1954

Studies with new insecticides against the Mexican Bean Beetle.

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Thesis submitted in partial fulfillment of the requirements for degree of Master of Science

University of Massachusetts
Amherst, Massachusetts

November, 1954

The writer wishes to acknowledge the valuable advice rendered by Dr. HARVEY L. SWEETMAN, when this study was being made, and during the preparation of the paper.

Grateful acknowledgment to the OFICINA DE ESTUDIOS ESPECIALES and THE ROCKEFELLER FOUNDATION for the economic support during my period of study. Further thanks to my profesors and classmates for their kindness and encouragement, which made possible a pleasant and profitable stay at the University of Massachusetts.

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INTRODUCTION

The Mexican bean beetle is one of the major pests of cultivated beans in North America. Available records for about a century show that the insect was restricted to, and caused moderate damage in certain regions of central Mexico and the southwestern United States. This isolation was caused by the expanse of dry territory lying between the Rocky Mountains and the humid regions east of the 99th meridian. About 1920 it was accidentally introduced into the eastern United States, where it found favorable conditions. This, together with the great expansion of agriculture, stimulated investigations concerning the habits, natural enemies, and the control of the insect. The development of new synthetic organic insecticides during and since the second World War initiated a new period of research with these promising chemicals.

The purpose of this study is to determine the action of some new insecticides on the Mexican bean beetle and on bean plants.

ORIGIN, HISTORY, AND DISTRIBUTION

The Mexican bean beetle was discovered in Mexico and described as Epilachna varivestis (Mulsant, 1851). However, it has been described under other names now regarded as synonymous (Chapin, 1936).

It is frequently stated that the insect originally came from Mexico. Marcovitch (1930), after an analysis of prevailing climatic and orographic conditions affecting the insect, states: "The original home of the Mexican bean beetle is the tablelands of Mexico and Central America." However, the evidence is inadequate and the beetle may have inhabited southwestern United States also.

The first authentic account of its presence in the United States is by Bland (1864) who described the insect from the Rocky Mountain region. However, Chittenden (1924) presents some evidence of the presence of the insect as early as 1850. The first citation concerning its injurious habits was from Colorado (Riley, 1883), and the first account of the insect describing the stages and type of damage was by Gillette (1892). Fall and Cockerell (1907) indicated the distribution in New Mexico, and Morrill (1913) published a note concerning its distribution in Arizona. Merrill (1917) in New Mexico gave a comprehensive account of damage, life cycle, distribution, and control of the insect.

Preceding 1920 Arizona, New Mexico, Colorado, Texas, and some areas of Mexico and Central America were known to be infested. In 1920 the beetle was introduced into Alabama (Hinds, 1921). The insect spread rapidly northeast along the Mississippi river. Sweetman and Fernald (1930) indicate the years in which the various States were invaded. It reached Canada in 1927, and Maine in 1930. It was introduced along the Pacific Coast in 1946, where later it was eradicated (Armitage, 1947). The United States Department of Agriculture (1953) gives the distribution in the eastern States. The western infestation covers separated irrigated areas near foothills, and the Latin American distribution probably occurs only on the high irrigated plateaus.

ANALYSIS OF LITERATURE

Biology

The Mexican bean beetle is one of the lady beetles in the family Coccinellidae. Its morphology and biology are similar to other members of the group. It has complete metamorphosis with four larval instars. It has one to four generations annually and the life cycle requires about 35 days, under favorable conditions. It hibernates in October and emerges in the spring to invade bean fields. The bean beetle is phytophagous rather than predacious, as is typical for the majority of the Coccinellids, and it is one of the most harmful insects.

It has been studied intensively, and a number of reports are available. Sweetman (1930) has studied the external morphology of the adult, and Merrill (1917) has given a detailed description of the larval instars. Considerable variation in size and color, as a result of the age and the environmental conditions, has been recorded.

The life history of the insect has been studied under controlled conditions by many investigators, such as Mallory (1920), Chittenden and Marsh (1920), and List (1921,1922) in Colorado; Howard (1922) and Thomas (1924) in Alabama; Eddy and McAlister (1927), and Eddy and Clarke (1929) in South Carolina; Douglas (1933a) in New Mexico; and others.

Habits

Physical and biological factors affecting hibernation have been studied by Thomas (1924) in Alabama; Eddy and McAlister (1927) and Sherman and Todd (1939) in South Carolina; Douglas (1928) in New Mexico; Elmore (1949) in California; and others.

In the autumn adults enter hibernation, which is accelerated by lack of food and by cold weather. They migrate preferably to forest woodlands, where they are found gregariously and singly in a dormant or semi-dormant condition under the leaves or stones. Moist but well drained places are required for successful hibernation. Emergence occurs in spring with the advent of warm weather following heavy rains. They fly and locate suitable food plants where after a few days mating and oviposition occurs. The insects feed on the foliage, destroying leaves, blossoms, pods, and even the stems. Howard (1941) has described the feeding process in detail. The beetles may fly several miles a day. This is partially responsible for its rapid spread (Howard, 1922).

Howard (1922) in Alabama reported five wild hosts on which the insect feeds, when suitable hosts are lacking. Howard and English (1924), and Sherman and Todd (1939) conducted studies of host preference, concluding that all varieties of common bean are primarily attacked. Thomas (1924) found ten hosts in which complete development occurred when the plants were grown on heavily infested bean fields. Elmore (1949) studied thirteen wild plants in California as possible hosts, but none was suitable. Many other studies of the bean beetle host plants have been made. The common bean (*Phaseolus vulgaris* Linn.) appears to be the preferred host; second choices are lima bean (*P. lunatus* Linn.), tepary bean (*P. acutefolious* Gray), and the cow pea (*Vigna sinensis* Endl.), on which complete development may occur. In the absence of the mentioned hosts, the insect may attack many related legumes such as kudzu, alfalfa, clovers, and others, on which no complete development occurs in natural conditions. Turner (1932) reported the insect feeding on rye after the beans were killed by the frost.

Environmental Resistance

Physical Environment.

Physical factors, particularly temperature and moisture, greatly influence abundance of the bean beetle. Thomas (1924) observed that rain storms and winds are responsible for a great mortality of larvae. Graf (1922) in a current note said that a dry season checked the pest in New Mexico. Later (1925) after considering the clime of the three major infested areas in the northern hemisphere, he believed that temperature and moisture are not limiting factors in the distribution of the pest. Pyenson and Sweetman (1929), Sweetman and Fernald (1930), Miller (1930), and Douglas (1930a) studied the moisture and temperature relationships of the various stages, under laboratory conditions. High moisture but well drained situations are essential for a successful hibernation, and successful spring emergence is dependent for the most part upon plentiful precipitation (Douglas, 1933b; Sherman and Todd, 1939; and Elmore, 1949). Temperature and moisture affecting the percentage of emergence were studied under controlled conditions by Howard (1924), Thomas (1924), Eddy and McAlister (1927), and others. The immature stages, eggs and young larvae, are quite susceptible to dry conditions. Sweetman (1929, 1931) after studies of moisture in irrigated areas as compared with non-irrigated ones, concludes that precipitation records do not give an adequate measure of moisture under irrigated conditions, which explains the pest distribution especially in the southwest. Marcovitch (1930) after a regional analysis of the temperature and rainfall, suggested a map of the probable future distribution of the insect in the United States. Later Sweetman (1932), after an analysis of the relative moisture conditions, suggests another map.

Biological Environment.

Plants and animals are able to affect the life of the Mexican bean beetle. Few attempts have been made to evaluate the effectiveness of those enemies under natural conditions, even over a limited area. However, after the introduction of the insect into Alabama, the biological enemies were subjected to intensive study with the hope of utilizing them for control of the pest.

