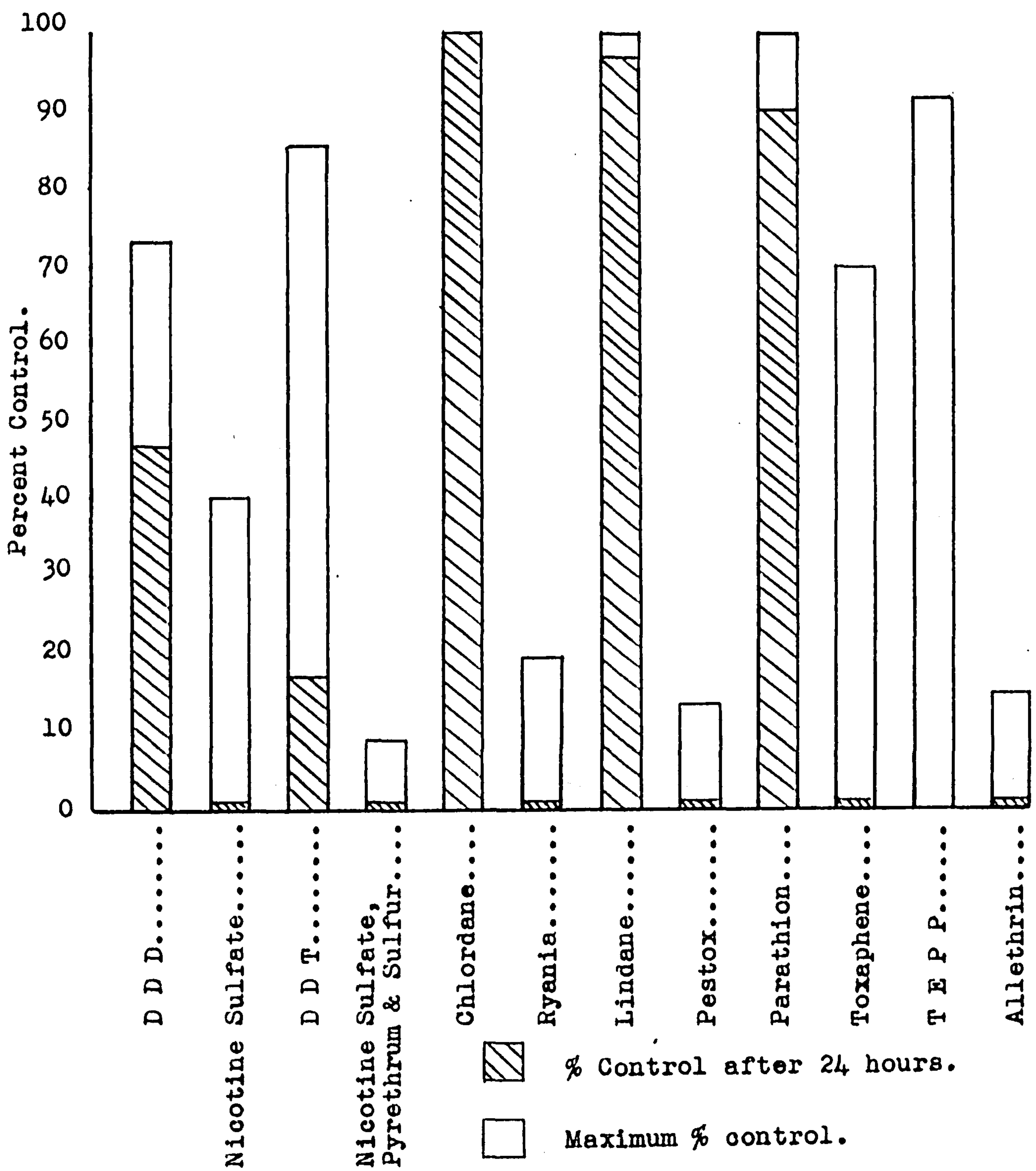


FIG. 21. MAXIMUM RESIDUAL EFFECT OF VARIOUS INSECTICIDES AT MEDIUM CONCENTRATION.

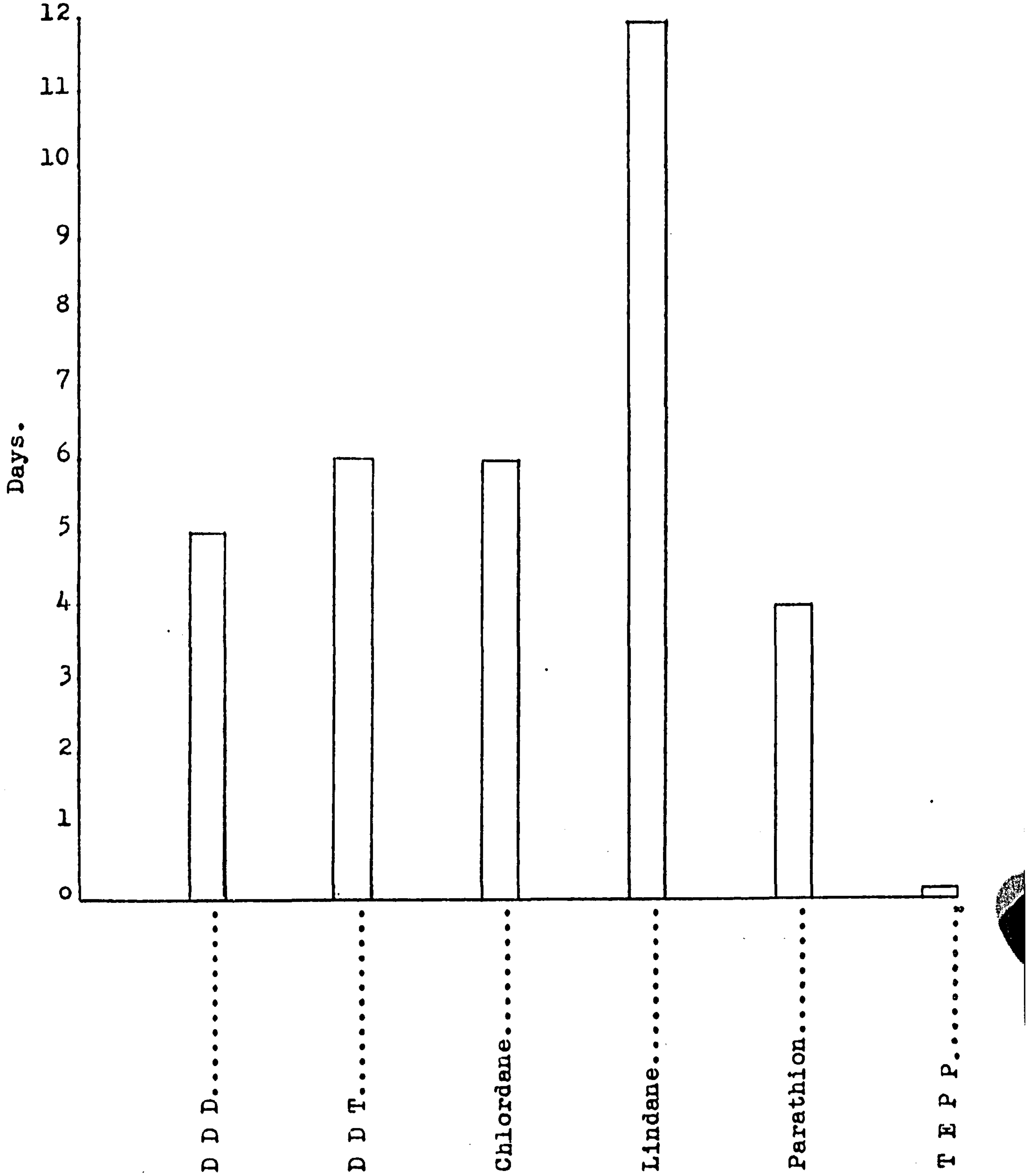


TABLE VI

DESIGN OF SPLIT PLOT EXPERIMENT FOR THE CONTROL OF <u>L.</u> <u>OBLINEATUS</u> WITH LINDANE ON CELERY

	Replication I	
H A 2 0 4 6	L C 6 2 0 4	M B 6 4 2 0
M C 6 4 2 0	H B 0 6 2 4	L A 6 0 4 2
L B 0 2 4 6	M A 6 0 4 2	H C 0 6 4 2
	Replication II	
M B 6 2 4 0	H A 6 0 4 2	L C 6 2 4 0
L A 0 6 2 4	M C 0 2 4 6	H B 2 0 4 6
H C 6 2 4 0	L B 4 6 2 0	M A 2 6 0 4
	Replication III	
L C 6 0 4 2	M B 4 0 2 6	H A 0 4 6 2
H B 6 0 2 4	L A 2 6 0 4	M C 4 0 6 2
M A 0 4 6 2	H C 2 4 0 6	L B 4 0 2 6

H = High Concentration (32 ounces per 100 gallons).

M = Medium Concentration (16 ounces per 100 gallons).

L = Low Concentration (8 ounces per 100 gallons).

A = 200 bugs per cage.

B = 400 bugs per cage.

