Stage-Specific Mortality of *Coleomegilla maculata lengi* Timberlake[1] on Corn in Southern Ontario[2]

E. JANE WRIGHT[3] AND J. E. LAING
Department of Environmental Biology, University of Guelph, Guelph, Ontario, Canada N1G 2W1

ABSTRACT

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Factors affecting the mortality of *Coleomegilla maculata lengi* Timberlake were investigated at Guelph, Ontario from 1976 through 1978. It was found that most of the overwintering mortality of caged beetles occurred at the end of the winter. Parasitism by *Perilitus coccinellae* Shrank reduced survivorship of overwintering beetles. There was no significant difference found in overwintering mortality of beetles caged at three different densities. Predation of eggs of *C. m. lengi* was 44.8 and 48.6% in 1976 and 1977, respectively. Stage-specific mortality for the coccinellids of the first generation in corn (primarily *C. m. lengi*) at Guelph calculated for the period from egg to pupa was 93.8% in 1977. In 1978, mortality from egg to pupa of *C. m. lengi* was 95.4%. *C. m. lengi* displays a type IV survivorship curve of Slobodkin.

Coleomegilla maculata lengi Timberlake is a polyphagous coccinellid commonly found in southern Ontario corn fields. It overwinters in large aggregations in leaf litter in protected places such as fencerows and the edges of wooded areas. In spring the adults disperse to summer habitats where they undergo two generations. *Perilitus coccinellae* Shrank, a braconid parasite of *C. m. lengi* adults, has four or five generations per year and overwinters as a larva or an egg within the host (Wright and Laing 1979).

C. m. lengi is an abundant predator of the corn leaf aphid, *Rhopalosiphum maidis* (Fitch). This aphid can reach damaging populations in some years, and it appears that the coccinellids are incapable of controlling these outbreaks (Foott and Timmins 1973, Foott 1975). Therefore, a study was initiated to investigate the population dynamics of coccinellids on corn and their relationship to the aphid populations. The numerical response of *C. m. lengi* and a second coccinellid, *Hippodamia tredecimpunctata tibialis* (Say), to aphid populations have been reported by Wright and Laing (1980).This paper reports on various mortality factors acting on the populations of *C. m. lengi* on corn at Guelph, Ontario.

Materials and Methods

Overwintering Mortality

The success of overwintering of adults of *C. m. lengi* will greatly influence the size of the first generation of the next year. The following experiment was designed to determine if: (1) aggregation improves survival, (2) females mate before overwintering, (3) parasitism predisposes the adults to overwintering mortality, and (4) there is differential overwintering mortality between the sexes.

Adults of *C. m. lengi* were collected in November 1977 from an overwintering aggregation beside an abandoned house next to the field containing the population study plots (Wright and Laing 1980). To minimize temperature fluctuations that could affect the overwintering state of the beetles, they were stored at 4° C for the few days between their collection from and replacement into the field. A total of 10,200 beetles were removed from the leaf litter, counted, and placed into cages as follows: 8 cages with 25 beetles, 24 cages with 250, and 8 cages with 500. The cage used was the cylindrical bivalve cage with plywood ends and fine screening around the circumference (25 cm long by 13.5 cm in diameter) described by Wilde (1951). The cage was opened on its side, the lower screened portion filled to about 2 cm from the top with soil from the aggregation site. The same leaf litter from which the beetles had been removed was then placed on top of the soil, the beetles were added, and the cage was closed and latched. Half of the cages at each density were placed in each of two sites. The first site was along the foundation of the house where the beetles had been collected, and the second was under an apple tree in an orchard next to the field containing the population study plots, where other beetles were found to be overwintering. The cages were set into the soil so that the soil level inside and outside the cage was even. Leaf litter was placed up against each cage so that it was as continuous as possible inside and outside of the cage. The screened top portion of the cage then extended less than 6 cm above the level of the surrounding leaf litter. The cages were set about 4 cm apart in a row along the house foundation and in two rows in the orchard. The sites were carefully marked so that individual cages could be easily located under the snow for removal without affecting the other cages.

Two cages (density = 250 beetles) from each site were collected at the end of the first week of each month, January to April 1978. In May, all of the remaining cages were collected. During the winter the snow was dug away from the desired cages, and they were removed from the soil by using a hammer and brick chisel. After the cages were removed, the

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[1] Coleoptera: Coccinellidae.

