

as broadcast applications worked into the soil shortly before planting, are promising for the prevention of wireworm damage to potatoes. Their toxicities to wireworms and the influence of soil conditions on the effectiveness of each in preventing wireworm damage require further study; there is evidence that the effectiveness of Zinophos may be less consistent than that of N-2790. Minimum effective rates of either insecticide appear to be not hazardous with respect to color, flavor, and texture of Norland potatoes.

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Biological Observations on *Coleomegilla maculata* and Its Role as a Predator of the Fall Webworm¹

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ABSTRACT

Under laboratory conditions, overwintered adults of *Coleomegilla maculata* De Geer lived an average of 61.9 days (range 4-139) after they were collected from the field when held at a constant temperature of 26.7°C and 14 hours light. The females deposited an average of 49.8 eggs when fed liver. In the laboratory and field both

larvae and adults of *C. maculata* readily fed on egg masses of fall webworm, *Hyphantria cunea* (Drury). Adults fed on the larvae of the fall webworm but the larvae would not. Development of *C. maculata* was more rapid when fed eggs of the fall webworm, or its own eggs, than when fed liver.

Investigations on the natural enemies of the fall webworm, *Hyphantria cunea* (Drury), in 1962 (Tadic 1963) revealed that egg masses of this insect were frequently partially to wholly destroyed by predators. Larvae of *Chrysopa quadripunctata* Burns were observed attacking the fall webworm eggs, but only part of the predation could be attributed to them. The entomophages responsible for much of the egg predation thus remained unknown.

In the winter of 1965-66, preliminary experiments with overwintering adults of the convergent lady beetle, *Hippodamia convergens* Guérin-Méneville, and *Coleomegilla maculata* De Geer showed that both species would eat the eggs of the fall webworm under laboratory conditions. Because of the association of *C. maculata* with trees that had been infested with fall webworm, studies were conducted to determine its role as a predator.

Because of its predatory habits, both in the larval and adult stages, *C. maculata* is considered a beneficial insect. However, its diet is not limited to animal

food. Webster (1880) detected a mixture of animal and plant food taken by it. Forbes (1883) reported an average of 46% of animal food, the remainder consisting of spores, lichens, and pollen. Riley (1893) recorded *C. maculata* feeding on blades of corn, with both larvae and adults feeding on the soft kernels of corn. The predatory relationships of *C. maculata* to the European corn borer, *Ostrinia nubilalis* (Hübner) were described by Baker et al. (1949), Bartholomai (1954), and Conrad (1959). Whitcomb and Bell (1964) reported *C. maculata* as the commonest coccinellid in Arkansas cotton fields, where it is an important predator on eggs of the bollworm, *Heliothis zea* (Boddie). Hagen (1962) included a review of information relating to the behavior of *C. maculata*. Szumkowski (1952b), Smith (1960), and Atallah and Newsom (1966) reared *C. maculata* on artificial media with varying degrees of success.

It was necessary to rear *C. maculata* on both artificial and natural diets during the investigations reported here. The techniques of Szumkowski (1952b) were used as a base.

REARING.—*Methods*.—Adults of *C. maculata* for establishing laboratory studies were collected from overwintering aggregations at the bases of pecan trees near Fayetteville, Arkansas. Approximately 300 adults

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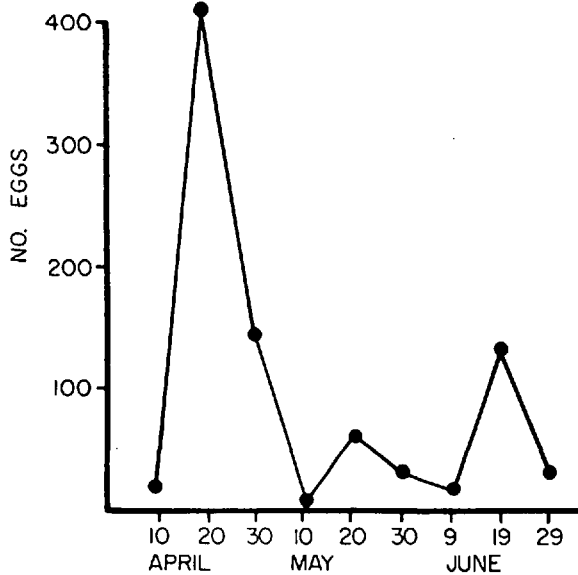


FIG. 1.—Amount and period of oviposition by 20 overwintered *C. maculata* females at 26.7°C.

were collected March 8, 1966, and transferred to stock cages (plastic boxes $5\frac{1}{2} \times 5 \times 1\frac{1}{2}$ in.). The adults were provided small pieces of pork liver for food, to which 1 or 2 drops of a liquid vitamin mixture (Deca-Vi-Sol) had been added. A few blades of grass to serve for resting sites were placed in each cage. The bottom of each cage was lined with paper toweling to which a few drops of water were added as needed. For most of the study period the cages were held in a temperature cabinet at 26.7°C. The RH in the cages was about 90%. The food was replaced every 2 days.