As early as 1919 Chittenden (1919) mentioned three species of lady beetles as destroying the eggs. Howard (1922) found some lepidopterous larvae and ants preying on immature stages. Thomas (1924) in Alabama reported on some of the more important enemies. Howard and English (1924) summarized and analyzed the literature on the principal enemies (24 insects); they also found two unidentified species of bacteria in dead larvae. Eddy and McAlister (1927) reported in South Carolina that two lady beetles were its principal predators. Friend and Turner (1931) gave a list of 20 insect enemies (14 in Connecticut). Plummer and Landis (1932) from a laboratory study of the Mexican predators said that 31 species of insects fed on E. varivestis, and gave a list of the 15 more important ones. Douglas (1933b) reported a fungus destroying overwintering beetles. Sherman and Todd (1939) reported on the six principal predators in South Carolina. Howard et al (1948) cited insect enemies in the eastern United States.

Consequently the search to find suitable enemies of the bean beetle to be used for biological control purposes has been unsuccessful. The families Tachinidae, Coccinellidae, and Pentatomidae include the more important species, but unfortunately their biological potential is very low in relation to that of the bean beetle.

The following list includes the known enemies of the Mexican bean beetle, cited by the before-mentioned investigators.

Parasites

Scientific Name	Family
Nemorilla maculosa Meig.	Tachinidae
Paradexodes epilachnae Ald.	"
Phorocera claripennis Macq.	"
Helicobia helicis Towns.	Sarcophagidae
H. rapax (Walk.)	"
Sporotrichum globuliferum Speg.	Dematiaceae (Fungi Imperfecti)

Predators

Adalia bipunctata L.	Coccinellidae
Ceratomegilla fuscilabris Muls.	"
Coccinella novemnotata Hbst.	"
C. sanguinea L.	"
C. transversoguttata Fab.	"

Epilachna varivestis Muls.	Coccinellidae
Hippodamia convergens Guer.	"
H. 5-signata Kby.	"
Calosoma laeve Chev.	Carabidae
C. sayi Dej.	"
Harpalus caliginosus Fab.	"
Onypterygia thoreyi Mann.	"
Scarites subterraneus Fab.	"
Tetracha carolina L.	Cicindellidae
T. virginica L.	"
Enoclerus bombycinus Chev.	Cleridae
Callopus bipunctatus Say	Melyridae
Acrosternum hilaris (Say)	Pentatomidae
Euthyrhynchus floridanus (L.)	"
Oplomus dichrous (H.S.)	"
O. nigripennis pulcher Dall.	"
Perillus bioculatus (Fab.)	"
P. confluens (H.S.)	"
P. virgatus Stal.	"
Piezodorus guildinii Westw.	"
Podisus lineolatus (H.S.)	"
P. maculiventris Say	"
P. sagitta (Fab.)	"
Stiretrus anchorago (Fab.)	"
S. caeruleus Dall.	"

Apiomerus pictipes H.S.	Reduviidae
Arilus cristatus L.	"
Pselliopus zebra (Stal.)	"
Sinea confusa Caud.	"
S. diadema Fab.	"
Zelus rubidus L.S.	"
Heliothis obsoleta Fab.	Noctuidae
Laphygma frugiperda S. & A.	"
Prodenia ornithogalli Guen.	"
Chrysopa oculata Say	Chrysopidae
C. rufilabris Guen.	"
Pheidole sp.	Formicidae
Solenopsis geminata Fab.	"

Control

The control of the Mexican bean beetle has been attempted by many methods.

Mechanical Control.

The practice of hand-picking overwintered beetles and egg masses, and brushing the larvae off the plants, was helpful in protecting the home garden early in the season (Thomas, 1924).

Ecological Control.

This includes cultural measures which are frequently recommended to reduce the damage by the pest. Some research work was conducted in this field. Chapman and Gould (1928, 1930) buried the insects at various depths, and concluded that the larvae can not survive coverage by plowing. Turner (1935) found that major damage occurred when plants were crowded, thus increasing the moisture conditions. Early or late planting may avoid severe infestation from overwintering beetles. Preventive cultural measures, such as early planting, plowing the debris, destruction of hibernating shelters, may reduce the chances of infestation, if they are performed according to cooperative programs and to protect isolated infested areas, but for the most part the reduction in damage does not compensate for the cost of the campaign.

Legislative Control.

Bean production areas with suitable environmental conditions for the bean beetle, if isolated by natural geographic barriers, may be protected against the natural spread of the insect by quarantine measures. Surveys to determine abundance of beetles in infested areas, to assist in the development of plans for future combat, have been profitable (Haeussler and Leiby, 1952).

Biological Control.

After the introduction of the Mexican bean beetle into Alabama, its biological enemies were subjected to intensive study with the hope of utilizing them to combat the pest.

Shortly after its introduction into Alabama, an attempt was made to eradicate the pest, and to prevent or reduce the rate of spread, by means of the Tachinid fly Paradexodes epilachnae. This fly, described by Aldrich in 1923, was reared and liberated in 19 States. The first year the fly destroyed a good percentage of the larvae but due to failure in climatic adaptation the project was abandoned the next season (Clausen, 1952). However, this parasite may be important in areas with favorable environment, as in central Mexico where it was found originally. Consequently, with one or two exceptions, all reports on biological enemies are largely the listing of parasites and predators with little attempt to evaluate them.

Chemical Control.

The use of insecticides against the Mexican bean beetle was first reported from New Mexico. Paris green, London purple, and kerosene were highly toxic to both the insect and the bean plants (Wielandy, 1891; Gillette, 1892; and Griffin, 1897). These insecticides were replaced by other arsenicals such as magnesium calcium, lead arsenates, and zinc arsenite, which were used in spite of their phytotoxicity to the plants. Meanwhile important insecticidal research was conducted in Colorado by Chittenden (1919), Mallory (1920), List (1921), and others.

After the introduction of the insect into Alabama, the screening of insecticides to combat the pest was intensified, but in spite of the many tested products, the arsenicals proved to be advantageous over rotenone and pyrethrum. The latter was unavailable at that time (Howard, 1922). During that time important tests were made in Alabama by Hinds (1921) and Thomas (1924) which demonstrated that calcium arsenate was the most advantageous insecticide. List (1925) in Colorado considered arsenicals superior. In Tennessee Marcovitch (1925, 1930), Marcovitch and Stanley (1929, 1936, 1943), and List (1943) in Colorado, carried out intensive screening with flourine compounds. Later Stanley and Marcovitch (1947) concluded that the most advantageous products were cryolite and rotenone. Howard (1922, 1924, 1928), and Howard and Brannon (1930) in the East, after intensive experimentation with arsenicals, concluded that magnesium arsenate was the most advantageous one. Later Howard _et al_ (1933) subjected rotenone to further tests, without much success. Howard _et al_ (1935) reviewed the insecticidal research and concluded that rotenone and cryolite were the most promising insecticides, and in 1948 regarded rotenone as superior to arsenicals and flouring compounds.

Today rotenone is one of the most popular insecticides for combatting the pest. However, it looses its toxicity rapidly under direct sunlight, particularly in the southern States (Armitage, 1947; and Todd, 1938). Sherman and Todd (1939) and Wene and Hansberry (1944) studied the repellent properties but obtained contradictory results.

Many other products have been tested against the pest, particularly in recent years. Many of them are highly toxic to the bean beetle. Marcovitch (1925), from laboratory tests, found mustard gas (dichlorethyl sulfide) effective in the laboratory. Cory et al (1930) made important tests with pyrethrum, with negative results. Later pyrethrum with a synergist proved useful (Weigel, 1945; Ditman and Bickley, 1951).