C = 800 bugs per cage

0, 2, 4 and 6 refer to number of sprays.

TABLE VII

WEIGHT IN OUNCES OF NINE UNTRIMMED CELERY PLANTS HARVESTED FROM PLOTS TREATED WITH LINDANE

Replications	Infestations	Low Concentration 8 ounces per 100 gallons				Medium Concentration 16 ounces per 100 gallons				High Concentration 32 ounces per 100 gallons			
		Number of Sprays				Number of Sprays				Number of Sprays			
		0	2	4	6	0	2	4	6	0	2	4	6
I	A	456	441	465	320	408	485	360	342	449	379	501	506
	B	342	412	435	357	450	465	499	399	397	387	534	463
	C	358	514	527	411	424	444	444	394	361	438	455	442
II	A	337	448	511	493	473	405	444	388	448	483	511	512
	B	480	406	470	439	474	488	494	412	413	447	435	412
	C	450	443	472	387	410	495	471	386	506	481	549	456
III	A	403	433	514	348	458	435	492	484	341	412	450	361
	B	476	485	482	477	355	456	459	517	402	435	451	371
	C	444	449	466	408	379	450	435	344	375	440	448	520
Total		3746	4031	4342	3640	3831	4123	4098	3666	3692	3902	4334	4043

Infestation A = 200 bugs per cage.

Infestation B = 400 bugs per cage.

Infestation C = 800 bugs per cage.

TABLE VIII

ANALYSIS OF VARIANCE OF THE DATA PRESENTED IN TABLE VII

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Replications	2	11472	5736
Infestations (I)	2	600	300
Concentrations (C)	2	1024	512
I x C	4	11893	2973
Error 1	16	55566	3473
Sprays (S)	3	54970	18323**
I x S	6	3778	630
C x S	6	18381	3064
I x C x S	12	14221	1185
Error 2	54	143175	2701

**Denotes significance at 1% level.

TABLE IX

WEIGHT IN OUNCES OF NINE TRIMMED CELERY PLANTS HARVESTED FROM PLOTS TREATED WITH LINDANE

Replications	Infestations	Low Concentration 8 ounces per 100 gallons				Medium Concentration 16 ounces per 100 gallons				High Concentration 32 ounces per 100 gallons			
		Number of Sprays				Number of Sprays				Number of Sprays			
		0	2	4	6	0	2	4	6	0	2	4	6
I	A	301	285	309	256	254	280	246	240	289	239	304	301
	B	228	258	271	214	316	330	383	303	277	267	362	350
	C	243	362	322	319	272	278	304	285	250	263	307	316
II	A	224	287	373	360	289	248	262	236	253	320	300	278
	B	296	253	246	289	295	300	348	313	255	280	287	269
	C	300	297	279	264	245	304	268	207	328	351	418	353
III	A	213	239	378	228	259	224	312	342	171	196	263	184
	B	268	315	325	339	169	241	255	317	244	201	276	197
	C	252	240	320	277	228	259	288	225	192	303	317	281
Total		2325	2536	2823	2546	2327	2464	2666	2468	2259	2420	2834	2529

Infestation A = 200 bugs per cage.

Infestation B = 400 bugs per cage.

Infestation C = 800 bugs per cage.

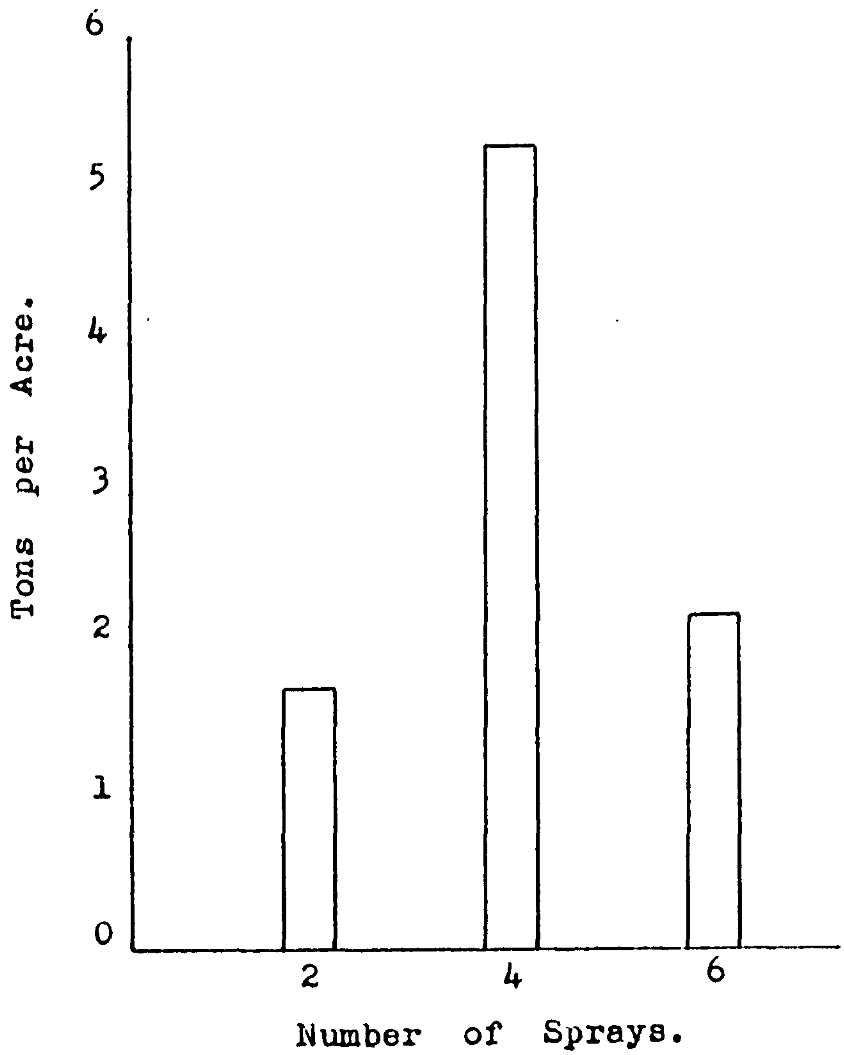
TABLE X

ANALYSIS OF VARIANCE OF THE DATA PRESENTED IN TABLE IX

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Replications	2	22178	11089
Infestations (I)	2	4788	2394
Concentrations (C)	2	1315	658
I x C	4	20197	5049
Error 1	16	67958	4247
Sprays (S)	3	37881	12627**
I x S	6	4193	699
C x S	6	1569	262
I x C x S	12	16005	1334
Error 2	54	67734	1254

**Denotes significance at 1% level.

FIG. 22. INCREASE IN THE YIELD OF CELERY (STRIPPED)*
IN THE PLOTS TREATED WITH LINDANE.



*Trimmed.

TABLE XI

VARIATION IN THE YIELD OF CELERY (UNTRIMMED)
DUE TO THE NUMBER OF SPRAYS

	Number of Sprays			
	0	2	4	6
Total Weight (oz.)	11269	12056	12774	11349
Mean Weight (oz.)	417.4	446.5	473.1	420.3