Newly hatched larvae were offered other diets including those developed for the bollworm (Berger 1963), the boll weevil, *Anthonomus grandis* Boheman (Vanderzant et al. 1959), and eggs of their own species. The rate of survival on the bollworm diet was low, while none survived on the boll weevil medium. Eggs of their own species were readily accepted as food and larval development was normal.

The stock cages were observed daily. When adults were observed in copulation, the mating pair was removed and placed in an individual plastic cage as previously described. Twenty pairs were thus established for observation and oviposition records.

Because of the cannibalistic nature of adults and larvae, the eggs and larvae were isolated singly in 2-in.-diam. plastic petri dishes, the halves of which were held together by rubber bands. When the eggs hatched, the larvae were supplied with food as de-

scribed for the adults. More than 120 individuals were established in this fashion. They were observed daily to determine the duration of the various stages.

Results.—Copulation of the overwintered adults was 1st observed April 4, 26 days after collection from winter quarters. However, egg deposition began April 3. The females deposited about 10% of their eggs on the sides of the plastic boxes, 10% on the grass near the roots, and 80% on the moist paper toweling wrapped around the roots of the grass. The females appeared to prefer a moist situation in which to oviposit (Hodson 1937). From 20 ♀ under observation, 847 eggs were obtained; 3 ♀ did not oviposit. The number of eggs per ovipositing female ranged from 10 to 226, and averaged 49.8.

The rate of oviposition from the overwintered females was greatest during the 3 weeks following initial deposition, tapering off to termination on June 25 (Fig. 1). Following collection from winter quarters on March 8, and exposure to a constant temperature of 26.7°C and 10 hr of darkness alternating with 14 hr of light provided by four 20-w fluorescent lamps, the overwintered females lived an average of 61.9 days, ranging from 4 to 139.

Duration of Egg Stage.—Under the described conditions, embryonal development lasted from 1 to 6 days, averaging 2.8 (Fig. 3 a). Toward the latter stages of development the embryo could be readily discerned through the transparent chorion.

Larval Development.—When embryonal development is complete, the young larvae chews an exit hole through the chorion and leaves it. It is greenish with black hairs and pigmented spots. Young larvae often remain in the immediate vicinity of the original egg mass and will feed on unhatched eggs as well as on the chorion of recently hatched eggs. They may also attack their siblings.

C. maculata has 4 larval instars (Fig. 2), although under laboratory conditions some larvae may have 5 instars. Under the conditions of these experiments, during which the larvae were reared on liver, 50% (16 of 32) survived. The total developmental period when reared on liver averaged 20.6 days, ranging from 11 to 22 (Table 1). The duration of stages, based on percentage values, is shown graphically in Fig. 3, b-f.

The Pupal Stage.—When ready to pupate, the larvae attached themselves, typically, by the tip of the abdomen to the wall of the petri dish. At 26.7°C, the pupal period ranged from 2 to 6 days, averaging 4.0 (Fig. 3f). Soon after eclosion the adults began to forage for food.

C. MACULATA AS A PREDATOR OF FALL WEBWORM.—To our knowledge, *C. maculata* has not previously been recorded as a predator of the fall webworm. The eggs of the fall webworm are covered with hair scales which would provide some protection against attack by predators or parasites. Szumkowski (1952a)

Table 1.—Comparison of the rate of development of *C. maculata* when reared on 2 different diets at 26.7° C.

Diet	Avg duration (days) of each larval instar ^a					Pupal period	Total (avg)
	1	2	3	4	5		
Pork liver	2.7 (32)	2.9 (32)	4.0 (25)	5.6 (16)	8.0 (3)	4.0 (16)	20.6
<i>H. cunea</i> eggs	3.4 (16)	2.4 (16)	3.2 (16)	5.3 (16)	3.0 (1)	3.8 (16)	18.2

^a Numbers in parentheses are numbers of larvae reared for each instar.