Wolfenbarger and Heuberger (1945) found that dithane acts upon the insect as a systemic insecticide which is conducted by the plant tissues. Huckett (1931) and Peairs (1936) reported barium carbonate was inferior to magnesium arsenate. List (1943), after tests with phenothiazine, concluded it was inferior to arsenicals. Stearns et al (1947) found toxaphene was slightly less effective than rotenone. Hunt (1947) found wide variations in toxicity to the bean beetle in 61 dust diluents tested. Ditman and Cory (1948) found an aerosol of rotenone plus DDT controlled the bean beetle and leaf bean beetle. Kenaga (1949a, 1949b) tested 66 organic compounds against the insect, without definitive results. Wright and Apple (1950) found Methoxy DDT promising. Ginsburg et al (1950) found no residues of parathion 12 days after application. Eyer (1953) reported successful tests with dieldrin.

Recently many other products have been tested against the bean beetle. Promising insecticides such as EPN, dilan, malathion, diazinon, penthion, and others have been tested on a limited scale.

METHODS AND PROCEDURES

Biological Observations

As an addition to the knowledge of the insect, observations regarding damage to bean leaves by the feeding forms of the insect, and measurements of larval forms in all instars, were made.

A stock of beetles of unknown history was maintained under greenhouse conditions, for the purpose of obtaining desired stages; from this material, lots of insects were reared under laboratory conditions. Cheesecloth cages were used to enclose individual lots. Artificial light was provided during the day. The temperature and relative humidity were recorded, with thermograph and higrograph, respectively. Temperature ranged around 70° - 75° F., and relative humidity around 45 - 55 per cent during October, decreasing progressively to 20 - 30 per cent in January.

The potted bean plants with single egg masses were transferred to the laboratory, and the eggs permitted to hatch. As the larvae developed, measurements and foliage damage were determined at least twice daily. After each measurement the larvae were transferred to new plants. The length of a representative larva from each lot of insects was measured with an ocular micrometer.

The feeding area was estimated by placing the damaged leaves under a grid ruled in units of 6.3 sq. mms. The number of insects of each lot was progressively reduced due to death, loss by migration, and removal of the injured or abnormally developed individuals.

Phytotoxicity Insecticidal Tests on Bean Plants

Phytotoxicity tests with several insecticides were conducted in controlled conditions.

Lots of bean plants of the same age and appearance were subjected to the following dust treatments: untreated, rotenone 1 per cent, toxaphene 10 per cent, methoxychlor 5 per cent, EPN 1 per cent, parathion 1 per cent, dilan 1 per cent, diazinon 4 per cent, penthion 5 per cent, malathion 4 per cent, and calcium arsenate 10 per cent in sulfur. Plants were grown in soil in wooden flats 13 x 12 x 5 inches or clay pots of 3 liters capacity. For individual lots, the same type of container with a mixture of 3/4 loam plus 1/4 sand was used. The plants were kept in a relatively humid and semi-shaded greenhouse with an average temperature ranging around 80° F. Temperature was estimated by observations of the thermometer.

Four similar tests were conducted, two of them simultaneously. A lot of eleven plants selected for similarity in size and color were subjected individually to different insecticidal treatments. Three applications were made: the first nine days after planting, the second and third at intervals of 16 days.

A heavy dosage (probably two to three times the recommended one) of insecticide was applied, to emphasize the insecticidal phytotoxic properties. The plants were moistened with water and enclosed individually in the dust chamber. The insecticidal dust was injected through an opening in the chamber.

Observations regarding degree of burning, defoliation, size, color, and precocity were made at four-day intervals, throughout the vegetative cycle. The yield and general quality of the crop were measured when mature.

Residual Effect of Insecticides on the Bean Beetle

Two lots of individual bean plants, four weeks old, were dusted with rotenone 1 per cent, toxaphene 10 per cent, methoxychlor 5 per cent, EPN 1 per cent, parathion 1 per cent, dilan 1 per cent, diazinon 4 per cent, penthion 5 per cent, and malathion 4 per cent. Successive lots of adults and 4th instar larvae were exposed to the treated plants in wire cages, 12 x 12 x 14 inches. Tests were carried out in a relatively dry and semi-shaded greenhouse with a daily average temperature ranging around 75° F.

The growing tips and buds were pruned from the bean plants, just before insecticidal treatment, to restrict the development of untreated foliage. The plants to be treated were moistened with water before being enclosed individually in the dust chamber, where the insecticide was injected through an opening. This resulted in a heavy dosage of insecticide adhering to the plants, soil, and container.

TEST 1. After the treatments, the test plants were moved to the greenhouse. Over a period of 36 days, lots of relatively young adults selected by color were exposed successively to each plant at two-day intervals.

TEST 2. After the treatments, the plants were maintained for seven days in a relatively sunny and humid greenhouse, before being moved to the formerly described greenhouse. During the next 30 days, lots of medium age 4th instar larvae, selected by size, were exposed to each plant for two days, by placing the larvae on dusted leaves. When they were established, a wire cage was placed over the plant, enclosing the larvae.

Three observations regarding the number of moribund insects (insects dead and dying) were made over a period of two days for each lot.

Insecticidal Tests on Pupae and Prepupae of the Bean Beetle

The pupae and prepupae, in field observations, appeared to be the most resistant forms of the insect. Two preliminary tests, under controlled conditions, were conducted in the laboratory to determine the effect of various insecticides on these stages. Lots of pupae and prepupae were spread over the bottom of petri dishes, to be subjected to the action of the following insecticidal treatments: rotenone 1 per cent, toxaphene 10 per cent, methoxychor 5 per cent, EPN 1 per cent, parathion 1 per cent, dilan 1 per cent, diazinon 4 per cent, penthion 5 per cent, and malathion 4 per cent. Calcium arsenate treated lots were added as controls for tests 1 and 2, respectively. Wire cages were used to protect the insects throughout the tests, which were carried out inside of a semi-shaded greenhouse with a day and night temperature ranging from 65° - 80° F. and 55° - 60° F. respectively.

Pupae, prepupae, and 4th instar larvae of the insect were collected from bean gardens the day previous to the test. Lots of 20 pupae plus 5 prepupae, and 35 pupae plus 3 young prepupae up to 12 hours old, were used for tests 1 and 2, respectively. The insects, with a piece of leaf to which they were attached, were placed on paper in a petri dish. Individual lots, moistened with an atomizer, were enclosed in a chamber and dusted with the insecticides. As a result, the exposed surface of the insects and container were covered by a heavy dosage of dust. After the dusting the dishes were moved to the greenhouse and protected individually with a wire cage; no more moisture was added throughout the test.

Observations on the development of the insects were made every two days for ten days.

Field Tests with Insecticides on the Bean Beetle

Three row plots of beans, 6 and 5 feet in length, and 3 feet apart, for tests in 1953 and 1954 respectively, were randomized in 5 blocks to test the following insecticides.

1953 TEST

Insecticide	Dust Per cent	Spray Per cent
Rotenone	0.5	0.025
Toxaphene	10.0	1.0
Methoxychor	3.0	0.25
EPN	1.0	0.1
Parathion	1.0	0.1

1954 TEST

Insecticide	Dust Percent
Rotenone	1.0
Toxaphene	10.0
Methoxychlor	5.0
EPN	1.0
Parathion	1.0
Dilan	1.0
Diazinon	4.0
Penthion	5.0
Malathion	4.0

In addition, untreated control plots were added to each test.

In 1953 the bean plots were sowed on June 23.

Three applications of each insecticide were made, the first 6 weeks after planting, the second one week later, and the third two weeks after the second. One application was made in 1954, four weeks after planting. For the two tests, only the middle row of each plot was treated. Insecticides were applied early in the morning, while the plants were moist with dew. Hand dusters and sprayers were used.

