Insect Predators for Controlling Aphids[1] on Potatoes. 8. Green Peach Aphid Consumption by *Coccinella septempunctata* and *C. transversoguttata*[2]

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ABSTRACT

When offered increasing numbers daily, pairs of adults of *Coccinella septempunctata* L. containing nondiapausing females consumed the largest percentage of green peach aphids, *Myzus persicae* (Sulzer), when the number offered was 170 or 200, as compared with 154 or 174 for those containing diapausing females. As the number of aphids per beetle introduced daily was increased from 58 to 115, the estimated daily consumption of nondiapausing females increased from 56 to 99, whereas that of diapausing females increased from 50 to 87. Daily aphid consumption by nondiapausing females was greater when they were fed aphids only or aphids daily along with a liquid food supplement every 4th day than when fed aphids daily plus the liquid supplement every 2nd day. Under similar conditions, daily aphid consumption by diapausing females was increased by including the liquid food supplement in the diet, whether offered every 4th or every 2nd day.

The larvae of *C. septempunctata* consumed from 619 to 750 green peach aphids (of all sizes), on average, between hatching and pupation, depending on time of year. The comparable range in numbers for *C. transversoguttata* Faldermann was 699 to 756. Differences between coccinellid species in numbers of aphids eaten per larva were not significant ($P=0.05$).

Managed populations of coccinellids through supplemental introduction of adults, eggs, or larvae of *Coccinella septempunctata* L. have proved of value for suppressing population growth of the bean aphid, *Aphis fabae* Scopoli, on sugarbeets in large field cages (I. Hodek, personal communication; Hodek et al. 1965a, b), of the potato aphid, *Macrosiphum euphorbiae* (Thomas), and the green peach aphid, *Myzus persicae* (Sulzer), on potatoes in large field cages and in plots (Shands et al. 1972a, b, c; Shands and Simpson 1972a, b), and of the cotton aphid, *Aphis gossypii* Glover, on cucumbers in the greenhouse (Gurney and Hussey 1970).

Effectiveness of coccinellids for controlling aphids depends basically upon their voracity and the number, timing, and duration of their generations in relation to the dynamics and seasonal trends of the aphid populations. Sundby (1966) found that the minimum number of aphids required by developing larvae of *C. septempunctata* is considerably smaller than the number actually consumed. Thus, voracity in this predator involves the numbers of aphids eaten as a minimum requirement for development, plus any consumed additionally.

Much variability was found in the numbers of aphids consumed by larval and adult stages of several species of coccinellids (Blackman 1967; Clausen 1940; Cutright 1924; Dunn 1952; Ellingsen 1969; Gurney and Hussey 1970; Hagen and Sluss 1965; Hodek 1957a, b; Iperti 1965; Sundby 1966; Szumkowski 1955; Wadley 1931). The number of aphids consumed by *C. septempunctata* during larval development varied between 100 and 1930 (Hodek 1957a). At constant 21±3°C, the average number of *M. persicae* consumed by the larvae was 173±14 (Gurney and Hussey 1970) whereas at 25°C it was 240 (Iperti 1965).

Abiotic factors such as temperature may have had little effect upon the observed variability in aphid consumption by larval coccinellids. Clausen (1940) reported that the number eaten was roughly proportional to their size, but Iperti (1965) found little difference in numbers of aphids consumed by developing larvae of 5 species of coccinellids, including *C. septempunctata*, when reared at 16°C or 25°C. Hodek (1957a) reported similar results with *C. septempunctata*, but under conditions of alternating warm and cool temperatures, the daily consumption of aphids was doubled. The factor probably influencing most of the observed variability in consumption of *M. persicae* by developing larvae of *C. septempunctata* was the size of the aphids used as food. Iperti (1965) fed 1st- and 2nd-stage aphids to 1st- and 2nd-stage beetle larvae, and later 3rd- and 4th-stage aphids to 3rd- and 4th-stage beetle larvae. Gurney and Hussey (1970) fed apterous adults to 1st instars, and apterous adults and large nymphs to later instars.

The numbers of aphids consumed daily by coccinellid adults is influenced by several factors including species and sex of the beetle and density of the prey (Cutright 1924, Wadley 1931, Hodek 1957b). In most instances, males ate 50–80% as many as did females, but much variability was observed. Hodek (1957b) stated that aphid consumption was greatest in ovipositing females, less in nonovipositing females, and least in males. Our observations tend to confirm this for *C. septempunctata*, but variability in daily consumption of green peach aphids by adults is so great and is affected to such an extent by other factors that numerical differences in daily aphid consumption among beetles of these categories cannot be indicated with certainty.