[2] Received for publication 9 September 1980.

[3] Present address: Division of Biological Control, University of California, Berkeley, 1050 San Pablo Ave., Albany, CA 94706.

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snow was replaced to minimize changes in the microclimate. These cages were then stored at 4° C until the contents thawed. The leaf litter was checked carefully, and the soil was sifted to remove all dead beetles. Since many dead beetles broke apart, the numbers of right and left elytra were counted, and the number of dead beetles was defined as the greater of the two.

The surviving beetles were held at ca. 7° C, which is below the developmental threshold of the beetle or its parasite (Wright and Laing 1979). At least 40 surviving beetles per cage were chosen randomly and dissected to determine the incidence of parasitism, the sex ratio, and the proportion of the females that had mated.

Overwintering mortality was analyzed by using the Kruskal-Wallis one-way ANOVA (analysis of variance) by ranks (Siegel 1956) rather than parametric ANOVA because of the possible nonindependence of the mortalities within each cage. Incidence of parasitism through the winter was analyzed by using the chi-square test.

Summer Parasitism

The incidence of parasitism of *C. m. lengi* by *P. coccinellae* was studied in a 15-ha field of corn at the Guelph Research Station in 1977 and 1978. At least 600 plants were chosen randomly and checked twice a week for populations of coccinellids and aphids. All cocoons of *P. coccinellae* observed on these plants were returned to the laboratory and held for emergence of the parasites or hyperparasites.

Egg and Pupal Predation

To estimate the effect of predation on the eggs and pupae within the 15-ha corn field, individual egg clusters and pupae were observed after oviposition or pupation to successful maturation or death. At the start of the observation period, the areas around the existing egg clusters and pupae were marked with a felt pen on randomly selected plants. The plants were checked daily thereafter, and new egg clusters or pupae that appeared were used for this experiment. In 1976, groups of plants from all parts of the field were observed for eggs from 28 July to 11 August. In 1977, 40 plants in a row in the center of the corn field were checked daily for eggs and pupae from 10 July to 17 September. It was observed that the hatching larva does not eat the chorion of the egg and that the chorion remains attached to the leaf. Predation, however, is characterized by a complete disappearance of eggs, by collapsed eggs, or more often by trace remains of uneaten portions of eggs attached to the leaf. Therefore it was possible to determine the fate of each egg by observation of the remains. The date, number of eggs, and location on the plant were recorded for each egg cluster. Each day the number of eggs that remained, had hatched, or had been destroyed was noted. The results were tested by using ANOVA and chi-square.

Stage-Specific Mortality

Since we sampled this population at intervals through time, it was possible to estimate the numbers in each stage and the stage-specific survival and mortality rates. Of the several methods for doing this (Southwood 1966, Manly 1974), we chose the graphical method of Southwood and Jepson (1962), in which the area under the population curve for each stage was measured and divided by the mean duration of that stage to give the estimate for the numbers that entered the stage. The mean duration of a stage was calculated by finding the average number of degree-days accumulated per day above the appropriate threshold (t) for that period and dividing it into the number of degree-days (K) (Wright and Laing 1979) required for the stage to give the mean developmental time. This method tends to underestimate the population if there is mortality at any time during the stage, since individuals are not present for the full developmental time. Thus, the accuracy of this method depends upon the accuracy of the estimates for the developmental time for each stage and the degree of mortality in that stage.

Before analyzing the population data collected in 1977 and 1978, the accuracy of the graphical method was tested, using the data from the predation study of 1977 where we had the stage frequency data but we also knew the actual numbers entering each stage from actual counts.

Results and Discussion

Overwintering Mortality

The site near the house was low lying, and in March and April it was covered by water during thaws. The orchard site was on a slight slope and was much drier. Both sites were covered by more than 0.5 m of snow for most of the winter, but the orchard site remained snow covered for a longer period in the spring. Six of the 40 cages disintegrated or were damaged so that the results from these cages could not be used.

When the frozen cages were returned to the laboratory it was observed that the beetles had remained within the leaf litter and had only moved down into the soil where it had cracked. They did not appear to have burrowed into the soil.

The progression of overwintering mortality for both sites is shown in Table 1. Mortality was much greater at the house site than at the orchard site—59.8% in January, reaching 100% in March when the site was flooded. At the orchard site, however, mortality in January was only 6.8% and increased gradually in February and March and then more rapidly to reach 57.1% in May. These mortality rates are much higher than the 3 to 9% overwintering mortality for *C. maculata* in New York (Benton and Crump 1979).

