The Effect of Insecticides on a Beneficial Coccinellid, *Hippodamia convergens* Guer.

G. W. Haug and Alvah Peterson, *Ohio State University, Columbus*

Comparatively little information exists in the entomological literature relative to the effect of insecticides on beneficial insects. Clausen (1936) has reviewed the work on this subject and shows that a number of general observations have been recorded, but no extensive studies have been conducted on the effect of a series of common insecticides on any beneficial insect.

It is hoped that this contribution will awaken interest among entomologists in the question, "How and to what extent do insecticides affect the natural enemies of insect pests?" The authors are of the opinion that, sometime in the future, field results with insecticides on economic pests will include the effect of the insecticides employed upon the natural enemies of the pest the investigator is attempting to control. This will be particularly true among pests where it is apparent that biological control plays an important role in checking devastations.

Several years ago the junior author proposed the problem discussed in this paper. The senior author accepted the problem for his graduate research work. At the outset and throughout the investigation, the senior author developed some interesting and new methods and equipment to keep the beetles alive, to produce eggs, to rear larvae, etc. It is hoped that the senior author will be able to publish his results on this matter in the near future. The junior author prepared the final draft of this paper for publication in order that the insecticide results might appear at an early date.

The coccinellid selected for this study was *Hippodamia convergens* Guer. This species is very satisfactory for several reasons. It is an important species and found in most parts of the United States and elsewhere. It feeds readily on many species of aphids and on frozen aphids which makes it easy to rear. Also it may be purchased in large quantities from commercial insectaries.*

General Methods.—All the insecticide tests reported in this paper on adults, eggs and larvae were conducted in a greenhouse or in basement laboratories. Temperature and humidity records were taken during the period of each experiment. An air pressure gun was used for spraying, at 12 pounds pressure for adults (in screen cages) and at 6 pounds pressure for eggs and larvae. All spraying was done in the laboratory with clean equipment, and each spray mixture was made up carefully in distilled water before it was applied. All figures on the per cent of kill are based on the well known formula $\frac{x-y}{x} \times 100$, where x = the per cent living in the checks and y = the per cent surviving the treatments. In the determination of adult mortality, the beetles were classified as living, moribund and dead. A living beetle was one that could move forward no matter how feeble it might be. A moribund beetle was alive and could move its appendages yet was unable to crawl. In determining kill, moribund beetles were grouped with individuals that showed no signs of life. Many of the feeble beetles classed as living died after three days. This was particularly true when derris was used.

Methods with Adults.—The adults used in the tests were taken from two separate shipments (March, May, 1936) from California. Upon arrival, via air express, the adults were placed in a refrigerator at 2° C., watered periodically and removed when needed.

Three types of cages were used for the adults. The plant cage was the one used most extensively, fig. 1. It was made of 12-mesh galvanized screen and resembled an inverted cone with a flat top. The measurements were $8\frac{1}{2}$ inches high, $3\frac{3}{4}$ inches across the bottom opening and $6\frac{1}{2}$ inches across the closed flat top. The screen door was made of the same material as the cage and covered a small opening on one side. The door swung on three hinges of soft wire, was oversized and was kept closed by a short, straight piece of spring steel wire with the two ends forced by bowing through the screen mesh. The cage was placed over aphid-

* A. W. Morrill, California Insectaries, Inc., Glendale, Calif.

infested nasturtium plants or portions of other plants. A small aluminum strip tag was wired to each cage. Before each test the cages were washed thoroughly and paraffined. To paraffin a cage it was rolled

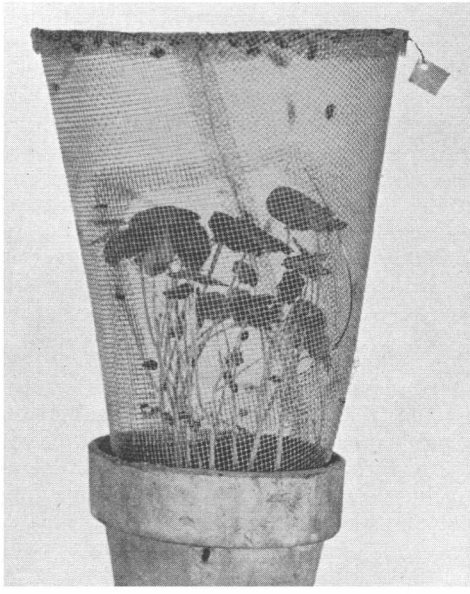

FIG. 1.—Plant and adult cage.

in melted, smoking paraffin until the sides were covered completely. The flat top also was dipped into the paraffin. It was then lifted out of the paraffin quickly and hit sharply with the left hand to free the meshes of excess paraffin. The lower margin of the cage was pushed into the moist soil in a 4-inch flower pot. The space between the edge of the cage and the sides of the pot was filled with dirt and packed tightly.