The feeding rate of adults as well as that of larvae of *C. septempunctata* was influenced by temperature (Dunn 1952, Hodek 1957b). The effectiveness of introduced adults of this predator in holding down abundance of the bean aphid on sugarbeets in large field cages was considered as being influenced by climatic factors, especially temperature (Hodek et al. 1965a, b). In a cool season, the aphid was controlled satisfactorily when at the time of introduction up to 70 aphids/beetle were on the plants, whereas in a hot season, control was excellent when at the time of introduction 200 aphids/beetle were on the plants.

The results reported herein are from studies conducted at Presque Isle, Maine, in which we at-

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tempted to determine daily consumption of green peach aphids by adult beetles and developing larvae of *C. septempunctata* and *C. transversoguttata* Falderman under controlled conditions of temperature and light and in the presence or absence of a liquid food supplement.

METHODS AND MATERIALS.—*Food Consumption by Adults.*—Specimens of *C. septempunctata* were reared to maturity on green peach aphids under a photoperiod of 18 hr/day of fluorescent light in a growth chamber held at 22±1.1°C. At emergence, between Feb. 1 and 6, 1967, adults were sexed, and 30 of each sex were paired and placed by pairs in cages. The cages basically were ½-pint pasteboard ice cream cartons (Shands et al. 1970). Cages were placed on a glasshouse bench on Feb. 6 and kept out of direct sunlight by a canopy of tobacco-plant-bed cloth (28×32 strands/in.^{2}) which was stretched over a wooden frame 2 ft above. The temperature at bench height was maintained at 22±1.8°C except for short periods around midday on clear days, when it rose as high as 26.7°C.

Ten of 30 caged pairs of beetles were assigned randomly to each of 3 specific diets or food categories. From emergence until Mar. 31, 1967, beetles in each of these 3 food categories were subjected to their respective diets except for the number of aphids fed daily during the test. A surplus of aphids was introduced daily into each cage before and after the test period, which was Feb. 13–23.

The 3 categories of food were aphids fed daily only, aphids fed daily + a liquid food supplement (Shands et al. 1970) supplied every 2nd day, and aphids fed daily + the food supplement every 4th day. The food supplement was made up of 4 g protein hydrolysate, 0.4 g dried bees' pollen, 5 ml bees' honey, in 45 ml of water. The same increasing numbers of aphids of all sizes were introduced in all cages during the 10-day test period beginning at ca. 115/cage and gradually increasing to 230.

Since this experiment was not so much concerned with beetle nutrition as such but rather with an attempt to learn how to rear large numbers of beetles, no effort was made to weigh the aphids fed or to segregate them into size classes. The important statistics for rearing beetles involve the number of aphids on the host plant and the proportion that a beetle or its larva will consume.

Food supplement was freshly prepared prior to each feeding. Balls of absorbent cotton ca. 0.8-cm diam were soaked in this liquid, then placed 1/cage on small squares of waxed paper on the floors of the cages. Old cotton balls were discarded and replaced with freshly soaked balls at the end of 48 or 96 hr in cages of these 2 food categories.

The green peach aphids fed daily in all cages were reared in the glasshouse insectary on radish, *Raphanus sativus* L.; Chinese cabbage, *Brassica chinensis* L., or collard, *B. oleraceae* L. var. *acephala* De Candole. Infested leaves were cut into sections, and each held the approximate number of aphids needed for 1 cage. After the aphids on a leaf section (ca. 25–50 cm^2) were counted and recorded, the leaf section was placed dorsal side up in a cage. Fresh leaf sections were introduced at about the same time every day. At that time, the old leaf section and any living aphids on it or anywhere in the cage were removed and counted. The number of aphids consumed by the beetles in a cage was considered to be the number introduced minus the number recovered 24 hr later.