Since the bean plots were planted after the beetles had emerged from the hibernation quarters, artificial infestations were provoked. Around 3800 beetles were liberated in 1953, during the fourth and fifth week after planting. The first eggs were observed just before blossom time, and a heavy infestation was built up progressively, and two generations developed.

In 1954 the bean plots were sowed on June 8.

Large numbers of larvae, pupae, and adults were transferred to the plots during the fourth week after planting, and the first ovipositions were observed at that time. The plants did not develop well, because of the low fertility of the soil and unfavorable physical condition as a result of the leveling process of the field. However, regardless of the relatively low amount of insects per plot, the infestation may be considered severe in relation to the scarcity of the plant foliage.

Counts of the various stages of the insect were made at least one day before and after each insecticidal treatment. The yield of mature beans was measured.

Index "A" (Table 2) was used to change each count of larvae and adults per plot to a common figure. The data were subjected to statistical analysis.

EXPERIMENTAL RESULTS

Biological Observations

The length of the stadia and amount of damage produced by the various stages of the insect was determined for 19 lots of insects under laboratory conditions. The partial and grand daily average feeding capacities by individual per lot was calculated from the original data (Table 1). The number of tested insects for each instar for each lot was variable. Thirty-three days were required to develop from the egg to the adult stage. The equivalent of injured leaf area per individual throughout the immature stage and for part of the mature stage is recorded in tables and shown graphically in Figure 1.

Indices of feeding capacity. In an attempt to evaluate the relative importance of the feeding stages of the insect, two indices of feeding capacity for the feeding stages were calculated (Table 2).

INDEX A. The relative daily feeding capacity of the stages was based on the first instar daily area damage which was rated as one.

INDEX B. The relative feeding capacity through the larval stadia and first 14 days of the adult stadium was based on the first instar larvae area damaged through the stadium which was rated as one.

The increase in damage of the larval instars for index A was more than doubled for each succeeding instar, so that the fourth instar injured 18 times more leaf surface than the first instar. Thus the fourth instar injured approximately 4 sq. cms. of leaf area during a day. The increase in damage of the feeding stages for index B was about three times for each succeeding stage.

Three well defined periods were observed during the development of the larval instars.

POST-EMERGENCE PERIOD. A relatively short inactive period; the color was deep yellow, and distention of the body and expansion of spines occurred.

ACTIVE PERIOD. The larvae crawled and fed, the body color became light yellow, and the spine tips darkened. They gradually increased in size.

PRE-MOLTING and PRE-PUPATION PERIODS. The time ranged from a few hours for the first instar to about two days for the fourth. The larvae stopped feeding and attached themselves by the tip of the abdomen to the leaf. The body color gradually changed to a cream color, and the body length was reduced as the larvae became stout and quiescent. The length of the larvae during each period is given in Table 3.

Phytotoxicity Insecticidal Tests on Bean Plants

The response of the bean plants to three dust applications of heavy dosages* of insecticides is given in Table 4. The date of planting, application, and harvesting for tests A and B, which were carried out simultaneously, was as follows:

Planting	July 18
1st insecticidal application	July 27
2nd " "	Aug. 12
3rd " "	Aug. 28
Harvesting	Oct. 5

Three plants in wooden flats were used in test A

Two plants in clay pots were used in test B

The area of the plant foliage was estimated by comparison with checked leaves of the following known areas: 100, 85, 65, 50, 35, 25, 15, 10, 6, 4, 3, 2, and 1 square centimeters.

Defoliation-yield relationship. The foliage area and number of pods (measured 13 days after the second application) and the foliage area and dry beans measured 24 days after the third application, were directly related (Table 4, Figure 2).

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* Approximately 2-3 times more than dosages recommended in field conditions.

The plant defoliation caused by the phytotoxicity of some insecticides, in particular the majority of phosphate compounds tested, was quite evident. From the phytotoxicity viewpoint, three principal groups of insecticides may be considered, by comparison with the untreated plants:

GROUP I. ROT, MET, EPN, and DIL. Slight phytotoxicity Bean foliage was apparently normal.*

GROUP II. TOX, PAR, DIA, and PEN. Heavy phytotoxicity. Foliage area was about one-half that of Group I.

GROUP III. MAL and As. Severe phytotoxicity. Foliage area was about one-fourth that of Group I.

The results from the relation of the set of pods and foliage injury from the insecticides, as outlined above, anticipates the relation obtained between yield of beans and foliage area. Meanwhile, a third application of insecticides had been made.

When the foliage area and yield of dry beans was compared (24 days after the third application) the three

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* Some insecticides and treatments were abbreviated as follows: Rotenone (ROT), toxaphene (TOX), methoxychor (MET), parathion (PAR), dilan (DIL), diazinon (DIA), penthion (PEN), malathion (MAL), calcium arsenate (As), and untreated (UNT).

before-mentioned groups still remained. This suggests that in a final analysis the phytotoxic effect from MET, EPN, and DIL, which was indicated by the enlarged cotyledonary leaves, was largely overcome at harvest time, as shown by the great increase in total leaf area 24 days after the third application of insecticides. The yield from ROT treated plants was lowest among those in Group I, because the foliage area in final measurements was slightly reduced over the figure obtained after the second application. The plants in Groups II and III had a similar area of leaf surface after the second and third applications, probably as a result of replacement of the leaves injured in earlier treatments.

Residual Effect of the Insecticides on the Bean Beetle

The data in Table 5 show the differences in rate of toxic action of the various insecticides . PAR, DIA, PEN, and MAL/for about six days acted faster than the other insecticides and within a few hours after exposure. However, DIA and PEN, in spite of 100 per cent kill of the insects within 48 hours after exposure, their effectiveness dropped sharply after that time to a very low rate. MAL, DIL, and EPN, after about three weeks, were still killing a very high percentage of beetles, within 48 hours after exposure. MET, TOX, and PAR after about two weeks were still killing a high percentage of beetles within 48 hours after exposure. ROT after about ten days was still killing a very high percentage of beetles within 48 hours after exposure.

The data in Table 6 show that the toxic effect of the tested insecticides (including an arsenical) on the 4th instar larvae was less noticeable than on the adults. Available data from the 7th to 37th day after application show that there was a little difference in the speed of action of the insecticides. MAL, PEN, and DIA seemed to act faster than the other insecticides. Residual toxicity persisted through the 37th day after application; all insecticides still were killing 30 to 70 per cent of the insects after 38 hours exposure. MAL killed the highest percentage of larvae, 90 - 100 per cent until the 31st day after application, and never less than 70 per cent. Calcium arsenate killed the lowest percentage, but the residual toxicity persisted through the 37th day after application and still produced a mortality of 30 per cent.

Insecticidal Tests on Pupae and Prepupae of the Bean Beetle

The response of the pupae and prepupae of the bean beetle to heavy dosages of insecticides was observed through 10 days following application (Table 7).

The insects used for each treatment in Test I were caged separately, and the emerged adults crawled over the insecticidal residues. All insects except the emerged beetles from control lot were killed by the tenth day after application.

The insects for all treatments in Test II were caged together, so emerged beetles were removed as soon as observed, to prevent insecticidal contamination to the remaining pupae and prepupae. All the remaining insects were killed by the tenth day.

PAR, DIA, PEN, and MAL killed a very high percentage of pupae (79 - 100 per cent). All of the small number of newly formed prepupae tested were killed in Test II, while only a small percentage, which were older, were killed in Test I. ROT killed a moderate number of pupae (about 24 per cent) but was effective against the small number of newly formed prepupae tested. MET and DIL killed only a negligible number of insects, while TOX, EPN, and As did not kill any of the pupae or prepupae.