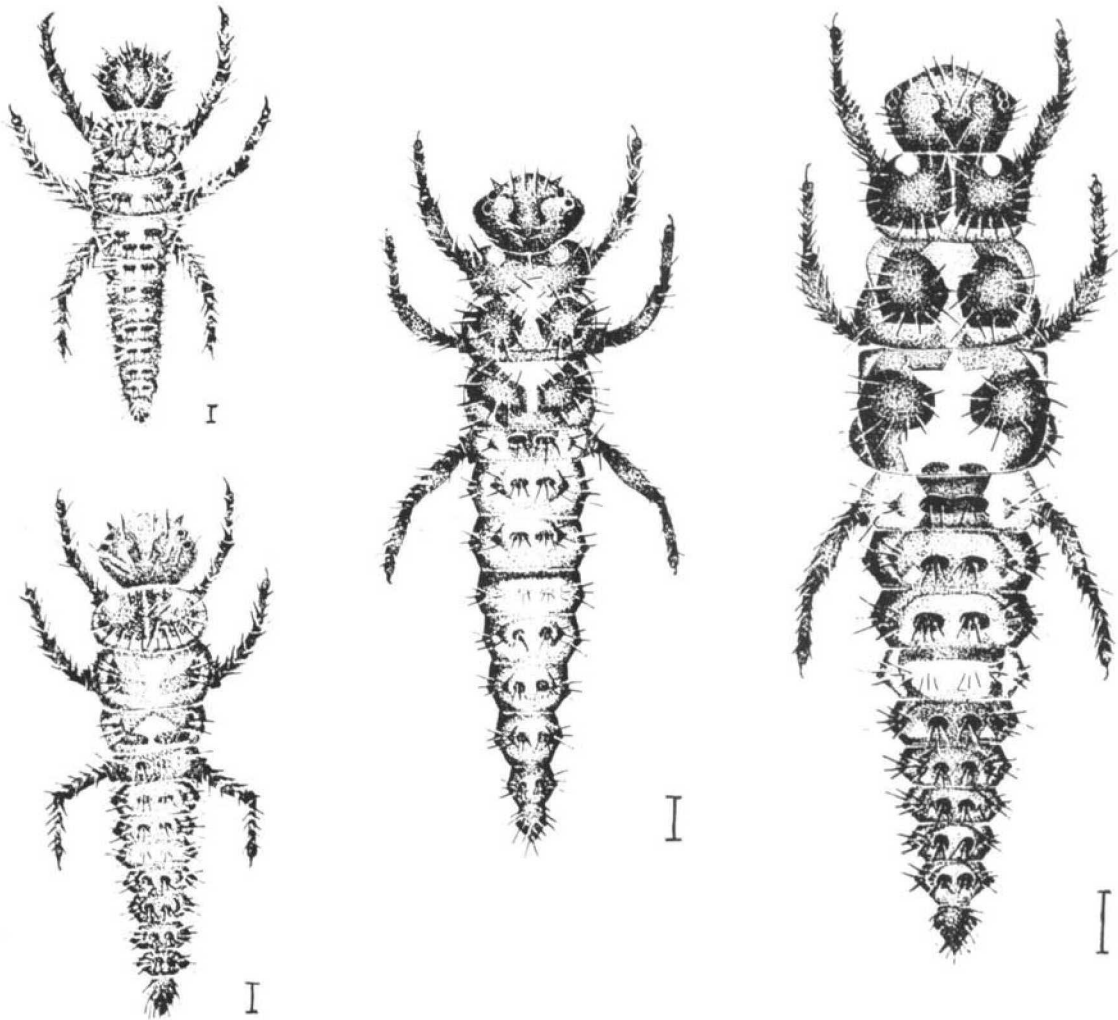


FIG. 2.—Comparative size of the 4 larval stages of *C. maculata*.

reported that *C. maculata* attacked the eggs of the fall armyworm, *Spodoptera frugiperda* (J. E. Smith), which are normally covered with hairy scales. The hairy egg masses were rarely completely eaten and then only by adult beetles.

During our observations, many egg masses of the fall webworm were found which had been partially destroyed, and sometimes evidences of egg masses were observed from which the eggs had been completely devoured or destroyed. Both laboratory and field investigations were conducted in the summer of 1966 at Fayetteville to investigate further the response of *C. maculata* to eggs and larvae of the fall webworm as food.

Egg masses of the fall webworm were collected in the field and provided to the newly hatched larvae in groups of 50. These were readily accepted as food by the newly hatched *C. maculata* larvae. It should be noted that in separating and counting the eggs many of the hairy scales were removed.

Sixteen larvae were fed fall webworm eggs as needed. All pupated and became adults. Each larvae consumed 200–400 eggs during development and averaged 272 eggs/larva.