A second type of cage, fig. 2, for adults was a flat wire screen container made of 12-mesh galvanized wire screen. It was 4 inches×4 inches×$\frac{3}{4}$ inch deep with a 2×2 inch square opening on the upper side. The door swung on two soft wire hinges and was closed by a short piece of spring steel wire. The whole cage was washed and paraffined before each spray test.

The third type of cage for adults was one-half of a Petri dish covered with 12-mesh wire screen. The beetles, 50 in each cage, were sprayed through the screen sides of the cage. After spraying, the screen side of the cage was placed downwards.

Bean aphis, *Aphis rumicis* L., on nasturtium plants proved to be satisfactory as food for sprayed coccinellids. Under high temperatures and a continuously moist soil, satisfactory plants and an ample aphid population can be produced in 13 to 15 days. At lower temperatures or with less soil moisture, plant production was slower. The first nasturtium sprouts appeared above ground three days after the seeds were planted. Six days after planting, when the sprouts averaged one-half inch in height, the plants were infested with aphids. Seven to nine days later, the plants were just the right size to use in the plant cages and had become heavily infested with aphids.

In planting seeds, pretreated with "Cupricide" dust, an aluminum ring, $2\frac{3}{4}$ inches in diameter and made from an aluminum strip, $\frac{1}{2}$ inch in width, was placed on the surface of the soil in the center of a 4-inch flower pot. The seeds were placed inside the ring and then covered with soil. The ring was removed and soil was packed tightly over the seeds in the pot.

Five methods were used in conducting tests with adults. The majority of the tests were with method 1. Under method 1, 25 adults were placed in a wire screen plant cage, fig. 1, in which were nasturtium plants heavily infested with bean aphids. In the early tests, the beetles were permitted to feed for 24 hours before they were sprayed. This was found to be un-

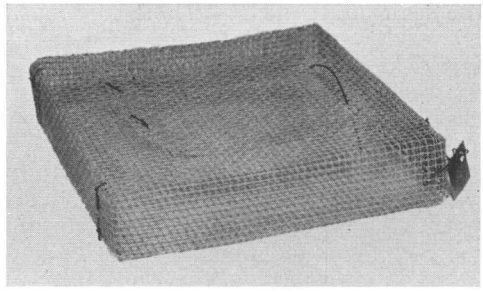

FIG. 2.—Wire screen cage for adults.

necessary and the practice was dropped. With the spray gun held in the right hand 12 inches away from the screen cage, the spray was directed on to the beetles and the plants within the cage, while the left hand slowly revolved the pot over

which was the cage. Each sprayed cage was replicated four times for each test of a given insecticide. After a cage was sprayed it was wiped dry with soft cheesecloth and set aside in the greenhouse. If the temperature of the greenhouse was too high, the cage was placed in the laboratory. On the third day after spraying, the mortality counts were made and the tests discontinued. The above method favored the insecticide because the adults were forced to remain on sprayed plants and aphids. To eliminate this difficulty method 2 was applied.

In method 4, the adults, 50 per cage, were sprayed in small screen cages, fig. 2; they were kept in these cages until the third day, when the results were recorded.

Method 5 is the same as method 2 except for predrinking; that is, the adults were sprayed with distilled water one or more times previous to the application of the spray. During the progress of the investigations, it was discovered that thirsty beetles reacted differently to a few

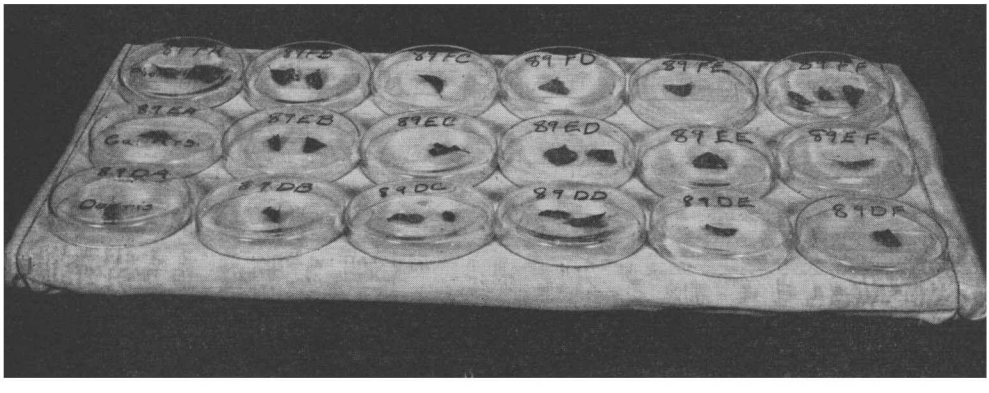

FIG. 3.—A gauze covered tray bearing sprayed eggs on foliage placed on glass slides below halves of Petri dishes.