Field Tests with Insecticides on the Bean Beetle

Tests to determine the effectiveness of some insecticides used to combat the Mexican bean beetle were conducted under field conditions during 1953 and 1954.

The insect feeding population (larvae and adult) per plot was recorded several times during the test. The figures representing the number of each feeding stage of recorded insects, per plot per count, were summarized in a single figure by the Index A (Table 2). The square root of such figures, as well as the yields, were subjected to statistical analysis (Table 8). The general results were as follows:

1953 TEST

Differences in insect feeding population:

Per treatment, highly significant.

Dust versus spray treatments: Significant, except in the 1st, 3rd, and last count. Dust treatments shown to be more efficient than spray.

Differences in yield were not significant.

According to the square root of the transformed figures from the insect feeding population (Table 8), the effect of insecticidal treatment upon such feeding insect populations was as follows:

ROT dust. One day after application the population was reduced; on the following days increasing at the rate of about 20 per cent per day.

ROT spray. The population was slightly reduced one day after the application, increasing moderately the following days.

TOX dust. One day after applications around 17 per cent of young larvae* were killed; advanced stages increased apparently due to migration from surrounding plants.

TOX spray. Little reduction of population just after treatments, increase moderate during the following days.

MET dust. One day after treatments, approximately 40 per cent of the young larvae were killed, and advanced stages remained at the same level.

MET spray. About 17 per cent reduction just after application, increase moderate during the following days.

EPN dust. One day after application approximately 35 per cent of young larvae, and 15 per cent of advanced stages were killed; little increase in the following days.

EPN spray. About 30 per cent reduction just after application; increase moderate during the following days.

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* More young larvae were recorded in the counts one day previous to 1st and 2nd applications than before the 3rd one.

PAR dust. One day after treatment the population was reduced strongly (about 60 per cent); increase moderate during the following days.

PAR spray. One day after treatment the population was reduced about 47 per cent; increase moderate the next two days, and increase greater beyond the 4th day.

UNT. Through 26 days, when counts of insect population were made, a progressive increase was recorded. At the 26th day the population was about tripled. Young larvae were slightly affected due to the insecticidal drift, especially following applications, and the population was increased due to migration from nearby plants.

1954 TEST

Differences in insect population and yield, corresponding to insecticidal treatments, were not significant.

Bean plants were small, due largely to the low soil fertility, and offered little protection to the insects against physical factors. All insecticides tested were highly effective under these conditions, so the insect feeding population was reduced more than 78 per cent by the second day after treatment. Moderate phytotoxicity was observed from malathion, penthion, and diazinon treatments.

Table 1. The area of leaf surface consumed by various stages of *Epilachna varivestis* Muls. during development in laboratory

Average development in days, and daily units injured (6.3 sq. mm. each) per individual

Lot	Eggs A/No/I	Eggs Days	Eggs Units	1st instar larvae A/No/I	1st instar larvae Days	1st instar larvae Units	2nd instar larvae A/No/I	2nd instar larvae Days	2nd instar larvae Units	3rd instar larvae A/No/I	3rd instar larvae Days	3rd instar larvae Units
1	55	8	0	25	6	4.7	12	4	7.3	8	4	15.8
2	75	7	0	10	6	5.3	8	4	7.4	8	4	14.7
3	50	7	0	15	5	3.2	9	3	7.2	8	3	27.7
4	50	7	0	16	5	1.8	16	4	6.1	13	3	25.3
5	27	6	0	20	5	3.1	13	3	12.3	8	4	26.2
6	68	7	0	30	5	3.6	13	3	13.0	-	-	-
7	62	6	0	30	5	2.2	13	3	12.8	-	-	-
8	54	7	0	-	-	-	-	-	-	-	-	-
9	58	7	0	20	4	2.8	7	3	13.7	5	5	16.8
10	54	6	0	20	5	2.3	7	3	14.3	5	5	24.7
11	65	6	0	20	4	3.9	9	4	10.5	5	4	33.8
12	60	6	0	20	4	3.5	12	4	10.2	6	4	29.0
13	58	6	0	15	4	3.1	9	4	9.5	5	4	32.2
14	51	7	0	25	4	4.4	9	3	10.6	6	5	19.6
15	-	-	-	40	5	3.5	6	3	19.4	5	4	30.0
16	58	7	0	20	5	4.3	-	-	-	-	-	-
17	52	7	0	15	5	4.0	8	4	9.1	5	4	20.3
18	52	6	0	25	6	3.4	10	4	11.5	6	4	23.9
19	62	7	0	30	5	3.2	15	3	14.1	10	4	20.7
Total	1011	120	0	396	88	62.3	176	59	188.9	103	61	360.5
Grand Average	56	6.7	0	22	4.9	3.5	10	3.5	11.0	7	4.1	24.0

Lot	4th instar larvae A/No/I	4th instar larvae Days	4th instar larvae Units	Pupae A/No/I	Pupae Days	Pupae Units	Adult A/No/I	Adult Days	Adult Units
1	6	7	56.1	4	8	0	4	14	92
2	6	7	69.1	4	7	0	1	13	44
3	6	8	59.1	5	7	0	1	14	51
4	6	6	80.0	3	7	0	2	14	86
5	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-
9	4	8	99.1	4	6	0	2	15	95
10	3	7	53.6	2	6	0	2	13	84
11	4	7	54.3	3	6	0	1	13	64
12	3	7	47.1	1	7	0	1	14	75
13	4	8	41.8	3	6	0	2	14	58
14	5	7	59.4	5	6	0	4	14	79
15	-	-	-	-	-	-	-	-	-
16	-	-	-	-	-	-	-	-	-
17	4	7	59.5	3	7	0	3	15	62
18	3	7	67.8	3	7	0	3	14	74
19	5	6	88.8	4	6	0	2	15	92
Total	59	92	853.7	44	86	0	28	182	956
Grand Average	5	7.1	64.0	3	6.6	0	2	14	74

A/No/I - Approximate number of insects

Table 2. Indices of feeding capacity by feeding stages of *Epilachna varivestis* Muls.

Insect stage	A/No/I*	Length of stage (days)	Units injured per day (6.3 mms.)	Area injured per day (mms.)	Index A	Area injured during development (mms.)	Index B
Egg	1011	6.7	0.0	0	-	0	-
1st instar	396	4.9	3.5	22	1	108	1
2nd instar	176	3.5	11.0	69	3	243	2
3rd instar	103	4.1	24.0	151	7	620	6
4th instar	59	7.1	64.0	403	18	2861	26
Pupa	44	6.6	0.0	0	-	-0	-
Adult	28	First 14	74.0	466	21	6524	60

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* Approximate number of insects

Table 3. Average body length of the larval periods of *Epilachna varivestis* Muls.

Larval instar	POSTEMERGENCE	ACTIVE	PREMOLTING
First	1.2 mms.	2.4 mms.	2.2 mms.
Second	1.9 "	4.4 "	3.8 "
Third	3.8 "	5.8 "	4.9 "
			PREPUPATION
Fourth	5.5 mms.	8.5 mms.	6.7 mms.