Aphid Consumption by Larvae.—At hatching, the larvae of *C. septempunctata* or *C. transversoguttata* were placed singly with an artist's brush in 78-cm diam plastic petri dishes. Each dish contained a 1- to 2-cm^2 piece of moisture-absorbent paper which was moistened daily with a drop of water, and a 10- to 25-cm^2 section of a collard leaf infested with green peach aphids which had developed on this plant in the insectary. A fresh leaf section, holding a definite counted number of aphids known to be in excess of that required as food by the coccinellid larva, was introduced in each petri dish at about the same time each day. Simultaneously, the old leaf section and all living aphids remaining in the dish were removed and counted. The number of aphids consumed by a coccinellid larva was considered to be the number introduced minus the number remaining 24 hr later. Only apterous adults of the aphid were supplied the coccinellid larvae during the 1st stadium; thereafter, leaf sections held the naturally occurring colonies containing all aphid instars. Young collard plants were utilized for producing the aphids fed to developing larvae, and the size of the aphids in these vigorous colonies for this species was average or above average in all stages. All the coccinellid larvae were reared under a photoperiod of 18 hr of fluorescent light in 1967 or 16 hr in 1969 in a growth chamber held at 22±1.1°C.

RESULTS AND DISCUSSION.—*Food Consumption by Adults.*—Not all the females of *C. septempunctata* deposited eggs during the 10-day test, although the start of it was delayed until after the duration of the normal preoviposition period of nondiapausing females had passed. Of the 30 ♀, only 16 oviposited from the time of emergence until the end of the study on Mar. 31, and 3 of these deposited only 1 cluster of eggs each during the entire period. Nonovipositing females were considered to be in diapause; the remainder were considered to be nondiapausing females. For nondiapausing females, the averages in Table 1 are based on data for the 10-day period from 5 caged pairs of beetles that were fed aphids only daily, 4 pairs that were fed aphids daily + the food supplement every 4th day, and 7 pairs fed aphids daily + the supplement every 2nd day. Corresponding numbers for diapausing females were 5, 6, and 3, respectively.

Daily consumption of aphids by pairs containing the 2 kinds of females appeared to differ substantially. Numbers of aphids and percentages of introduced aphids eaten by diapausing females and associated males generally appeared to be somewhat smaller and more erratic on a day-to-day basis than was the case with nondiapausing females and their associated males. To assess this hypothesis, aphid-consumption records for pairs of beetles were separated on the basis of the kind of female in each, and an attempt was made to approximate the numbers of aphids eaten daily by nondiapausing and by diapausing females. Since consumption of no definite proportion of the aphids eaten daily by pairs could be attributed to the males, we assumed that male and female beetles ate approximately equal numbers of the aphids introduced in cages containing nondiapausing females. (Estimates resulting from this assumption minimize rather than increase any difference in daily aphid consumption between the 2 kinds of females.) Thus, the number eaten by diapausing females was the total number consumed in cages containing the diapausing females minus the number eaten by males in cages containing the nondiapausing females. Approximately the same number of aphids was introduced in cages having diapausing as nondiapausing females. We did not attempt to make a similar adjustment for percent of aphids consumed. This comparison was based on numbers of aphids introduced and remaining at the end of each day in cages having the 2 kinds of females. There was no evidence of diapause in any of the males; all had been reared and kept throughout the experiment under conditions which did not favor the likelihood of diapause.

Analysis of variance was made of daily aphid consumption by pairs of beetles and by the females only, including numbers and transformed angles of the percentages of aphids offered that were eaten (Table 1). For nondiapausing females, the numbers of aphids eaten and the percent of those offered that were consumed were smaller when the diet included the food supplement every 2nd day than when only aphids were offered daily or when the diet was aphids + the supplement every 4th day. In contrast, for diapausing females, the food supplement increased aphid consumption but did not affect significantly ($P=0.05$) the percent of aphids offered that were eaten. The increase in numbers of aphids eaten did not differ at the 5% level, whether the supplement was offered every 2nd day or every 4th day.

When all diets were combined, the average number of green peach aphids eaten daily by nondiapausing females increased from 56 to 99 each as the number made avilable to them increased from 58 to 100 (Table 1). The decrease in daily consumption from 99 to 94 aphids/female as the number made available increased from 100 to 115 was not significant at the 5% level. In contrast, diapausing females, with minor exceptions, showed a rather steady increase in numbers of aphids eaten per day per female from 50 to 87 as the number of aphids introduced daily increased from 58 to 115/female. However, because of erratic variability in numbers of aphids eaten from day to day, differences in the increasing average numbers eaten daily when the number introduced daily increased from 69 to 115 were not significant at the 5% level.