In method 2, the adults were placed in small, flat wire screen containers, fig. 2, and sprayed. As soon as the spraying was complete the cage was jarred slightly over the back of one hand to remove the excess spray; also all visible spray was wiped off with a clean cheesecloth. The cage containing the sprayed adults was then allowed to stand for 15 minutes in front of an electric fan; within a few minutes the beetles and cage were dry. Then the 25 beetles from each replicate cage were removed from the wire screen cage by means of a suction collector and transferred to clean plant cages containing unsprayed aphid-infested nasturtiums. Mortality records were made on the third day. This method parallels conditions in the field where sprayed adults might migrate to unsprayed foliage and aphids.

In method 3, the adults, 50 per cage, were placed in Petri dishes covered with screening, and sprayed. The screen side of the dish was placed downwards and the adults were kept in these cages until the third day.

of the insecticides than beetles that had been in contact with water previous to the application of the insecticide.

METHODS WITH EGGS.—All the eggs used in the ovicide tests were deposited by adults shipped from California. The eggs were deposited on smooth foliage of *Spiraea Vanhouttei* Zabel in oviposition chambers.* The original incubation chamber consisted of a cheesecloth covered embroidery hoop placed over a small half of a paraffined Petri dish containing water and covered with the top half of a petri dish. This method was later discarded for a tray system, fig. 3. A shallow metal pan 12 inches×25 inches×$\frac{3}{4}$ inch deep was filled with strips of cellucotton saturated with water. A removable eight mesh hardware cloth cover was placed over the top. This was covered with two layers of cheesecloth held in place by rubber bands at each end. The sprayed

* Oviposition and rearing methods will be discussed in a paper to be prepared for publication by the senior author.

egg clusters, always on foliage (usually Spiraea) were placed on small glass slides that rested on the cheesecloth over the moist chamber. Each cluster of 25 or more eggs in a given replicate was covered with one-half of a Petri dish. Each insecticide had six replicates and one tray held 18 replicates.

When the eggs were sprayed, a leaf bearing a cluster of normal, uninjured eggs was lifted from the container by a pair of forceps and held in the spray about two feet from the spray gun. Each cluster was thoroughly moistened with the spray. The excess spray was drained and absorbed from the leaf by a small piece of cellucotton. Then the leaf bearing the sprayed egg cluster was placed on a glass slide, 1×3 inches, on the cloth cover over the water tray and covered with one-half of a Petri dish.

As soon as hatching started among treated and check eggs, they were examined every two or three hours during the daytime and every six hours at night as long as hatching took place. Even though this precaution was taken, about 12 per cent of the eggs were injured by the newly hatched larvae. At a temperature of 76° F. and in the presence of high humidity, the first hatch occurred within 48 to 72 hours and nearly all had hatched in 72 to 96 hours. At 82° F. and in high humidity the first hatch occurred in 24 to 48 hours and was completed in 48 to 72 hours.

METHODS WITH LARVAE.—All larvae tested were reared first stage larvae. The tests were conducted at 77° to 84° F. The first instar larvae were from eggs deposited on spiraea foliage located under one-half of a Petri dish on cheesecloth stretched across embroidery hoops. The embroidery hoops were placed above dishes containing water. Frozen poplar gall aphids (Haug, 1936) were used as food in the insecticide tests.

The great activity of newly hatched larvae necessitated rapid work in making the spray tests. Fifteen larvae were transferred with a camel-hair brush to the bottom of a Petri dish covered with filter paper previously moistened with the insecticide to be tested. The free moisture on the paper slowed down the activity of the larvae while the spray was directed on to them. After spraying was complete, the 15 larvae were transferred quickly by a camel-hair brush to dry cheesecloth stretched over an embroidery hoop on which numerous frozen poplar gall aphids were located. The cloth of the embroidery hoop was placed over a dish of water and the larvae and aphids were covered with one-half of a petri dish. There were six replicates to each test. To resemble field conditions more nearly, the aphids in some of the tests were also sprayed with the respective insecticides. A few tests conducted indicated that this procedure made no difference in the results. Mortality counts were made the day following the day of spraying.

INSECTICIDE RESULTS.—About a dozen common insecticides were tested. They are discussed in alphabetical order. The effect of each insecticide on adults, eggs and larvae are presented under the respective insecticide.