Figure 1.- Life cycle, and equivalent of injured areas of bean leaves, by _Epilachna_ _varivestis_ Muls., from egg to first 14 days of adult stage, under controlled conditions. 1 unit of injury = 6.3 mm^2

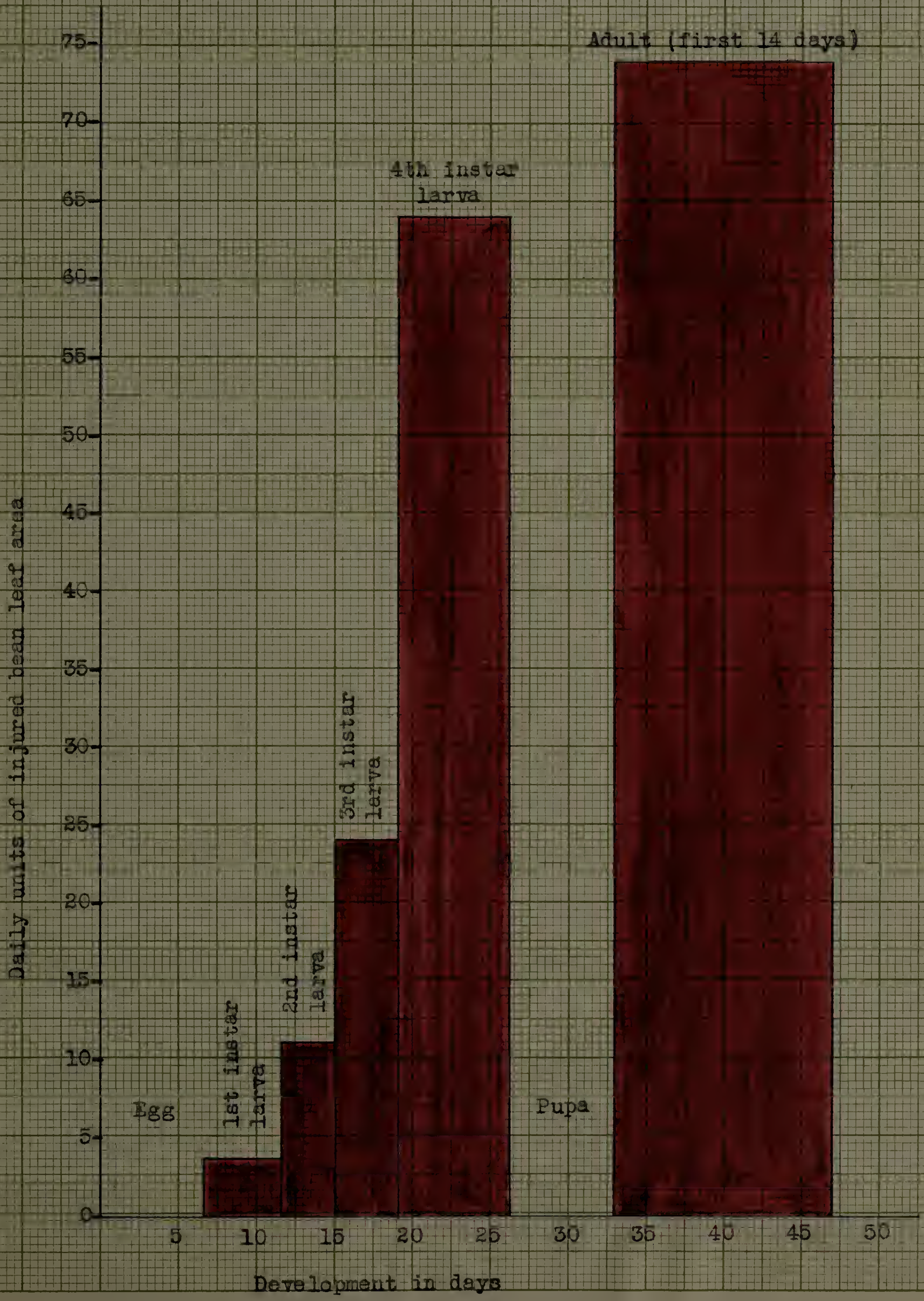

Table 4. Effect of insecticidal dust applications on foliage area and yield of bean plants

Treatments	13th day after 2nd application: Foliage area per plant sq. cms.	13th day after 2nd application: Number of pods per 5 plants	24th day after 3rd application: Foliage area per plant sq. cms.	24th day after 3rd application: Grams of beans per 5 plants
ROT	584	16	544	21
TOX	379	11	385	12
MET	590	16	784	24
EPN	653	19	872	26
PAR	444	13	419	14
DIL	599	17	769	23
DIA	391	13	357	13
PEN	356	11	380	14
MAL	183	9	165	7
As	159	7	215	6
UNT	587	21	862	28

Figure 2.- Relationship of foliage area and yield after insecticidal treatments to bean plants.

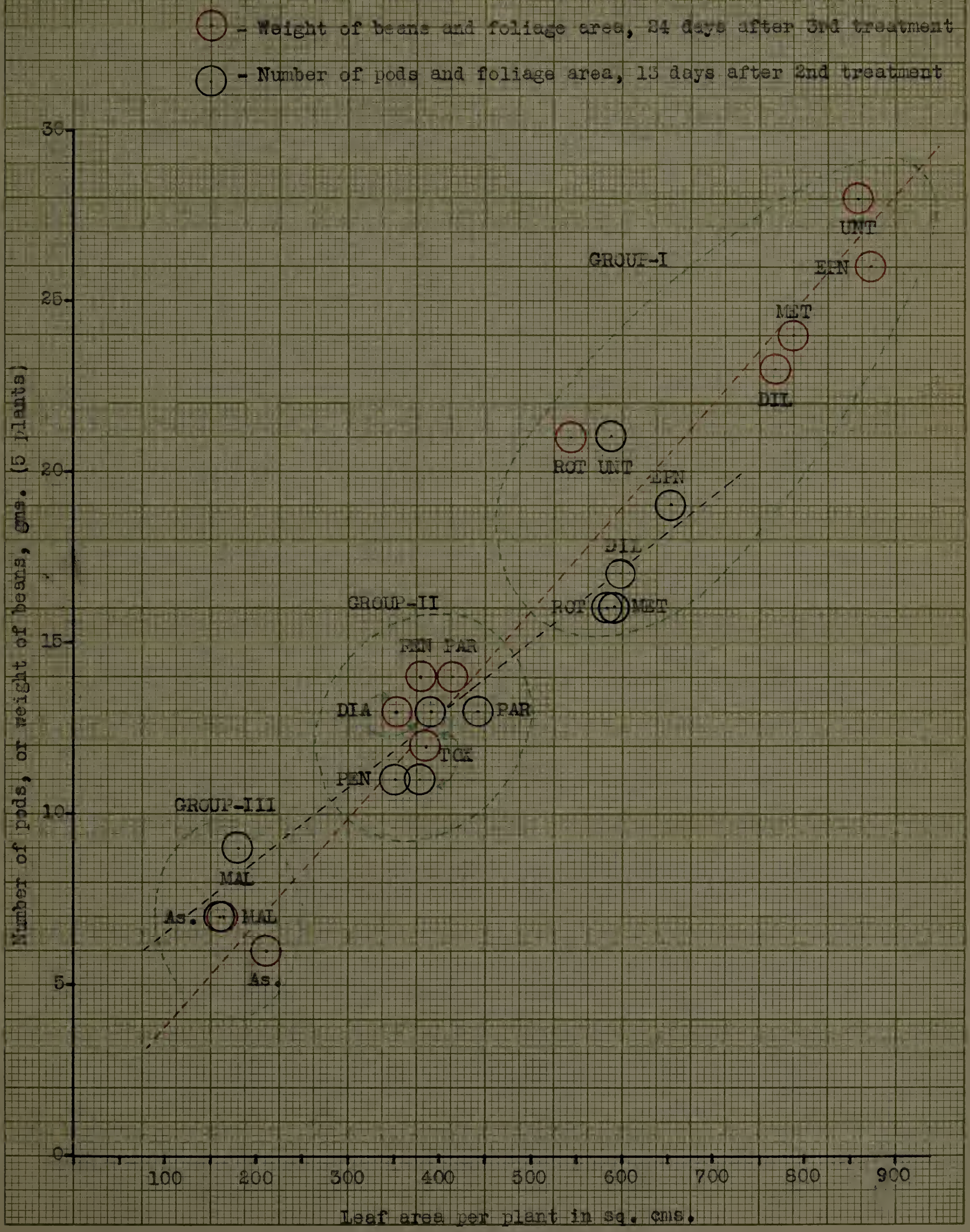

Table 5. The moribund adult bean beetle, produced by insecticidal residues, when successive lots of 10 insects were caged over the treated bean plants, at intervals of 48 hours, immediately after application and continued for a period of 36 hours