There was general similarity between pairs of beetles containing nondiapausing or diapausing females as to the percentage eaten of the numbers of aphids introduced daily; virtually all were eaten when 170 aphids/cage were introduced (Table 1). The percentages eaten did not differ at the 5% level when 200 or 154 aphids were introduced in cages having pairs of beetles with nondiapausing or diapausing females, respectively. The percentages eaten decreased with increasing or decreasing numbers of introduced aphids above or below these numbers for pairs having either kind of female. However, the amount and rate of decrease were greater for pairs with diapausing females than for those with nondiapausing females. Probably there is a difference in searching ability between the 2 kinds of females, but it could not be separated from that of the males in the pairs or from differences between the two kinds of females in daily aphid consumption requirements.

Aphid Consumption by Larvae.—The average total

Table 1.—Average consumption of green peach aphids by adults of *C. septempunctata* caged as pairs and offered variable food sources including daily increasing numbers of aphids.

Diet		Nondiapausing females		Diapausing females	
		Avg no./female eaten daily	Reconverted % eaten of no. introduced daily[a]	Avg no./female eaten daily	Reconverted % eaten of no. introduced daily[a]
BY FOOD CATEGORY					
Aphids only daily		84.3 a[b]	97.5 a	65.5 b	90.1 a
Aphids daily + liquid food supplement:					
Every 4th day		82.9 a	96.0 a	78.6 a	93.1 a
Every 2nd day		76.4 b	90.5 b	77.2 a	89.0 a
BY NUMBER OF APHIDS INTRODUCED					
Day no.	Avg no. introduced aphids/cage				
1	116	56.3 e	96.8 c	50.3 c	91.2 cde
2	127	59.3 de	94.5 cde	60.0 bc	94.0 bc
3	138	65.0 d	95.8 cd	65.7 ab	93.8 bcd
4	154	75.3 c	98.8 b	78.7 ab	98.4 ab
5	170	84.7 b	100.0 a[c]	85.3 ab	100.0 a
6	185	84.3 b	91.4 ef	75.3 ab	87.0 def
7	200	99.3 a	99.8 ab	73.3 ab	87.0 def
8	215	96.3 a	90.0 f	77.7 ab	80.9 ef
9	230	97.7 a	85.8 g	84.3 ab	79.5 f
10	230	93.7 a	82.4 g	87.0 a	78.8 f

[a] The data are for pairs of beetles rather than for females only.
[b] Numbers followed by the same letter, vertically in each section of the table, do not differ significantly ($P=0.05$) by Duncan's multiple range test.
[c] 99.99%.

Table 2.—Daily consumption of apterous green peach aphids by larvae of *C. septempunctata* or *C. transversoguttata* in a growth chamber.

Days after hatching	Avg no. consumed by indicated species[a]				
	C. septempunctata			*C. transversoguttata*	
	1967	1969		1969	
	July 10–22	Aug. 11–22	Aug. 20–Sept. 1	Aug. 11–22	Aug. 20–Sept. 1
1st instar					
1	0.6	1.5	0.7	0.8	0.6
2	2.3	3.8	2.7	3.1	2.6
3	3.5	4.7	3.3	5.4	4.0
2nd instar					
4	5.9	5.5	7.1	7.1	6.0
5	10.0	10.3	20.6	9.1	20.6
3rd instar					
6	43.7	44.5	22.7	41.6	18.3
7	79.1	67.4	47.9	73.9	42.8
4th instar					
8	92.8	90.1	93.7	92.6	88.8
9	140.2	141.4	108.7	143.3	150.8
10	155.8	162.8	160.1	173.3	163.0
11[b]	216.1	204.6	151.1	204.6	201.6
Total	750.0	736.6	618.7	756.0	698.8

[a] Avg in columns 2, 3, 4, 5, and 6 are based on feeding records from 10, 10, 10, 7, and 8 specimens, respectively.
[b] A few of the larvae required part of the 12th day to complete development. In such instances, the numbers of aphids consumed on the 11th and 12th days were added and are shown as being for the 11th day.

numbers of green peach aphids consumed by larvae of *C. septempunctata* during development ranged from 619 to 750 each, depending upon the time the tests were made (Table 2). For larvae of *C. transversoguttata*, the corresponding range was 699–756. Because of the relatively few specimens and the variability among specimens, differences were not significant at the 5% level between the average numbers of aphids consumed by larvae of *C. septempunctata* in the 1967 test and in that carried out Aug. 11–22, 1969. Neither were there significant (P=0.05) differences among averages from the 4 tests conducted in 1969, although more aphids were consumed by larvae of *C. transversoguttata* than by those of *C. septempunctata*. For both species, more aphids were consumed in 1969 by larvae developing during the period Aug. 11–22 than from Aug. 20 to Sept. 1. Observations showed that there was greater variability among specimens in aphid consumption by larvae of both species developing during the tests that were started Aug. 20 than in those begun Aug. 11. We did not determine whether there was any relationship between aphid consumption of larvae and diapause in the resulting adults.