Anabasine sulfate, 40 per cent, 1 part to 400 parts of water. This product was tested once on first instar larvae. The kill was 2 per cent.

Black Leaf 40, 55 per cent nicotine sulfate, 1 part to 800 parts of water plus Red A soap, 1 part to 100 parts of volume. *Black Leaf 40* on the adults under method 1 in eight experiments gave 12 to 47 per cent kill, averaging 26 per cent; under method 3 in four experiments it gave 2 to 8 per cent kill, averaging 5 per cent; under method 4 in two experiments it gave 20 to 23 per cent kill; and under method 5 in one experiment gave 6 per cent kill.

Greater variation occurred in the results with *Black Leaf 40* on adults than with any other insecticide. In some measure this may be the result of the fumigation effect of nicotine, particularly in method 1 in which the beetles were confined to sprayed foliage. In the methods where the beetles were not confined with the spray on foliage or elsewhere, the kill was consistently low.

Three experiments with *Black Leaf 40* were conducted on eggs and the results were 0.4 and 0 per cent kill. Four experiments with *Black Leaf 40* were conducted on first instar larvae and the results were 0, 0, 0 and 20 per cent kill, averaging 3 per cent.

Bordeaux mixture, formula 4–4–50. Bordeaux mixture on adults under method 1 in four experiments gave 2 to 25 per cent kill, averaging 15 per cent; under method 3 in one experiment it gave 13 per cent

kill; and under method 4 in two experiments it gave 45 to 83 per cent kill.

Five experiments with Bordeaux mixture were conducted on eggs and the results were 0, 0, 14, 7 and 0 per cent kill, averaging 5 per cent. No tests with Bordeaux mixture were conducted on larvae.

The results with Bordeaux mixture were variable. It is believed that the mortality of beetles was greatest among adults that did not have access to water. Further tests are needed to ascertain the effects of Bordeaux mixture on adults.

Calcium Arsenate, 1½ pounds to 50 gallons of water plus 4 pounds of hydrated lime. Calcium arsenate on adults under method 1 in four experiments gave 16 to 31 per cent kill, averaging 24 per cent and under method 4 in one experiment gave 100 per cent kill. One experiment with calcium arsenate on eggs and one on first instar larvae gave no kill.

Cryolite, a synthetic mixture of fluoaluminates, etc., chiefly sodium aluminum fluoride, 3 pounds to 50 gallons of water. Cryolite on the adults under method 1 in three experiments gave 7 to 23 per cent kill, averaging 14 per cent.

Five tests were conducted with cryolite on eggs and the kill was 13, 0, 11, 0 and 0 per cent, averaging 4 per cent.

Three experiments were conducted with cryolite on larvae, and the kill was 28, 9 and 18 per cent, averaging 19 per cent.

Derris, ground root suspension, rotenone analysis 5 per cent in 14 per cent ether extractive, 1½ pounds to 50 gallons of water. Derris on the adults under method 1 in six experiments gave 67 to 74 per cent kill, averaging 71 per cent; under method 2 in three experiments it gave 98 and 99 per cent kill; under method 3 in three experiments it gave 37 to 71 per cent kill, averaging 57 per cent; under method 4 in three experiments it gave 63 to 86 per cent kill, averaging 72 per cent; and under method 5 in two experiments gave 73 to 78 per cent kill.

The results with derris on adults were practically constant. Except for one test out of 17, which gave 37 per cent kill, the percentage of dead beetles ran high, in most cases about 70 per cent.

Derris was used in eight tests on eggs and produced 0, 3, 11, 25, 16, 19, 13 and 7 per cent kill, averaging 14 per cent. These percentages are based on actual hatching. They are not true figures of the mortality that resulted, because many of the newly hatched larvae died a short time after they left the empty egg shell.

Derris was used in three tests on first instar larvae, and the kill was 47, 43 and 48 per cent, averaging 46 per cent.

Dutox, active ingredient barium fluosilicate 72 per cent and sodium fluosilicate 8 per cent, 1½ pounds to 50 gallons of water. *Dutox* on adults under method 1 in three experiments gave 11 to 18 per cent kill, averaging 14 per cent; under method 4 in one experiment it gave 13 per cent kill. The results with *Dutox* were fairly constant.

Dutox was tried on eggs in two tests and produced no kill. It was also tried on first instar larvae in two experiments and gave 0 and 2 per cent kill.

Evergreen, pyrethrum extractive 6 per cent, 1 part to 400 parts of water. No tests were conducted on adults or eggs. *Evergreen* was tried in two experiments on first instar larvae and gave 13 and 3 per cent kill, averaging 8 per cent. *Evergreen* was tried in three tests on eggs and gave 0, 2 and 9 per cent kill, averaging 3 per cent.