	Lots number of insects																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	Number of days after application when lot was exposed to plants																	
Treat-	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
ments	Moribund insects after 3 hours of exposure to treated plants																	
ROT	6	2	1	1	0	1	4	1	0	0	0	0	0	0	0	0	0	0
TOX	2	1	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0
MET	4	2	7	2	6	5	3	3	4	1	1	1	0	0	0	0	1	0
EPN	5	9	5	4	1	2	6	5	1	0	0	5	4	2	2	5	1	0
PAR	10	8	8	0	0	2	2	0	0	2	2	2	1	1	0	0	0	1
DIL	6	8	4	4	3	1	0	1	0	2	2	2	0	0	0	0	0	0
DIA	9	5	3	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0
PEN	8	8	6	1	0	0	0	2	0	0	0	2	1	0	0	0	0	0
MAL	7	9	10	4	4	4	6	4	0	0	0	3	1	0	1	0	0	0
UNT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Moribund insects after 18 hours of exposure to treated plants																	
ROT	9	6	7	6	3	3	4	0	0	3	0	1	0	0	1	0	0	0
TOX	10	5	8	5	5	5	5	2	2	2	1	0	1	0	0	1	0	0
MET	8	2	6	2	7	7	7	5	6	8	3	2	1	0	0	3	2	0
EPN	9	9	9	7	6	6	8	5	2	4	7	8	4	2	2	4	1	2
PAR	10	10	10	8	2	4	6	1	2	3	7	4	3	1	3	0	0	0
DIL	6	9	8	8	8	7	4	4	0	7	8	7	0	1	0	0	0	0
DIA	10	8	10	3	0	0	1	0	0	0	0	1	1	0	0	0	0	0
PEN	9	10	9	3	0	0	0	0	0	1	1	1	0	0	0	0	0	0
MAL	9	9	10	10	8	7	7	7	3	5	7	5	2	1	0	0	0	0
UNT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Moribund insects after 48 hours of exposure to treated plants																	
ROT	10	10	6	8	5	8	2	2	6	5	5	5	0	0	1	0	0	0
TOX	10	10	6	10	7	10	9	6	9	8	7	9	2	0	4	3	0	0
MET	8	8	6	5	7	6	5	7	10	8	6	3	1	0	1	2	2	0
EPN	10	10	10	10	9	8	9	8	4	8	9	8	4	5	5	5	4	2
PAR	10	10	10	10	10	7	8	8	8	5	8	9	4	1	3	1	1	0
DIL	9	10	9	8	9	9	8	9	7	10	9	10	1	2	7	1	1	0
DIA	10	10	10	3	0	0	0	1	0	0	0	2	2	0	0	0	0	0
PEN	10	10	10	5	1	8	1	1	1	1	1	1	0	0	0	0	0	0
MAL	10	10	10	10	10	10	10	10	10	10	7	10	7	6	4	3	1	0
UNT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 6. The moribund 4th instar larvae of bean beetle, produced by insecticidal residues when successive lots of 10 insects were caged over the treated bean plants, at intervals of 48 hours, from the 7th day to the 37th day after application

Treatments	Lots number of insects														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Number of days after application when lot was exposed to plants														
	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35
	Moribund insects after 5 hours of exposure to treated plants														
ROT	5	3	4	3	2	1	2	1	1	2	2	1	1	1	0
TOX	4	3	4	2	1	1	1	1	0	0	1	1	0	0	0
MET	2	4	5	5	2	2	3	2	4	4	3	3	2	2	1
EPN	5	4	4	2	3	3	2	2	2	0	1	3	3	2	2
PAR	8	7	9	7	3	2	3	2	2	0	0	1	2	1	0
DIL	3	4	4	4	5	4	3	2	5	2	0	1	0	1	0
DIA	5	4	4	3	4	2	1	0	1	1	1	0	3	2	1
PEN	3	2	2	3	1	0	1	1	2	1	1	1	2	3	4
MAL	3	6	6	6	8	6	3	3	2	3	3	3	2	1	3
As	4	4	3	2	3	2	0	0	1	0	1	0	0	2	0
	Moribund insects after 24 hours of exposure to treated plants														
ROT	7	7	6	6	2	2	2	1	2	4	5	3	6	5	2
TOX	5	6	6	4	1	2	3	4	2	2	4	5	3	4	3
MET	6	8	8	7	4	3	4	4	5	6	5	4	2	2	2
EPN	5	7	6	7	5	4	3	2	3	3	4	6	0	5	6
PAR	5	8	10	9	8	7	5	5	5	4	3	6	4	6	5
DIL	6	5	6	6	5	6	4	4	6	4	2	4	1	1	2
DIA	6	6	5	7	8	9	6	6	6	5	3	6	6	5	2
PEN	7	9	8	5	3	3	2	2	5	2	3	2	4	5	6
MAL	9	10	6	7	8	9	9	9	7	7	6	5	6	5	5
As	5	8	4	2	4	3	4	3	4	2	3	2	3	3	1
	Moribund insects after 48 hours of exposure to treated plants														
ROT	8	8	8	7	4	3	4	4	5	7	6	4	7	6	4
TOX	8	7	6	6	5	5	5	4	6	6	8	8	4	5	5
MET	9	9	8	8	6	5	6	6	9	6	7	6	5	3	4
EPN	8	9	8	8	9	8	6	6	7	6	6	7	7	6	7
PAR	9	10	10	9	9	8	9	9	7	5	7	8	7	8	7
DIL	8	9	8	9	6	6	8	7	9	8	6	6	3	2	5
DIA	10	10	10	9	8	9	10	10	9	6	8	7	9	2	3
PEN	8	10	9	7	8	5	7	6	9	7	4	5	6	6	7
MAL	10	10	10	10	9	9	10	10	9	7	10	10	7	7	7
As	7	9	6	5	4	3	5	4	5	6	3	4	4	5	3

Table 7. Effects of some insecticides upon pupae and prepupae of the Mexican bean beetle