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Insect Predators[1] for Controlling Aphids[2] on Potatoes. 9. Winter Survival of *Coccinella* Species in Field Cages Over Grassland in Northeastern Maine[3]

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ABSTRACT

Over a 5-year period at Presque Isle, Maine, winter survival of *Coccinella septempunctata* L. in cages over undisturbed grassland averaged from 6.3 to 79.5% and probably depended upon age and condition of the beetles when placed in the cages. Minimum winter temperatures and precipitation did not appear to influence winter survival. In a similar test, 19% of the beetles survived a 2nd winter in the cages. Winter survival for 3 native species was 76.9 and 19.4% during 2 winters for the transverse lady beetle, *C. transversoguttata* Faldermann; 0.5% during 1 winter for the thirteenspotted lady beetle, *Hippodamia tredecimpunctata tibialis* (Say); and 0% during 1 winter for the convergent lady beetle, *H. convergens* Guérin-Méneville. There are no data to suggest that *C. septempunctata* has become established at Presque Isle following 5 years of release of eggs and larvae in experimental plantings of potatoes.

In 1964, studies were begun at Presque Isle, Maine, to determine the feasibility of supplementing naturally occurring populations of arthropod predators in potato fields to obtain control of aphids on potatoes. One of the insect predators under investigation since the outset, not native to the area, was a lady beetle, *Coccinella septempunctata* L. The breeding stock used in our studies was imported from the vicinity of Paris, France, by the Entomology Research Division, Agric. Res. Serv., USDA. We continually have maintained and mass produced populations of this beetle at the Presque Isle laboratory since receiving an initial shipment from the Entomology Research Division laboratory at Moorestown, N. J. From the outset, studies were made to determine how well the beetle can withstand the rigorous Maine winters, although its success or failure for supplementing the natural agents in controlling aphids on potatoes in northeastern Maine is not dependent upon its establishment in the new environment. Reported herein are results of the study during the period 1964–69 with results from similar, but less extensive, tests with the native transverse lady beetle, *Coccinella transversoguttata* Faldermann; thirteenspotted lady beetle, *Hippodamia tredecimpunctata tibialis* (Say); and convergent lady beetle *Hippodamia convergens* Guérin-Méneville. Since 1941, *H. convergens* has occurred in trace numbers and only occasionally in Aroostook County, Maine, except in 1965 and 1966 when it was one of the 3 most common coccinellids on potatoes at Presque Isle.

Grassland is one of the more important overwintering environments of *C. septempunctata* in Central Asia (Savoiskaya 1965), whereas in Middle- and East-Europe it is typically found in cultivated areas (Hodek 1960).

METHODS AND MATERIALS.—The hibernation cages were 76×61×76 cm high. The wooden frames were covered with a combination of copper screening with 24 strands/cm and clear-plastic film on the sides and on top with two 20-cm strips of copper screen with a 20-cm strip of cotton ducking between, which was fitted with a zippered slit opening. The cages were placed in well-drained grassland. The 23-cm wooden baseboard siding around the bottom of the cage was sunk into the soil 10–12 cm after removing a strip of sod and soil ca. 5 cm wide. Soil was packed around the inside and outside of the baseboard to ground level to prevent escape of the beetles. Practically all snow was excluded except for small amounts blown through the fine screening on the side of the cages during driving snowstorms.

The beetles were reared during the summer in an insectary in field cages covered with Saran® screen with 13 strands/cm or in plastic-covered greenhouses in which potato plants were growing, or they were collected from potato fields in September. They were fed one or more species of the potato-infesting aphids, including the green peach aphid, *Myzus persicae* (Sulzer); the potato aphid, *Macrosiphum euphorbiae* (Thomas); the buckthorn aphid, *Aphis*

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