Kalo, a natural cryolite, sodium aluminum fluoride not less than 90 per cent, 2 pounds to 50 gallons of water. *Kalo* on adults under method 1 in three experiments gave 0 to 8 per cent kill, averaging 4 per cent; under method 4 in one experiment it gave no kill.

Kalo on eggs in two tests produced no kill. When used on first instar larvae in three tests it gave 14, 21 and 6 per cent kill, averaging 14 per cent.

Lead Arsenate, powder, 1½ pounds to 50 gallons of water. Lead arsenate on adults under method 1 in three experiments gave no kill; under method 4 in one experiment it gave no kill. Lead arsenate on eggs in one experiment gave no kill; also on first instar larvae in one experiment it gave no kill.

Manganar, active ingredient manganese arsenate 64 to 60 per cent, 2 pounds to 50 gallons of water. *Manganar* on adults under method 1 in two experiments gave 0 and 3 per cent kill; under method 4 in one experiment it gave 15 per cent kill. *Manganar* on eggs in one test gave no kill; also on first instar larvae in one test it gave no kill.

Paris Green, powder 1 pound to 50 gal-

lons of water and 4 pounds of hydrated lime. Paris green on adults under method 1 in four experiments gave 79 to 99 per cent kill, averaging 85 per cent; under method 2 in five experiments it gave 11 to 50 per cent kill, averaging 34 per cent; under method 3 in one experiment it gave 93 per cent kill; under method 4 in one experiment it gave 99 per cent kill; and under method 5 in one experiment it gave 7 per cent kill.

These results indicate that Paris green was very toxic to adults, especially when the adults were thirsty or were confined to plants or in cages covered with Paris green.

Paris green on eggs in five tests gave 14, 15, 0, 11 and 0 per cent kill, averaging 7 per cent. Paris green on first instar larvae in three tests gave 2, 4 and 2 per cent kill, averaging 3 per cent.

Phenothiazine with orvus, 1 per cent, at the rate of 2 pounds to 50 gallons of water. Phenothiazine on adults under method 1 in three experiments gave 100 per cent kill; under method 2 in two tests gave 100 per cent kill; under method 5 in one experiment gave 100 per cent kill; also in one test when applied as a dust diluted with talc, one part to ten of talc, gave 98 per cent kill.

Phenothiazine on eggs in seven tests gave 100 per cent kill except in two instances, in which the kill was 95 and 98 per cent. Also in three tests on newly hatched larvae the kill was 100 per cent. Phenothiazine dust, 1 part to 10 parts of talc, in one test gave 91 per cent kill.

Volck Nursery Oil, 3.2 per cent spray. *Volck Nursery Oil* on adults under method 1 in eight experiments gave 0 to 23 per cent kill, averaging 14 per cent; under method 3 in four experiments it gave 1 to 6 per cent, averaging 4 per cent; and in method 4 in two experiments it gave 0 to 3 per cent kill.

This oil spray on eggs in four tests gave 5, 0, 2 and 0 per cent kill, averaging 2 per cent. Also on first instar larvae in two tests it gave 1 and 7 per cent kill.

DISCUSSION AND SUMMARY.—The insecticide results on *Hippodamia convergens* Guer. presented in this paper were derived exclusively from indoor tests. They may be indicative of what happens to coccinellids when these sprays are employed under field conditions. Probably in the near future someone will be able to compare these results with field tests.

Of the insecticides tested phenothiazine and derris proved to be the most toxic to all stages of the coccinellid. Phenothiazine killed 95 to 100 per cent of the adults, eggs and larvae, and derris killed approximately 70 per cent of the adults, 46 per cent of the larvae and 14 per cent of the eggs. The egg mortality reported with derris is much greater, if the large number of larvae that died a short time after they hatched are included in the number of dead eggs.

Black Leaf 40 and some of the arsenicals, particularly Paris green and calcium arsenate, proved to be fairly toxic to adults especially if thristy adults were used or if adults were confined in sprayed cages with sprayed aphids. All other insecticides in the tests conducted produced an average kill of less than 25 per cent and in many cases no kill.

In general, the insecticides tested appeared to kill a higher percentage of adults than eggs or larvae.—7-18-37.

LITERATURE CITED

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UNDER CALIFORNIA quarantine proclamations relating to the peach mosaic disease as revised in October an embargo is placed on the entry of possible carriers of the peach mosaic disease from the infected areas in other states and on the movement of such carriers from infected areas in California. To the host list have been added apricot, almond, prune and plum trees and cuttings.