Except for the 1st instar, the rate of development of *C. maculata* was more rapid on fall webworm eggs than when reared on liver (Table 1).

Newly hatched larvae of the fall webworm were not acceptable as food to the larvae of *C. maculata*. In no instance did the larvae survive when offered newly hatched or immobilized 2nd-instar larvae. Under cage conditions, adult *C. maculata* fed on fall webworm larvae.

FIELD OBSERVATIONS.—Cornfields are a favorable habitat for *C. maculata* because of the presence of lepidopterous eggs, aphids, and pollen (Conrad 1959, Bartholomai 1954). In European countries, corn is often planted in fields adjacent to roadways lined with trees, frequently *Morus* sp., which fact suggests the possibility of *C. maculata* migrating from corn to other plants in search of food. This possibility was explored at the University Farm, Fayetteville.

On July 8, 1966, 24 egg clusters of fall webworm were fastened with pins to the leaves of elm trees adjacent to a cornfield where *C. maculata* was present. Egg clusters were placed also on leaves of the corn plants. The egg clusters were observed twice a day until July 28. Nearly every day adults of *C. maculata*

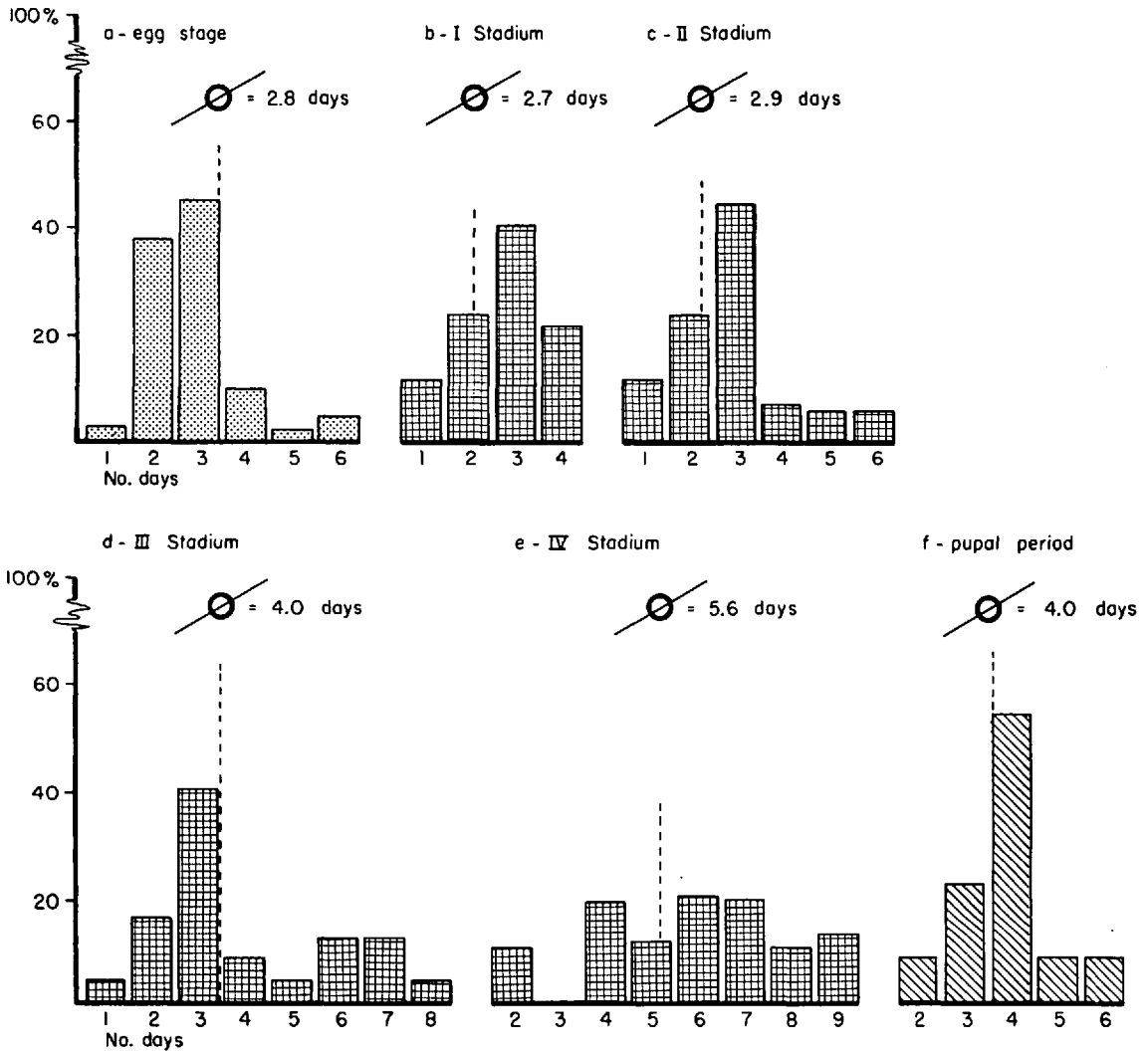


FIG. 3.—Rate of development of *C. maculata* from egg to adult at 26.7°C. (Expressed in percentage values for each stage.)