A. Difference between spray means to be significant at 5% level = 40.0.

B. Difference between spray means to be significant at 1% level = 54.0.

TABLE XII

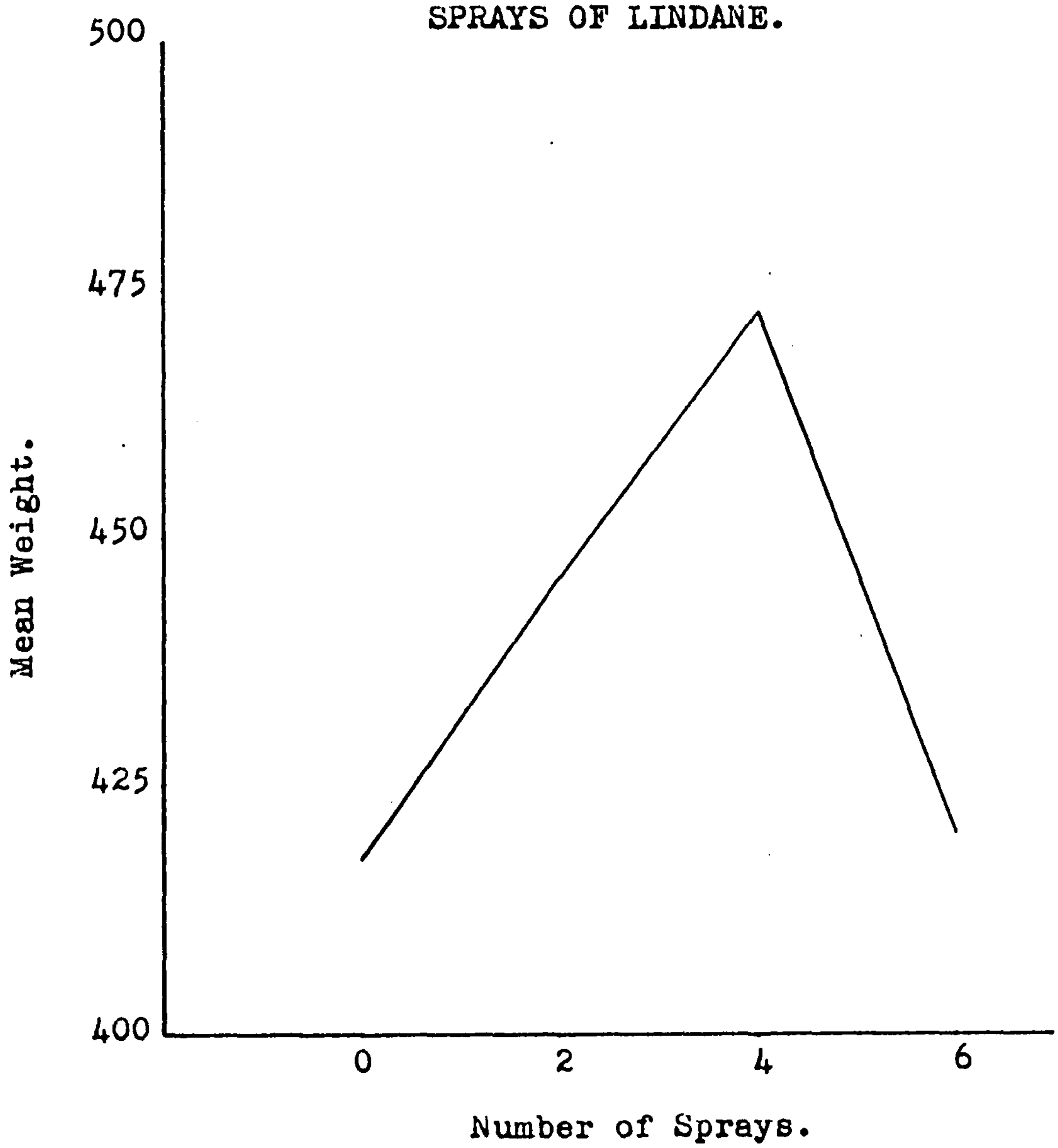
VARIATION IN THE YIELD OF CELERY (TRIMMED)
DUE TO THE NUMBER OF SPRAYS

	Number of Sprays			
	0	2	4	6
Total Weight (oz.)	6911	7420	8323	7543
Mean Weight (oz.)	256.0	274.8	308.3	279.4

A. Difference between spray means to be significant at 5% level = 26.9.

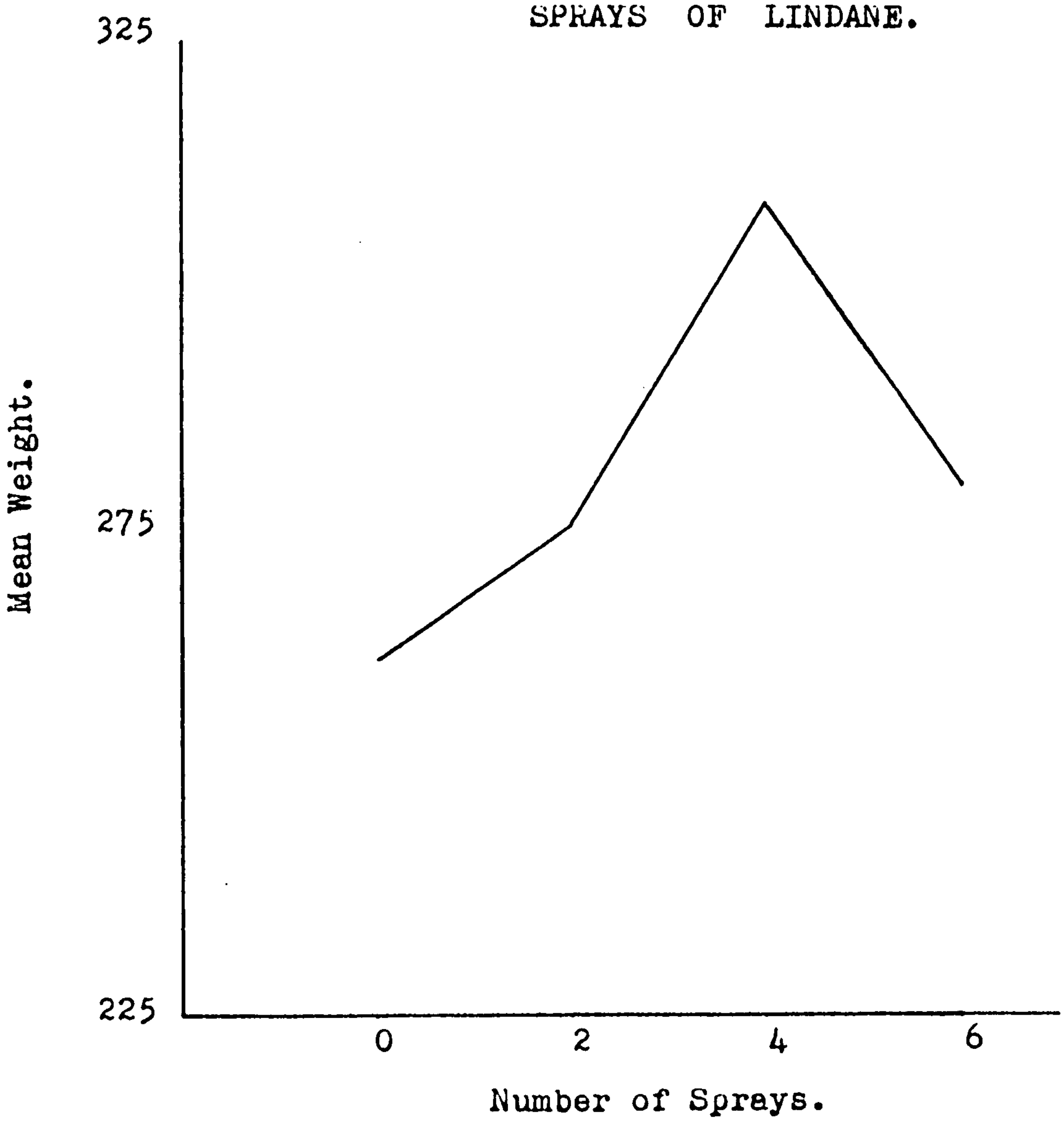
B. Difference between spray means to be significant at 1% level = 36.0.

FIG. 23. VARIATION IN THE MEAN WEIGHT OF CELERY (UNSTRIPPED)* DUE TO THE NUMBER OF SPRAYS OF LINDANE.



*Untrimmed.

FIG. 24. VARIATION IN THE MEAN WEIGHT OF CELERY (STRIPPED)* DUE TO THE NUMBER OF SPRAYS OF LINDANE.



*Trimmed.

TABLE XIII

THE INFLUENCE OF TREATMENTS ON THE NUMBER OF CELERY STALKS INJURED AND TOTAL NUMBER OF PUNCTURES BY L. OBLINEATUS*

No. of Sprays	Concentrations	Infestations	Replication I			Replication II			Replication III		
			Total Stalks	Injured Stalks	Total Feeding Punctures	Total Stalks	Injured Stalks	Total Feeding Punctures	Total Stalks	Injured Stalks	Total Feeding Punctures
0	L	A	29	10	42	35	12	38	23	8	20
0	L	B	26	14	64	30	17	71	27	12	78
0	L	C	38	19	59	27	18	80	25	12	102
0	M	A	26	10	28	28	11	26	30	10	29
0	M	B	36	20	85	29	12	65	24	10	63
0	M	C	27	11	44	28	15	62	32	14	89
0	H	A	29	11	55	28	8	18	21	5	16
0	H	B	30	12	48	24	13	42	29	9	55
0	H	C	27	9	41	32	20	105	24	9	46
2	L	A	27	12	37	32	9	25	31	10	27
2	L	B	26	12	49	32	10	32	33	13	63
2	L	C	30	16	54	28	10	29	29	11	49
2	M	A	27	12	42	23	6	14	27	8	18
2	M	B	31	15	50	36	15	40	28	8	21
2	M	C	27	9	34	26	9	22	31	11	44
2	H	A	30	12	31	26	6	18	24	6	14
2	H	B	31	10	44	28	8	23	28	8	22
2	H	C	26	15	58	37	18	50	38	12	40
4	L	A	33	9	25	28	4	8	31	7	12
4	L	B	25	8	23	27	8	17	25	7	15
4	L	C	30	12	27	28	9	23	29	10	27
4	M	A	28	8	21	25	5	12	27	5	10
4	M	B	32	8	13	28	7	17	26	6	11
4	M	C	28	7	21	28	7	18	34	9	26
4	H	A	28	2	3	28	2	2	22	2	3
4	H	B	31	6	13	32	6	9	28	5	12
4	H	C	30	9	23	35	8	21	42	10	29
6	L	A	35	5	7	38	4	9	27	2	2
6	L	B	29	8	17	26	6	10	34	8	14
6	L	C	28	9	18	24	5	13	27	8	24
6	M	A	25	3	9	27	5	8	26	2	2
6	M	B	33	6	11	38	7	11	28	2	4
6	M	C	36	9	17	26	8	11	29	3	7
6	H	A	30	0	0	26	1	1	28	0	0
6	H	B	30	3	4	28	3	4	30	2	2
6	H	C	29	5	11	41	5	8	25	3	7