By May, at the orchard site, average mortality was greater in the cages with low densities (25 beetles) than in the cages with high densities (Table 1), although this difference was not significant at $P \leq 0.05$

Table 1.—Percent overwintering mortality of adult *C. maculata* caged next to a house and in an orchard at Guelph, Ontario, 1977–1978[a]

		% Mortality on (date of collection):						
						May		
Site	Cage no.	January; 250[b]	February; 250	March; 250	April; 250	25	250	500
House	1	50.0	*[c]	100	100	96.6	100.0	99.8
	2	68.1	77.5	*	100	100.0	97.9	100.0
	3	—	—	—	—	100.0	99.6	100.0
	4	—	—	—	—	100.0	100.0	99.8
	Mean	59.8	77.5	100	100	99.9	99.0	99.9
Orchard	1	9.4	16.9	6.9	23.9	100.0	34.3	35.6
	2	4.4	7.1	15.4	44.7	100.0	87.8	93.9
	3	—	—	—	—	100.0	61.8	50.3
	4	—	—	—	—	45.8	47.2	34.3
	Mean	6.8	12.0	11.1	34.3	86.2	57.1	53.6

[a] There was no significant difference among the mean mortalities for each density at $P \leq 0.05$ (Kruskal-Wallis) for either the house or orchard site.
[b] Each value following month indicates number of beetles per cage.
[c] *, Cages damaged during the winter.

(Kruskal-Wallis one-way ANOVA by ranks). Therefore it is not clear whether there was a difference in the mortality of the various densities tested and, by extrapolation, whether aggregation improves overwintering survival.

Parasitism in the surviving beetles is summarized in Table 2. The incidence of parasitism, which was not significantly different for each sex, dropped from 54.6% in March to 36.5% in April. The decrease is significant at $P \leq 0.05$, the greatest decrease occurring during March. Dissections of dead beetles in March and April showed an overall increase in the percent parasitism (Table 2). Thus, it appears that in the period from early March to early April when the first sudden increase in mortality occurred at the orchard site, parasitized individuals were more likely to die than were unparasitized ones. Parker et al. (1977) also reported a sharp reduction in incidence of parasitism through the winter in Vermont.

The percentage of overwintering females that had been mated dropped from 11.9% in February to 1.9% in April, indicating that inseminated females entering the overwintering sites suffered disproportionately high mortality. The sudden increase in the proportion of inseminated females to 13.4% in May can probably be attributed to early spring mating. Solbruck (1974) observed mating within aggregations in April in Iowa. The proportion of females in the surviving population changed slightly over the winter as well, from about 60% females during February through April to only 48% in May (Table 2).

It was also observed that very few of the extremely small beetles survived the winter. Upon dissection, their fat bodies appeared to be proportionally much

Table 2.—Number of females, percent insemination, and percent parasitism as determined by dissection of adult *C. maculata* taken from the overwintering cages in the orchard site at Guelph, Ontario, 1977–1978

Beetles	Month	Cage no.	*n*	No. of ♀♀	% of ♀♀ inseminated	% of beetles parasitized
Living	February	1	50	34	5.9	48.0
		2	50	25	20.0	56.0
		Mean	100	59	11.9a[a]	52.0a
	March	1	50	30	10.0	58.0
		2	47	31	6.5	51.1
		Mean	97	61	8.2a	54.6a
	April	1	40	22	0	30.0
		2	43	30	3.3	48.8
		Mean	83	52	1.9a	39.8b
	May	1	50	23	4.3	38.0
		2	50	20	5.0	40.0
		3	50	35	20.0	30.0
		4	50	18	22.2	38.0
		Mean	200	96	13.4a	36.5b
Dead	March	1	17	7	—	20.0
		2	22	10	—	63.2
		Mean	39	17	—	44.1
	April	1	35	17	—	62.5

[a] For living beetles, column means followed by the same letter are not significantly different at $P \leq 0.05$ (chi-square).

smaller than were those of the large beetles. Since semistarved larvae typically produce small adults in the laboratory, it is likely that these very small beetles completed their development late in the season, when aphids and other prey were very scarce and the beetles could not build up an adequate fat body to survive the winter.