Treatment	Days after treatment: 0 — Number of insects (dead or alive)			2			4			6			8			10			Percentage failed to develop	
	Pupae	Prepupae	Adult	Pupae	Prepupae	Adult	Pupae	Prepupae	Adult	Pupae	Prepupae	Adult	Pupae	Prepupae	Adult	Pupae	Prepupae	Adult	Pupae	Prepupae
Test 1																				
ROT	20	5	0	25	0	0	19	0	6	11	0	14	6	0	19	6	0	19	24	0
TOX	20	5	0	25	0	0	14	0	11	6	0	19	0	0	25	0	0	25	0	0
MET	20	5	0	24	0	1	12	0	13	7	0	18	0	0	25	0	0	25	0	0
EPN	20	5	0	24	0	1	17	0	8	5	0	20	0	0	25	0	0	25	0	0
PAR	20	5	0	24	0	1	23	0	2	23	0	2	23	0	2	23	0	2	86	0
DIL	20	5	0	21	0	4	15	0	10	5	0	20	1	0	24	1	0	24	4	0
DIA	20	5	0	22	3	0	22	3	0	22	3	0	22	3	0	22	3	0	100	60
PEN	20	5	0	23	1	1	23	1	1	23	1	1	19	1	5	19	1	5	79	20
MAL	20	5	0	20	4	1	23	1	1	23	1	1	23	1	1	23	1	1	97	20
UNT	20	5	0	20	0	1	10	0	15	5	0	20	0	0	25	0	0	25	0	0
Test 2																				
ROT	35	3	0	25	3	10	19	3	16	9	3	26	8	3	27	8	3	27	23	100
TOX	35	3	0	28	3	7	20	0	18	7	0	31	3	0	35	0	0	38	0	0
MET	35	3	0	27	2	9	26	1	11	12	1	25	4	1	33	1	1	36	3	33
EPN	35	3	0	28	3	7	20	0	18	14	0	24	3	0	35	0	0	38	0	0
PAR	35	3	0	34	3	1	34	3	1	34	3	1	34	3	1	34	3	1	97	100
DIL	35	3	0	21	3	14	17	0	21	11	0	27	4	0	34	1	0	37	3	0
DIA	35	3	0	34	3	1	34	3	1	34	3	1	34	3	1	34	3	1	97	100
PEN	35	3	0	34	3	1	34	3	1	34	3	1	34	3	1	34	3	1	97	100
MAL	35	3	0	30	3	5	30	3	5	30	3	5	30	3	5	30	3	5	86	100
As	35	3	0	19	3	16	18	0	20	6	0	32	3	0	35	0	0	38	0	0

Table 8. Effect of insecticidal applications on bean beetle feeding population and the yield of beans produced

Treatment	Before application	Days after 1st application			Days after 2nd application				Days after 3rd application		Yield oz/plot
	1	1	3	7	1	5	11	13	1	3	
	Sq. root from figures from insect feeding population treatment										
						1953 Test					
ROT dust	17.2	6.2	10.8	13.0	5.4	9.4	12.8	23.4	14.6	17.3	14.1
TOX "	18.4	15.2	17.6	17.8	15.4	16.2	20.8	28.2	32.6	42.6	14.3
MET "	16.2	4.4	10.8	13.0	6.6	6.2	12.6	17.4	15.2	28.8	13.0
EPN "	19.2	12.0	11.4	11.2	7.8	12.4	19.6	24.2	20.8	23.6	15.4
PAR "	16.2	1.4	8.6	9.6	6.8	6.8	14.2	22.2	11.2	15.8	13.7
ROT Spray	15.2	13.8	16.0	21.0	21.2	30.6	40.0	46.2	45.0	44.2	11.1
TOX "	15.4	12.0	16.4	21.8	20.2	20.0	23.8	19.6	18.8	17.0	13.6
MET "	12.2	8.0	13.0	21.8	22.4	18.8	25.4	33.4	25.8	30.8	12.1
EPN "	15.4	12.0	9.2	16.8	11.0	15.2	20.0	28.2	20.0	23.4	13.8
PAR "	17.0	8.6	8.8	17.6	8.6	9.0	15.0	20.2	12.0	16.2	13.9
UNT	18.4	19.4	16.6	24.0	29.6	36.8	50.2	48.0	53.0	51.4	11.5
L.S.D. 5 p.c.	4.6	6.0	4.9	4.5	6.4	5.7	8.3	9.5	8.4	12.3	N.S.
L.S.D. 1 p.c.	6.0	7.8	6.5	5.9	8.4	7.5	10.9	12.4	10.4	16.2	N.S.
						1954 Test					
	1/2	1/2	2								
ROT dust	6.6	2.4	1.4								3.8
TOX "	6.2	3.0	2.2								4.3
MET "	6.4	2.1	1.0								4.6
EPN "	11.8	9.2	2.6								4.0
PAR "	4.4	3.2	1.0								4.0
DIL "	11.6	4.2	2.2								4.4
DIA "	11.2	4.8	1.6								3.7
PEN "	10.6	3.6	1.8								4.1
MAL "	11.2	3.4	1.0								3.8
UNT	6.2	6.2	7.4								3.6

SUMMARY

Insecticidal tests upon the Mexican bean beetle, Epilachna varivestis Muls., using rotenone, toxaphene, methoxychlor, EPN, parathion, dilan, diazinon, penthion, malathion, and calcium arsenate, and biological observations were conducted in Massachusetts during 1953 and 1954.

Biological observations.

The damage produced upon bean foliage by the feeding stages of 19 lots of insects throughout the immature, and part of the mature stage was measured under laboratory conditions. Measurements for length of the larvae were determined from 13 lots of insects under laboratory conditions.

Phytotoxicity insecticidal tests on bean plants.

The phytotoxic effect from three dust applications of various insecticides was evaluated by observations at 4-day intervals throughout plant development under controlled conditions.

Residual effect of insecticides on the bean beetle.

For 37 days the residual effect of insecticides was evaluated, on adults and 4th instar larvae of the bean beetle under greenhouse conditions. Lots of 10 insects were exposed successively to treated plants at 2-day intervals. The response of the insects was recorded three times each 48 hours.

Insecticidal tests on pupae and prepupae of the bean beetle.

The effect of insecticides upon pupae and prepupae of the bean beetle was evaluated during 10 days under controlled conditions. The insect development was recorded at 2-day intervals.

Field tests with insecticides on the bean beetle.

During 1953-1954, evaluation was made of the effect of some insecticides on field bean plots to control bean beetle infestation, which was built up by liberation of insects during the fifth week after planting. Insect feeding population of each plot was recorded several times. The number of insects per count per plot was reduced to a single figure by the feeding capacity index A; the square roots of such figures and yield were subjected to statistical analyses.

RESULTS

Indices A and B concerning the relative feeding capacity of the insect were calculated upon the basis of the 1st instar larvae feeding capacity rated as one (Table 2).

There are significant variations in the length of larvae for the same larval instar.

Bean plant defoliation caused by insecticidal phytotoxicity from three dust applications of heavy dosages of insecticides under laboratory conditions appeared to be directly proportional to decrease in yield. Accordingly the degree of phytotoxicity by the insecticides may be grouped as follows:

MET, EPN, and DIL slight; ROT moderate; TOX, PAR, DIA, and PEN strong; MAL and As severe.

The effect of residues from heavy dosage of insecticides on the bean beetle adult after exposure to treated bean plants was variable, as follows:

PAR, DIA, PEN, and MAL appeared to act very fast, but DIA and PEN have very short residual effectiveness. Most of the insecticides were highly effective within 48 hours after exposure for long periods after application. MAL, DIL, and EPN were effective for about 3 weeks; MET, TOX, and PAR for about 2 weeks; and ROT for about 10 days.

The differences in effectiveness among the insecticides to 4th instar larvae were appreciable under tested conditions.

All still were killing a relatively high percentage of the insectx at the 37th day.

The effect of a heavy dosage of insecticide to pupae and prepupae of the bean beetle under controlled conditions appeared to be as follows: PAR, DIA, PEN, and MAL highly effective; ROT moderately effective; MET, DIL,TOX, EPN, and As not effective.

Three dust applications with recommended dosages of ROT, TOX, MET, EPN, and PAR appeared to be effective, protecting the crop against a retarded heavy infestation of bean beetle under field conditions. PAR 1 per cent dust or 0.1 per cent spray was highly effective against heavy infestations.

One dust application with the recommended dosage of ROT, TOX, MET, EPN, PAR, DIL, DIA, PEN, and MAL upon a retarded bean beetle infestation, when unprotected against physical environment, gave results not reliable, due to the poor conditions of the test.

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November 20, 1954