*Figures represent total number from three trimmed plants randomly selected from each row

TABLE XIV

PERCENTAGE OF STALKS INJURED BY FEEDING PUNCTURES OF *L. OBLINEATUS*, AS RELATED TO THE TREATMENTS*

Replications	Infestations	Low Concentration 8 ounces per 100 gallons				Medium Concentration 16 ounces per 100 gallons				High Concentration 32 ounces per 100 gallons			
		Number of Sprays				Number of Sprays				Number of Sprays			
		0	2	4	6	0	2	4	6	0	2	4	6
I	A	34.5	44.4	27.3	14.3	38.5	44.4	28.6	8.0	37.9	40.0	7.2	0.0
	B	53.8	46.2	32.0	27.6	55.6	48.4	25.0	18.2	40.0	32.3	19.4	10.0
	C	50.0	53.3	40.0	32.1	40.7	33.3	25.0	25.0	33.3	57.7	30.0	17.2
II	A	34.3	28.1	14.3	10.5	39.3	26.1	20.0	18.5	28.6	23.1	7.2	3.8
	B	56.7	31.3	29.6	23.1	41.4	41.7	25.0	18.4	54.2	28.6	18.8	10.7
	C	66.7	35.7	32.1	20.8	53.6	34.6	25.0	30.8	62.5	48.6	22.9	12.2
III	A	34.8	32.3	22.6	7.4	33.3	29.6	18.5	7.7	23.8	25.0	9.1	0.0
	B	44.4	39.4	28.0	23.5	41.7	28.6	23.1	7.2	31.0	28.6	17.9	6.7
	C	48.0	37.9	34.5	29.6	43.8	35.5	26.5	10.3	37.5	31.6	23.8	12.0

*Computed on trimmed celery from the data presented in Table XIII.

TABLE XV

ANALYSIS OF VARIANCE OF THE DATA PRESENTED IN TABLE XIV

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Replications	2	786	393
Infestations (I)	2	2646	1323**
Concentrations (C)	2	1498	749**
I x C	4	377]]880	94]]44
Error 1	16	503]	32]
Sprays (S)	3	12862	4287**
I x S	6	210	35
C x S	6	245	41
I x C x S	12	371	31
Error 2	54	2273	42

**Denotes significance at 1% level.

TABLE XVI

THE EFFECT OF INSECTICIDE CONCENTRATION AND INSECT INFESTATION ON THE PERCENTAGE OF INJURED STALKS*

Infestations	Concentrations		
	Low	Medium	High
A	25.4	26.1	17.2
B	36.3	31.2	24.8
C	40.0	32.0	32.4
Mean	33.9	29.8	24.8

*Averages of 36 trimmed celery plants.

A. For testing significance of the difference between concentration means.

   i. Difference to be significant at 5% level = 2.82.

   ii. Difference to be significant at 1% level = 3.88.

B. For testing significance of the difference between two concentration means at different levels of infestations.

   i. Difference to be significant at 5% level = 4.90.

   ii. Difference to be significant at 1% level = 6.75.

TABLE XVII

THE EFFECT OF INSECTICIDE CONCENTRATION AND NUMBER OF SPRAYS ON THE PERCENTAGE OF INJURED STALKS*

Concentrations	Number of Sprays			
	0	2	4	6
Low	47.0	38.8	28.9	21.0
Medium	43.1	35.8	24.1	16.0
High	38.8	35.0	17.3	8.1
Mean	43.0	36.5	23.4	15.0

*Averages of 27 trimmed celery plants.

A. For testing significance of the difference between spray means.

i. Difference to be significant at 5% level = 3.47.

ii. Difference to be significant at 1% level = 4.62.

B. For testing significance of the difference between two spray means at different levels of concentration.

i. Difference to be significant at 5% level = 5.90.

ii. Difference to be significant at 1% level = 7.84.

TABLE XVIII

THE EFFECT OF INSECT INFESTATION AND NUMBER OF SPRAYS ON THE PERCENTAGE OF INJURED STALKS*

Number of Sprays	Infestations		
	A	B	C
0	34.0	46.6	48.4
2	32.6	36.1	40.9
4	17.2	24.3	28.8
6	7.9	16.1	21.1
Mean	22.9	30.8	34.8

*Averages of 27 trimmed celery plants.

A. For testing significance of the difference between infestation means.

i. Difference to be significant at 5% level = 2.82.

ii. Difference to be significant at 1% level = 3.88.

B. For testing significance of the difference between two infestation means at different levels of sprays.

i. Difference to be significant at 5% level = 5.90.

ii. Difference to be significant at 1% level = 7.84.

TABLE XIX

THE EFFECT OF INSECTICIDE CONCENTRATION, NUMBER OF SPRAYS AND INSECT INFESTATION ON THE PERCENTAGE OF INJURED STALKS*

	0			2			4			6		
	L	M	H	L	M	H	L	M	H	L	M	H
A	34.7	37.0	30.0	35.0	33.3	29.3	21.3	22.3	8.0	10.7	11.7	1.3
B	51.7	46.3	41.7	39.0	39.7	29.7	29.7	24.3	18.7	24.7	14.7	9.3
C	55.0	46.0	44.3	42.3	34.3	46.0	35.7	25.3	25.7	27.3	22.0	13.7
Mean	47.1	43.1	38.7	38.8	35.8	35.0	28.9	24.0	17.4	20.9	16.1	8.1

*Averages of 9 trimmed celery plants.

A. For testing significance of the difference between two spray means for the same treatment.

i. Difference to be significant at 5% level = 10.6.

ii. Difference to be significant at 1% level = 14.1.

B. For testing significance of the difference between two treatment means for the same or different sprays.

i. Difference to be significant at 5% level = 10.2.

ii. Difference to be significant at 1% level = 13.5.

TABLE XX

FEEDING PUNCTURES ON TRIMMED CELERY AS INFLUENCED BY TREATMENTS*

Replications	Infestations	Low Concentration 8 ounces per 100 gallons — Number of Sprays				Medium Concentration 16 ounces per 100 gallons — Number of Sprays				High Concentration 32 ounces per 100 gallons — Number of Sprays			
		0	2	4	6	0	2	4	6	0	2	4	6
I	A	145	133	76	20	108	155	74	36	190	104	11	0
	B	247	185	93	58	239	160	40	33	160	142	43	13
	C	155	181	92	64	163	127	75	45	153	225	78	38
II	A	110	79	29	24	94	60	48	30	66	69	7	4
	B	238	100	62	39	224	113	60	29	173	83	19	11
	C	293	104	83	54	220	83	65	49	331	136	60	20
III	A	87	87	38	7	97	68	37	8	76	58	14	0
	B	288	189	59	42	263	74	42	14	189	80	43	7
	C	408	171	93	89	280	142	77	24	191	104	69	28

*Computed on the basis of one hundred stalks.

TABLE XXI

ANALYSIS OF VARIANCE OF THE DATA PRESENTED IN TABLE XX

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Replications	2	4877	2439
Infestations (I)	2	78479	39240**
Concentrations (C)	2	21341	10671**
I x C	4	7403	1851
Error 1	16	27049	1691
Sprays (S)	3	429001	143000**
I x S	6	42571	7095**
C x S	6	2704	451
I x C x S	12	8570	714
Error 2	54	77209	1430

**Denotes significance at 1% level.

TABLE XXII

THE EFFECT OF INSECTICIDE CONCENTRATION AND INSECT INFESTATION ON THE NUMBER OF FEEDING PUNCTURES*

Infestations	Concentrations		
	Low	Medium	High
A	69.6	67.9	49.9
B	133.3	107.5	107.1
C	148.9	112.5	119.4
Mean	117.3	96.0	83.2

*Averages from the data presented in Table XX.

A. For testing significance of the difference between concentration means.

i. Difference to be significant at 5% level = 20.6.