Parasitism

There was a low, but relatively constant, population of pupae of *P. coccinellae* in 1977 (and therefore also dying adult *C. m. lengi*)(Fig. 1a). When this population was expressed as the proportion of the adult *C. m. lengi* population seen that day, two major periods of emergence of the larval parasites from the host were seen (Fig. 1a). The first period coincided with the beginning of the initial ovipositional period of the coccinellids on corn (ca. 7 July 1977, Wright and Laing [1980]). Thus, *P. coccinellae* effectively reduced the numerical response of *C. m. lengi* to the aphid population by removing adults from that population, just as the coccinellid oviposition period began.

Of 121 pupae of *P. coccinellae* collected from 8 July to 7 October 1977, 6 (5.0%) were parasitized by *Gelis* sp. (Hymenoptera: Ichneumonidae) and 7 (5.8%) were parasitized by *Eupteromalus* sp., possibly *viridescens* (Walsh)[4] (Hymenoptera: Pteromalidae). However, the hyperparasites were observed only on *P. coccinellae* pupae collected in September, and for that period, parasitism of the pupae of *P. coccinellae* was 19.4% by *Gelis* sp. and 22.6% by *Eupteromalus* poss. *viridescens.*

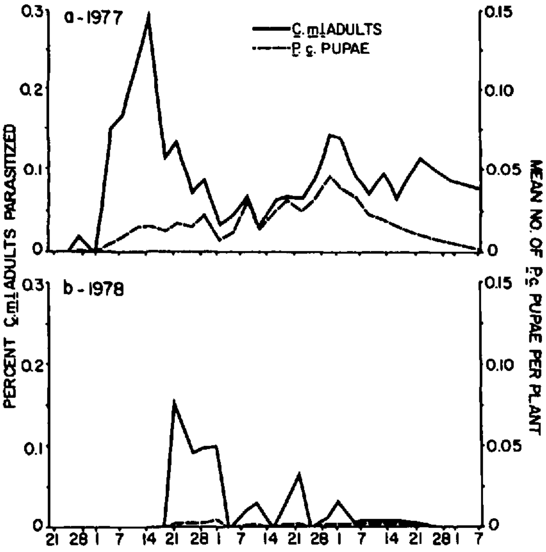

Fig. 1.—Seasonal abundance of the pupae of the parasite *P. coccinellae* (*P.c.*) and the percentage of adults of *C. m. lengi* (*C.m.l.*) from which the parasites had emerged on corn, Guelph, Ontario: (a) 1977; (b) 1978.

The number of pupae of *P. coccinellae* collected in 1978 was much lower than in 1977 (Fig. 1b). The adults of *C. m. lengi* which initially colonized the corn field were heavily parasitized, but for the rest of the season parasitism of adults was much lower. Comparisons of Fig. 1a and 1b for 1977 and 1978, respectively, suggest that a major peak in emergence of the parasites from the host took place in early to mid-July in 1977 and that the delayed colonization of the corn field by *C. m. lengi* in 1978 resulted in fewer parasitized beetles entering the corn. Most of the parasite pupae that emerged in mid-July 1978 would be found outside the corn field, and the adult parasites would have to disperse into the corn to attack the coccinellids instead of being carried into the corn with the host and emerging within the field as in 1977.

Only 22 parasite pupae were collected in 1978 during sampling of the entire corn field. Four of these, or 18.2%, were parasitized by *Eupteromalus* poss. *viridescens,* and none was parasitized by *Gelis* sp. As in 1977, no hyperparasites were found until late summer. The first parasitized pupa of *P. coccinellae* was collected on 29 August and, from then until the end of September, four parasitized cocoons were found, or 44.5% of the total cocoons collected during that period. Thus, it appears that hyperparasites can be a significant mortality factor for populations of *P. coccinellae* in corn but only towards the end of the season.

Egg and Pupal Predation

In 1976, 77 egg clusters were examined. The mean number of eggs per cluster was 13.6, the mean percentage of clusters attacked by predators was 44.4, and the mean mortality of eggs was 44.8%. In 1977, 736 eggs in 48 egg clusters were observed in the mortality plot, and of these, 37 clusters (77.1%) were attacked and 358 eggs (48.6%) were destroyed. Figure 2 shows the mean number of eggs per plant seen daily and the density that should have been observed if there had been no egg predation. The latter was determined by calculating the number of days each egg cluster would have been present based on the daily temperature. Predation of the eggs was greatest at and following the peak in egg density. The date when 50% of the eggs had been laid (50% occurrence) for the observed population was 23 July 1977; however, this date for the population predicted without mortality was 25 July 1977. Thus, predation had the effect of shifting the population curve to the left. The highest population of eggs observed in this plot also occurred on 23 July 1977, 4 days after the field population reached its peak, and was higher than the peak for the entire field (7.45 vs. 4.51 eggs per plant) (Wright and Laing 1980). The apparent discrepancy in density was to be expected because of the observed variance in the density of eggs from place to place within the field.