were observed feeding on the eggs of the fall webworm placed on both the elm trees and corn plants. Only 1 egg cluster survived this predation to hatch and form a larval colony. An adult *C. maculata* was observed feeding on eggs of the fall webworm on walnut foliage. Egg masses on which *C. maculata* fed resembled partially destroyed masses observed under field conditions. Thus it is concluded that under favorable ecological conditions *C. maculata* can be a very active predator of fall webworm. The presence of corn and related crops on which *C. maculata* for-

ages favors predation on fall webworm in the immediate vicinity.

When offered *C. maculata* eggs, newly hatched *C. maculata* larvae fed readily and developed normally. If the larvae were partially starved, the period of development was lengthened, although the total number of eggs consumed was similar (Table 2). The rate of development was not markedly different until the last larval instar. Partially starved larvae required almost twice as many days to complete the 4th stadium as fully fed larvae.

Table 2.—Rate of development of *C. maculata* larvae when reared on *C. maculata* eggs at 2 levels of availability.

Availability of food	No. larvae	Avg. no. days in instar				Pupal period	Avg. no. days to adult	Total eggs consumed
		1	2	3	4			
Ample food	10	3.0	2.0	3.7	8.5	3.9	21.1	76.3
Partially starved	8	3.5	1.9	2.9	13.1	3.4	24.8	72.1

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Toxicity of Insecticides to House Crickets and Bioassay of Treated Soils in the Laboratory¹

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ABSTRACT

The house cricket, *Acheta domesticus* (L.), proved to be a valuable and satisfactory bioassay test insect for these studies. After determining insecticide sensitivity through topical applications, crickets were used to determine bioactivity of insecticides in soils. Technical aldrin, diazinon, heptachlor, Niran® (stabilized ethyl parathion), and phorate were applied to Onawa silty clay, Sarpy loamy sand, Seymore silt loam, Marion silt loam (profile A), and

Marion silty clay (profile B), each at 2 moisture levels.

Biological response of insecticides varied from soil type to soil type, and from low to high moisture. Treated sandy soils showed higher initial mortality than most other soil types but resulted in shorter residual activity. Moisture level of the soil and the nature of the insecticide were of utmost importance within a soil type. Increased moisture generally resulted in increased mortality.

An important factor in any biological assay or screening study is the proper understanding and adjustment of percent control or response, as indicated by Abbott (1925). Preliminary studies by Edwards et al. (1957) indicated the value of bioassay as a tool in the study of soil insecticides. Chemical assays of soil insecticides cannot be complete in themselves, but require the additional information about residual toxicity which is provided by bioassay. The direct soil method of bioassay provides quantitative data of the relative degree of insecticide adsorption by different soils. This result could have practical application, since it is certain that the soil type should be taken into account before an insecticide is applied in the field.

Various test insects have been used to evaluate the

bioactivity of insecticides in soil (Lange and Carlson 1955, Wylie 1956, Young and Rawlins 1958, Lichtenstein and Schulz 1959, Mulla 1960, Harris and Mazurek 1964, Whitney 1967).

MATERIALS AND METHODS.—House crickets, *Acheta domesticus* (L.), were used as the bioassay test insects to evaluate bioactivity of insecticides in soil. Large numbers were mass reared for purposes of these studies.

Topical Applications.—To establish sensitivity levels or standard indices for each insecticide, topical applications were made with all insecticides used in the study. Upon reaching test age, 28 days for topical applications, a representative number of crickets were weighed to the nearest milligram on a torsion-type microbalance.

The insecticides used were aldrin, carbaryl, chlordane, diazinon, disulfoton, heptachlor, methyl parathion, Niran® (one of several available formulations of stabilized ethyl parathion), parathion, and phorate. The chemical names of compounds used but not identified by approved common names are:

Baygon®—*o*-isopropoxyphenyl methylcarbamate

Bomyl®—dimethyl 3-hydroxyglutaconate dimethyl phosphate

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