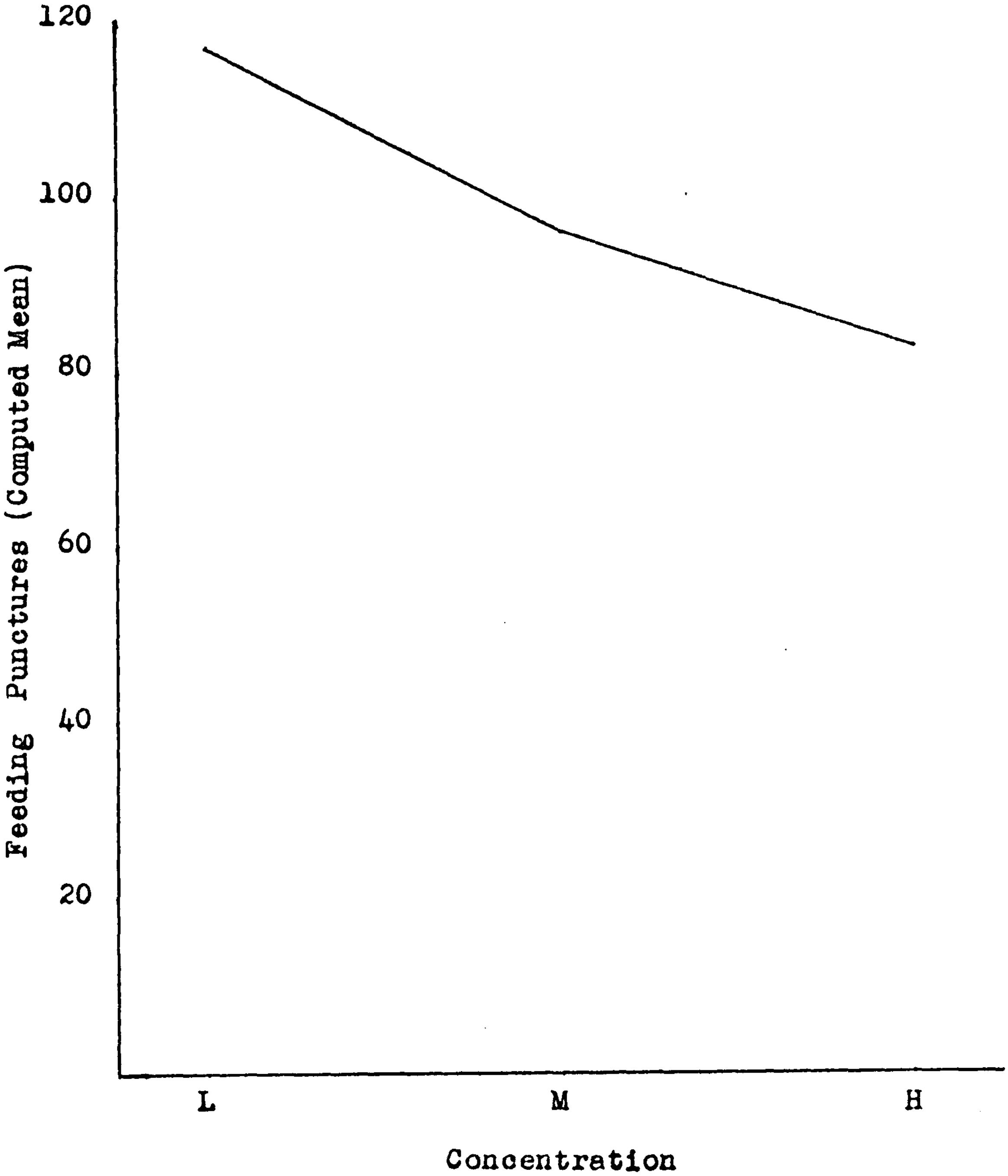
ii. Difference to be significant at 1% level = 28.3.

B. For testing significance of the difference between two concentration means at different levels of infestations.

i. Difference to be significant at 5% level = 35.6.

ii. Difference to be significant at 1% level = 49.1.

FIG. 25. EFFECT OF CONCENTRATION OF LINDANE ON THE CONTROL OF L. OBLINEATUS.



L- 8 oz./100 gal.

M- 16 oz./100 gal.

H- 32 oz./100 gal.

TABLE XXIII

THE EFFECT OF INSECTICIDE CONCENTRATION AND NUMBER OF SPRAYS ON THE NUMBER OF FEEDING PUNCTURES*

Concentrations	Number of Sprays			
	0	2	4	6
Low	219.0	136.6	69.4	44.1
Medium	187.6	109.1	57.6	29.8
High	169.9	111.2	38.2	13.4
Mean	192.1	119.0	55.1	29.1

*Averages from the data presented in Table XX.

A. For testing significance of the difference between spray means.

i. Difference to be significant at 5% level = 20.6.

ii. Difference to be significant at 1% level = 27.5.

B. For testing significance of the difference between two spray means at different levels of concentration.

i. Difference to be significant at 5% level = 36.3.

ii. Difference to be significant at 1% level = 48.6.

FIG. 26. EFFECT OF NUMBER OF SPRAYS OF LINDANE ON THE CONTROL OF L. OBLINEATUS.

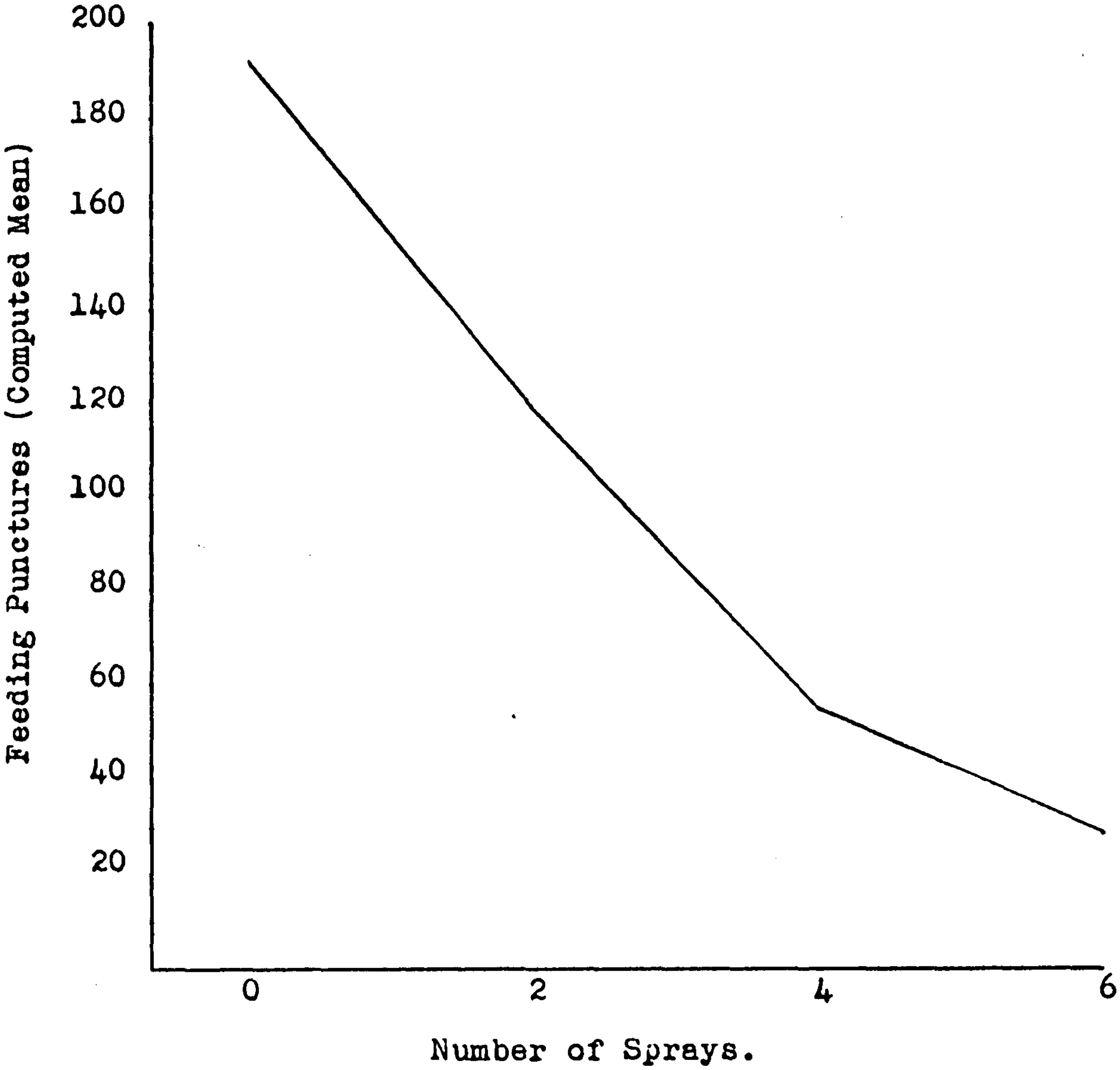


TABLE XXIV

THE EFFECT OF NUMBER OF SPRAYS AND INSECT INFESTATION ON THE NUMBER OF FEEDING PUNCTURES*

Number of Sprays	Infestations		
	A	B	C
0	108.1	224.6	243.8
2	90.3	125.1	141.4
4	37.1	51.2	76.9
6	14.3	27.3	45.7
Mean	62.5	107.1	126.9

*Averages from the data presented in Table XX.

A. For testing significance of the difference between infestation means.

i. Difference to be significant at 5% level = 20.6.