Most of the pupae appeared between 20 July and 10 August 1977 in the predation plot. Twenty pupae were observed, and only two were destroyed by

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[4] Determination by J. Huber, Dept. of Environmental Biology, and C. Yoshimoto, Biosystematics Research Institute, Ottawa.

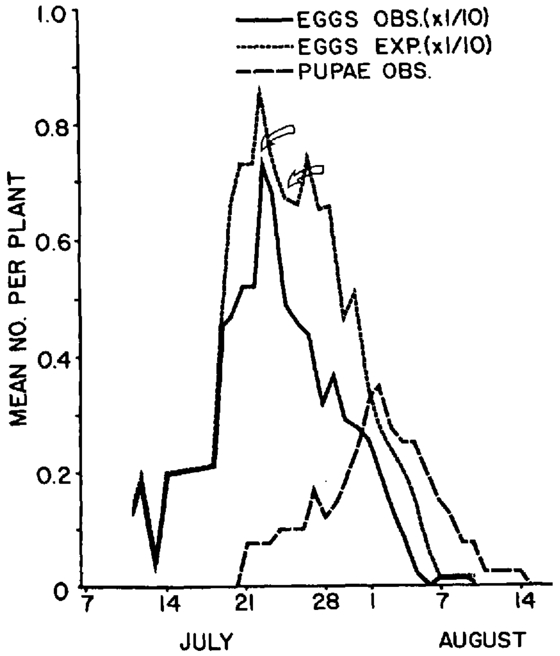

FIG. 2.—Populations of eggs and pupae of Coccinellidae observed in the mortality plot and the population of eggs that would be expected if no mortality had occurred on corn, Guelph, Ontario, 1977. Arrows indicate occurrence of 50% of the eggs.

predators. The highest population of pupae in the mortality plot (40-plant sample) occurred on 2 August, compared with 5 August for the entire field (600-plant sample), and the observed peak density was 0.35 pupae per plant compared with 0.34 for the entire field.

Stage-Specific Mortality

For the predation study of 1977, the actual number of eggs and pupae that entered that stage were known to be 19.2 and 0.55 individuals per plant, respectively, and the mortality from egg to pupa was 97.1%. The estimated numbers, using the graphical method, were 18.6 eggs per plant (3% error) and 0.8 pupae per plant (45% error). The estimated mortality for the entire developmental period was 95.7% and was taken as an acceptable estimate of the actual mortality (97.1%). Therefore, this method was used for the population data for the entire field for 1977 and 1978. The mortality from egg to pupa for the coccinellids of the first generation in corn in 1977 was estimated to be 93.8%. In 1978, this estimated mortality for *C. m. lengi* was 95.4%. For comparison, the mortality of a second species of coccinellid, *Hippodamia tredecimpunctata tibialis* (Say), in the same corn field in 1978 was estimated to be 91.5% (Wright 1978).

Predators destroyed 44.8% of the eggs in the predation plot in 1976 and 48.6% in 1977, so this mortality factor appeared rather constant from year to year. Similarly, analyses of the stage-frequency data showed that mortality over the period from egg to adult remained rather constant, 93.8% for all coccinellids on corn in 1977 and 95.4% for *C. m. lengi* in 1978. Overwintering mortality of the adults was 57.1% in 1977–1978, but this was quite variable, depending on the site. A further 37% of the surviving, overwintering beetles were parasitized in 1978 and therefore would never reproduce (Wright and Laing 1979). The emerging parasites would then attack the remaining adults and reduce their fecundity. Mortality was greatest in the early stages of life; thus, *C. m. lengi* showed a type IV survivorship curve of Slobodkin (1961). Density of beetles was not shown to affect the overwintering survivorship. Females showed higher mortality than males, and females inseminated before overwintering suffered very high mortality. There was no difference in the incidence of parasitism between overwintering males and females, but parasitism did cause an increase in overwintering mortality.

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