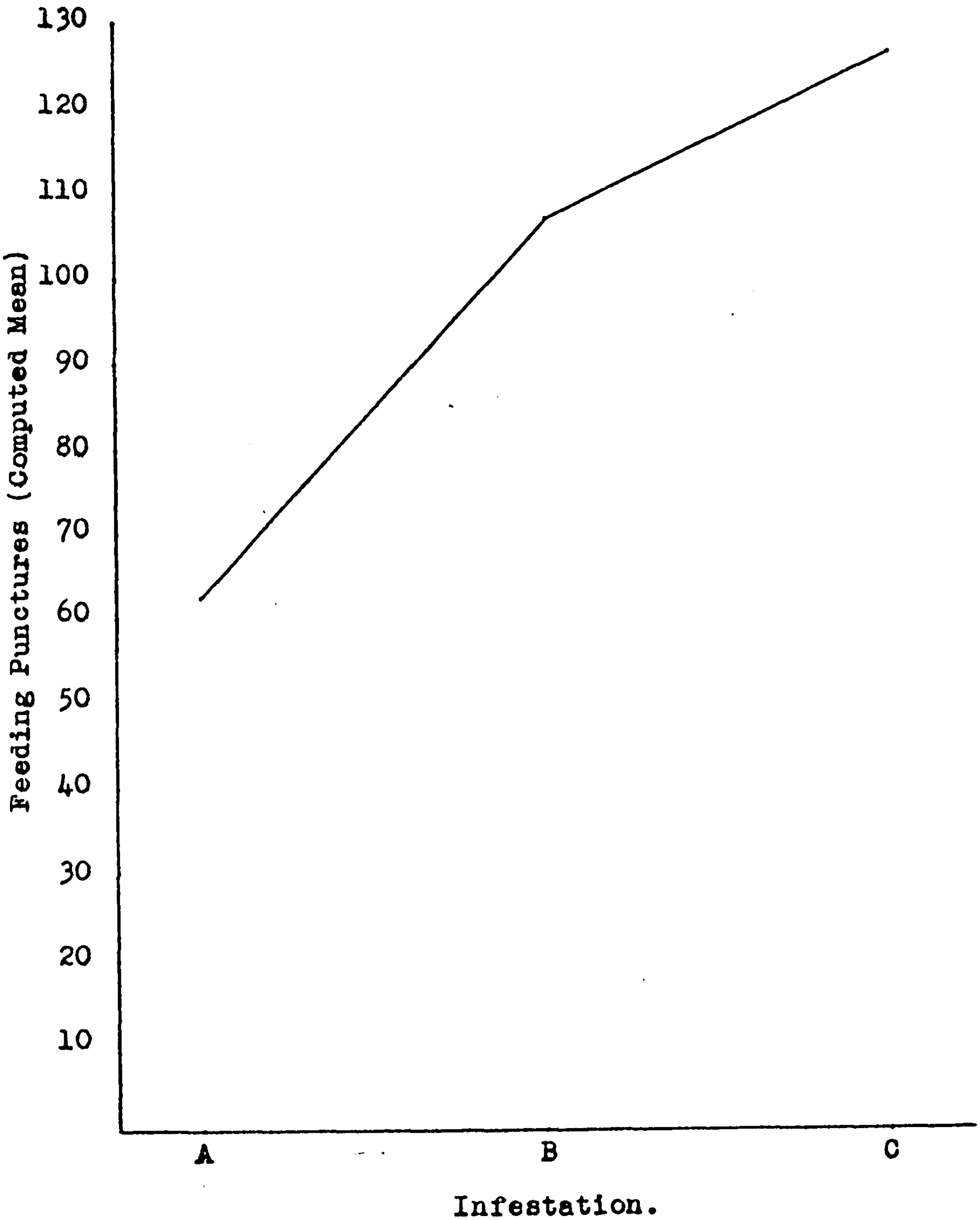
ii. Difference to be significant at 1% level = 27.5.

B. For testing significance of the difference between two spray means at different levels of concentration.

i. Difference to be significant at 5% level = 36.3.

ii. Difference to be significant at 1% level = 48.6.

FIG. 27. EFFECT OF INTENSITY OF INFESTATIONS ON THE CONTROL OF L. OBLINEATUS.



A- 200 bugs.

B- 400 bugs.

C- 800 bugs.

TABLE XXV

THE EFFECT OF INSECTICIDE CONCENTRATION, NUMBER OF SPRAYS AND INSECT INFESTATION ON THE NUMBER OF FEEDING PUNCTURES*

	0			2			4			6		
	L	M	H	L	M	H	L	M	H	L	M	H
A	114.0	99.7	110.7	99.7	94.3	77.0	47.7	53.0	10.7	17.0	24.7	1.3
B	257.7	242.0	174.0	158.0	115.7	101.7	71.3	47.3	35.0	46.3	25.3	10.3
C	285.3	221.0	225.0	152.0	117.3	155.0	89.3	72.3	69.0	69.0	39.0	28.7
Mean	219.0	187.6	169.9	136.6	109.1	111.2	69.4	57.6	38.2	44.1	29.8	13.4

*Averages from the data presented in Table XX.

A. For testing significance of the difference between two spray means for the same treatment.

i. Difference to be significant at 5% level = 61.7.

ii. Difference to be significant at 1% level = 82.3.

B. For testing significance of the difference between two treatment means for the same or different sprays.

i. Difference to be significant at 5% level = 63.0.

ii. Difference to be significant at 1% level = 83.6.

TABLE XXVI

DESIGN OF THE RANDOMIZED BLOCK EXPERIMENT FOR THE CONTROL OF *L. OBLINEATUS* ON CHINESE CABBAGE

S_1T_1	S_2T_2	S_3	S_0	S_1T_2	S_4	S_2T_1
S_2T_1	S_4	S_1T_2	S_1T_1	S_3	S_2T_2	S_0
S_0	S_1T_2	S_4	S_2T_2	S_2T_1	S_3	S_1T_1
S_2T_2	S_3	S_1T_1	S_4	S_2T_1	S_0	S_1T_2
S_4	S_0	S_2T_1	S_1T_2	S_2T_2	S_1T_1	S_3
S_3	S_1T_1	S_0	S_2T_1	S_4	S_1T_2	S_2T_2

TABLE XXVII

EXPLANATION OF THE LETTERS USED IN TABLE XXVI

	Treatment	Number of Sprays	Concentration Ounces per 100 gallons
S_0	Untreated	-	-
S_1T_1	Lindane 25%	4	16
S_1T_2	Lindane 25%	6	16
S_2T_1	Parathion 15%	4	24
S_2T_2	Parathion 15%	6	24
S_3	TEPP	6	16
S_4	Nicotine Sulfate 40% + Pyrethrum 18% + Sulfur 95%	6	[12 [16 [48

TABLE XXVIII

INFLUENCE OF TREATMENTS ON INJURY TO CHINESE CABBAGE BY *L. OBLINEATUS**

Treatments	Replications						Mean
	1	2	3	4	5	6	
Untreated	62	55	50	45	52	49	52.2
Parathion	22	30	25	29	28	18	25.3
Lindane	13	17	11	24	22	14	16.8
TEPP	26	23	20	27	25	34	25.8
Nicotine Sulfate + Pyrethrum + Sulfur	25	26	43	25	32	41	32.0

*Total number of punctures on the midrib of the leaves of four chinese cabbage plants.

TABLE XXIX

ANALYSIS OF VARIANCE OF THE DATA PRESENTED IN TABLE XXVIII

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatments	4	4241	1060**
Replications	5	19	4
Error	20	841	42

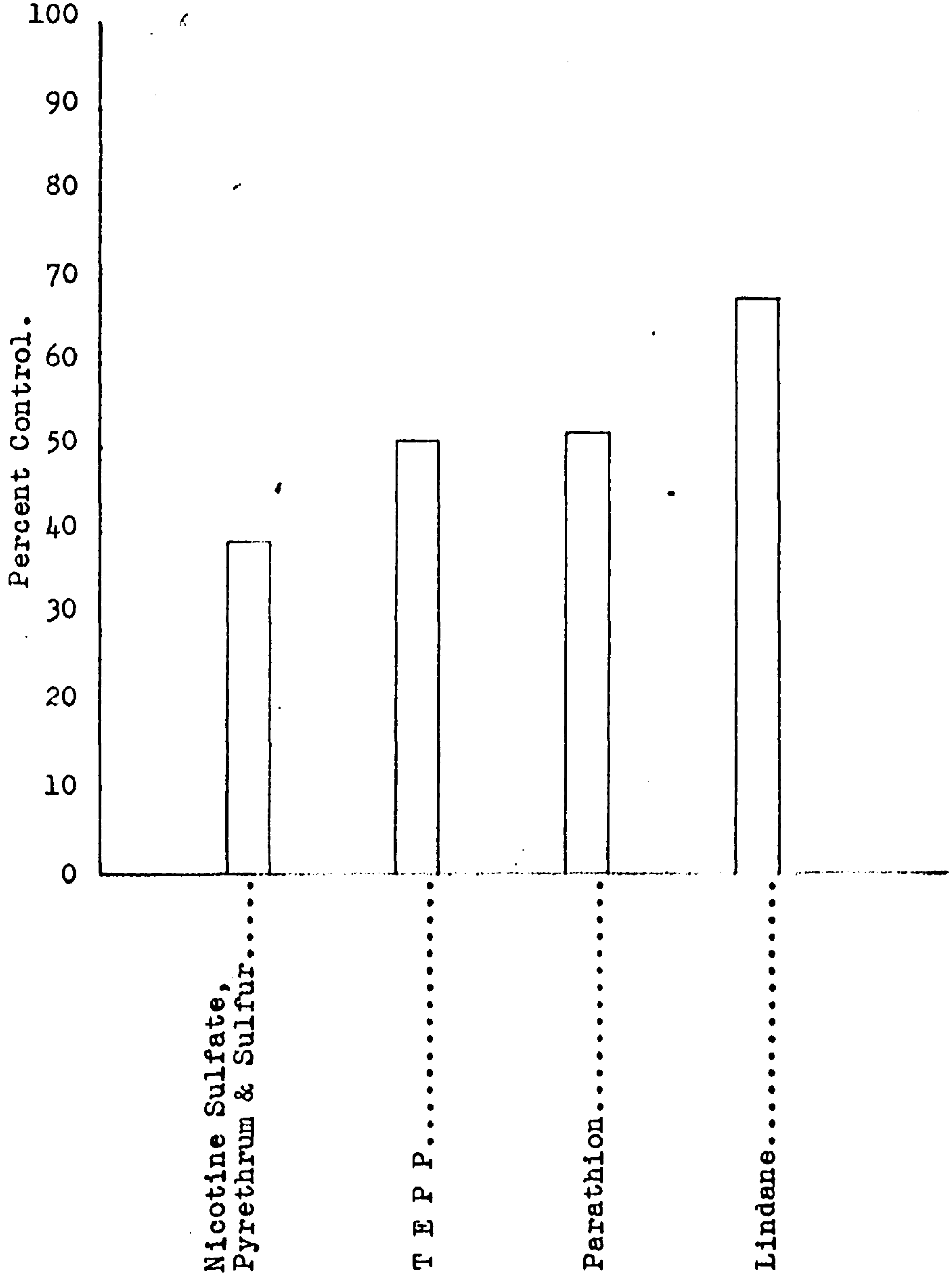
**Denotes significance at 1% level.

A. For testing significance of the difference between treatment means.

i. Difference to be significant at 5% level = 7.8.

ii. Difference to be significant at 1% level = 10.6.

FIG. 28. CONTROL OF L. OBLINEATUS ON CHINESE CABBAGE BY VARIOUS INSECTICIDES.



DISCUSSION OF RESULTS

In the following discussion and summary an attempt is made to demonstrate, in each experiment, the relative effectiveness of the insecticide at various concentrations, and to integrate the results of the various individual experiments.

Laboratory Experiments on Contact Sprays for the Control of *L. oblineatus*

The materials (Table IV) tested as contact sprays fall under two main categories, viz., natural organic insecticides and synthetic organic insecticides.

Natural organic insecticides.

1. Nicotine sulfate: It was found that at low concentration (eight ounces per 100 gallons) the accumulative percent control rose to forty in 96 hours (Table V and fig. 9) after which it lost effective toxicity. By using two and four times this concentration, the net increase in control at the end of 96 hours was only 2.9 percent and even at these higher concentrations the effectiveness was lost after four days.

2. Nicotine sulfate plus pyrethrum plus sulfur: Contrary to the results reported by many previous workers on the application of pyrethrum and sulfur, this combination along with nicotine sulfate did not produce

the same results (Table V and fig. 10). Although with the increase in concentration, mortality increased correspondingly, even at high concentration only 24.6 percent control was obtained. This, however, confirmed the finding of Sorensen (48) that there was no significant advantage over the control. Eighty to eighty-five percent control as reported by Smith and Scales (45 & 46) might have been due to the repellent action of sulfur at higher temperatures.

The fall in percent control as compared to nicotine sulfate might have been due to any of the following reasons:

a. Incompatability. The sulfur used* might either have caused rapid volatilization of nicotine sulfate or might have acted as sorptive agent, thus binding up the available nicotine.

b. Temperature. It might have been the effect of varying temperature.

c. Protective Stupefaction. Pyrethrum might have temporarily anaesthetized the bugs, thus putting them at a low ebb of metabolism and during this period of stupefaction they escaped from the toxic effect of nicotine sulfate due to the volatilization of the latter.

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*Commercial sulfurs commonly contain conditioning agents which vary with economic availability.

However, nothing can be stated with any degree of certainty from this experiment, as these phases need further investigation.

3. Rotenone: The results were not in accord with Shull (40) who reported 49 percent control under laboratory conditions. The maximum control in this experiment was 6.6 percent (Table V) and this was not affected by the increase in concentration of the material. Moreover the tarnished plant bugs took a longer time to die. They remained in a moribund condition at least for two days before death.

Actually the material lost its toxicity two days after spray.

4. Ryania: This was also a delayed action insecticide. It differed from the previous three insecticides in the fact that the mortality of tarnished plant bugs increased directly in proportion to the increase in the concentration of the material and also reduced the time of kill (Table V and fig. 11). The maximum control, 49.1 percent, was obtained with a concentration of 480 ounces per 100 gallons, but such a high concentration was not desirable on vegetables.

Synthetic organic insecticides. In order to get a better idea of the relative toxicity of the different synthetic organic insecticides it is better to consider them in groups.

1. Chlorinated Hydrocarbons. Among the chlorinated hydrocarbons, methoxychlor, DDT and DDD are structurally nearer each other than any other material used in these tests. Methoxychlor did not give any control at the three concentrations used (Table V). The maximum control obtained with DDT and DDD was 85.7 (Table V and figs. 12 & 13). DDT showed little difference between medium and high concentration but DDD showed an increase of 12.5 percent when the concentration of wettable powder of DDD was raised from 32 ounces to 64 ounces per hundred gallons of water. Moreover DDT had a maximum residual effect of six days against five days in the case of DDD. Thus it is clear that medium concentration (32 ounces of 50 percent DDT wettable powder in 100 gallons of water) is as good as 64 ounces of 50 percent DDD, if not better. Although it is not definitely decided which portion of the DDT molecule is toxic, from the above set of experiments it is clear that the p-chlorophenyl groups play an important role in its insecticidal action. In methoxychlor the p-chlorophenyl groups are replaced by p-methoxyphenyl groups and it is found that it loses all toxicity to tarnished plant bugs. If we accept the suggestion of Martin and Wain (25) that the toxic portion of the DDT molecule is the trichloroethyl group and that chlorophenyl rings provide lipoid solubility then it becomes clear that trichloroethyl group in methoxychlor is unable

to impart its toxicity to the tarnished plant bugs in the absence of the lipoid solvent. This theory is further strengthened by the results obtained from the application of DDD where the percent control falls due to the replacement of one Cl-group in the trichloroethyl group. The results on DDT were in accord with the results reported by Granovsky (11) who found that one percent and 2.5 percent DDT dust gave a control of about 85 percent.

Toxaphene differed from DDT and DDD in the fact that it did not kill or paralyze the tarnished plant bugs immediately (Table V and fig. 14). The structural formula for toxaphene is not known and therefore it is not possible to discuss the results in relation to DDT. The percent control was increased by 30 when the concentration of toxaphene 40 percent wettable powder was increased from 16 ounces to 32 ounces per hundred gallons of water but any further increase in concentration did not give additional control. Stearns, _et al_. (49) found that 50 percent water dispersible formulation of toxaphene at the rate of one pound per hundred gallons adversely affected cucumbers, cantaloupes and squash. Kelsheimer (19) also reported an almost complete loss of cucumber and squash crops in Florida due to the application of toxaphene. The present tests were made on chinese cabbage. No phytotoxic effects were noticed for ten days after the spray.

Chlordane appeared to be a very potent insecticide in the greenhouse. At low concentration (16 ounces of chlordane 40 percent wettable powder in 100 gallons of water) it gave 50 percent control after 24 hours but by doubling the concentration, the control also correspondingly doubled (Table V and fig. 15). Further increase in the concentration of chlordane did not make any appreciable difference in the residual power of the insecticide. Scales and Smith (38) compared the toxicity of toxaphene and chlordane dusts and reported that 20 percent toxaphene dust was superior to 20 percent chlordane dust. On the contrary at the same concentrations 40 percent chlordane wettable powder proved much superior to 40 percent toxaphene wettable powder. Chlordane showed a definite promise for the control of L. oblineatus as reported earlier by Marshall (24).

Lindane 25 percent wettable powder gave excellent results even at low concentrations (Table V and fig. 16). It combined both the desired qualities, i.e., immediate kill and longer residual effect. At a concentration of 16 ounces per hundred gallons of water it gave a maximum residual effect of 12 days (fig. 21) under the greenhouse conditions in August. In another series of experiments in May when, instead of spray, a dipping method was employed, the residual effect lasted for 16 days with medium concentration and one month with high concentration. It may be pointed out that temperature might have played an important part in the retention of toxicity in the early experiments, although it cannot be ignored that by dipping a thorough coverage was obtained with a greater amount of insecticide per square inch of leaf-area. Lindane was also tried in field experiments described in subsequent pages and it showed correspondingly good results. In a third series of experiments a concentration of four ounces per hundred gallons of water was used. It gave 40 percent control after 24 hours and reached the maximum of 75 percent after four days (Table V) but then the toxicity apparently faded out.

O,O-diethyl-O-p-nitrophenyl thiophosphate (Parathion) and tetra-ethyl pyrophosphate (TEPP) proved extremely toxic for L. oblineatus. TEPP gave 100 percent control with high concentration, 91.6 percent with medium concentration and 55 percent with low concentration (Table V and fig. 18). These results were obtained if the bugs were released immediately after the spray was applied but if they were released two to three hours after spraying, TEPP was hydrolized and lost its toxicity entirely. This was an excellent insecticide for immediate kill but had no residual power. Parathion on the other hand was more stable and showed greater toxicity at medium concentration as compared to TEPP (Table V and fig. 17) and had a residual toxicity extending to four days (fig. 21). However, the residual toxicity of parathion was mainly dependent on temperature.

The new systemic insecticide Pestox 3 was used as a contact spray but in the present series of tests it did not show much promise for the control of L. oblineatus. The maximum control obtained was 23.3 percent at high concentration.

Four percent allethrin containing four percent "264" and emulsifying agent Altox-1045A was also tried but it did not prove any better than Pestox 3.

From the foregoing discussion of results it is evident that under the set conditions of these experiments the natural organic insecticides did not manifest enough toxicity to give satisfactory control of L. oblineatus.

Among the synthetic organic insecticides, methoxychlor, Pestox 3 and allethrin can also be safely left out of discussion. DDT, DDD and toxaphene had a fairly high degree of toxicity and a moderate residual effect, but this group of hydrocarbons did not give 100 percent mortality which meant that some stronger strains or individuals of L. oblineatus were not killed. A question, therefore, arises whether by using these insecticides for the control of L. oblineatus, we are favoring the development of resistant strains as has been reported in the case of flies.

Chlordane, lindane, parathion and TEPP gave complete control. For immediate kill TEPP excelled all the other insecticides tested. It may prove invaluable in areas which are isolated from other sources of infestation but considering the general feeding habits of *L. oblineatus*, such a condition is not very likely if it is present as a pest amounting to any economic importance.

Parathion and chlordane ranked together as regards percent control but on the basis of residual toxicity chlordane proved slightly better.

Lindane was apparently much better than any of the other insecticides tested both with regard to net mortality and residual toxicity.

Field Experiments

Split plot experiment for the control of L. oblineatus on celery. This experiment was set up to test the efficiency of lindane under conditions approximating those in the field and to find out if there was any correlation between concentration of insecticide, number of sprays and the intensity of infestation. This problem could be tackled from many different angles and some of the criteria selected for evaluation of the objective of the experiment were as follows:

1. Yield.
2. Percentage of the celery stalks injured.
3. Total injury based on feeding punctures on the stalks of celery.

Tables VII and IX represent the actual data on the weight (in ounces) of nine celery plants in each row, untrimmed and trimmed respectively. An analysis of variance of the data (Table VII and IX) showed that the number of sprays was significant at one percent level in both cases, whereas concentrations and infestations did not play a significant part in producing any change in the yield of celery. Figure 22 shows that as compared to the check, the yield increased by 1.7, 5.3 and 2.2 tons per acre with two, four and six sprays respectively, on the basis of trimmed weight. However, statistically there was no difference between yields of two and six sprays from the check (Tables XI and XII) but the yield of four sprays was highly significant. Thus it clearly showed (fig. 12 and 13) that two applications of lindane stimulated growth of celery which was increased by four sprays but with six sprays it had a depressing effect on the yield on the basis of weight only. However, it was essential to take into consideration the quantity of the produce which was actually of marketable quality and for this purpose a random sample from each sub-plot consisting of 33 percent of the harvest was analyzed for the percent injured stalks and the total number of feeding punctures (Tables XIII, XIV and XX). An analysis of variance of the percent injured stalks (Table XV) reveals that the concentrations, the intensities of infestation, and the number of sprays are significant at the one percent level. A perusal of Table XVI shows that high concentration was significantly better than medium concentration which was in turn significantly better than low concentration, when average means of all the intensities of infestations were considered together. However, at C intensity of infestation (i.e., 800 bugs per cage) there was no difference between medium and high concentration although either was significantly better than low concentration. With regard to the number of sprays it was noticed (Table XVII) that the number of sprays were significantly different at one percent level on the basis of total means. Although six sprays with high concentration gave the least amount of injury, high concentration with four sprays was as good as medium concentration with six sprays which was only second to high concentration with six sprays. The intensities of infestation also produced highly significant differences in the percent injured stalks (Table XVIII) but the analysis (Table XIX) showed that for high intensity of infestation four sprays of medium concentration were as good as six sprays of medium concentration.

Almost similar results were obtained with the data (Table XX) based on the total number of feeding punctures. All the three variables were highly significant (Table XXI). Here high concentration was not significantly better than medium concentration, neither in the total means nor at the high intensity of infestation (Table XXII). As regards number of sprays it was observed (fig. 26) that injury due to feeding punctures sharply declined as the number of sprays increased from zero to four but this reduction followed the law of diminishing returns when the number of sprays was increased from four to six. The intensity of infestations also showed a similar trend although to a lesser degree (Table XXIV and fig. 27). Table XXV indicates that there was no significant difference between six sprays and four sprays of medium concentration at high intensity of infestation. It may however be brought out that for low intensity of infestation in all the different data so far discussed six sprays at high concentration were significantly better than the rest.

It was therefore obvious that unless the infestation was extremely high four sprays of medium concentration would give a more satisfactory control taking into consideration both yield and quality but in extremely high infestations it would pay to sacrifice the extra yield and save the quality.

A great objection to the use of BHC has been the off-flavor and off-taste which it imparted to many crops. Samples of celery were taken at harvest from sub-plots which were treated with six sprays of high, medium and low concentration of lindane and were tested by the Department of Food and Nutrition of the School of Home Economics at Michigan State College. In their report,* none of the judges noticed any off-flavor. Their comments and scores were based on the relative strength of the typical flavor of celery raised in this section of the country.

In the absence of any specific chemical test for lindane, the plant material could not be analyzed.

Randomized block experiment for the control of L. oblineatus on chinese cabbage. A study of the data (Tables XXVIII and XXIX) indicates that all the four treatments were significantly better than the check at one percent level. Although TEPP hydrolizes quickly when applied as a spray it is noticed that it gave as good a control as parathion. This was due to the fact that the infestation of tarnished plant bugs was low and therefore the bugs which were present on those plots

*Correspondence with Dr. Pauline Paul, Foods & Nutrition Department, dated September 22, 1950.

were killed by TEPP and fresh infestation did not build up immediately and before they could do any extensive damage the plants were sprayed again.

Lindane proved to be significantly better than the other treatments but there was no significant difference between parathion, TEPP and nicotine sulfate plus pyrethrum plus sulfur.

It may, however, be pointed out that these results are by no means final as the crop was completely ruined by hailstorm on August 7, 1950. It can only serve as a preliminary report on the possible use of lindane for the control of *L. oblineatus* on some vegetables and other crops.

SUMMARY

The work reported in part 2 of this paper consisted of (a) a series of tests in the greenhouse on the effect of various insecticides on the control of L. oblineatus, (b) a controlled field experiment to investigate the effectiveness of lindane under different intensities of infestation, concentrations and number of sprays and (c) a field test on the insecticidal value of four organic insecticides for the control of L. oblineatus.

The results may be summarized as follows:

1. Natural organic insecticides, viz., nicotine sulfate, pyrethrum, rotenone and ryania showed no satisfactory control of L. oblineatus.
2. Methoxychlor, Pestox 3 and allethrin proved ineffective in the greenhouse tests.
3. DDT and DDD gave a fairly good control of L. oblineatus in laboratory tests but did not give 100 percent mortality which showed that the stronger strains or individuals of L. oblineatus were not killed by these insecticides.
4. Toxaphene had no immediate toxic effect but showed results 48 hours after application.

5. Toxaphene 40 percent wettable powder applied at the rate of 64 ounces per hundred gallons of water did not produce any phytotoxic symptoms on chinese cabbage.
6. Chlordane, lindane, and parathion gave 100 percent control with medium concentration whereas TEPP gave 100 percent control with high concentration.
7. Lindane had the longest residual effect of twelve days followed by chlordane and DDT, six days; DDD, five days; and parathion, four days. TEPP lost toxicity within two to three hours of application.
8. Lindane (25 percent) increased the yield of celery (trimmed) over the check by 1.7 tons per acre, with two sprays, 5.3 tons per acre with four sprays, and 2.2 tons per acre with six sprays.
9. For medium or moderately high infestations four sprays of medium concentration of lindane gave a very practical field control of *L. oblineatus*.
10. For very high intensity of infestation it may be desirable to have a comparatively reduced yield of higher quality by the application of six sprays at high concentration of lindane.

11. Number of sprays were significantly the most important factor in the control of tarnished plant bugs.
12. Celery treated with six sprays at high, medium and low concentrations did not give any off-flavor or off-taste.
13. Lindane proved significantly better than parathion, TEPP and nicotine sulfate plus pyrethrum plus sulfur in the control of L. oblineatus on chinese cabbage.

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