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PARASITISM BY *PERILITUS COCCINELLAE [HYM. : BRACONIDAE]* OF INDIGENOUS COCCINELLID HOSTS AND THE INTRODUCED *COCCINELLA SEPTEMPUNCTATA [COL. : COCCINELLIDAE]*, WITH NOTES ON WINTER MORTALITY (1)

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Parasitism of *Coccinella septempunctata* L. by *Perilitus coccinellae* (SCHRANK) varies seasonally with an 11 % overall rate among beetles overwintering in the Hackensack Meadowlands, which is less than that reported in Europe. *P. coccinellae* may parasitize *C. 7-punctata* twice yearly. Female *C. 7-punctata* were parasitized more heavily than males. Although parasitism by *P. coccinellae* varied significantly among host species, it was not significantly different among 3 habitats. High host density favored greater parasitism in 3 coccinellid species. Rearing for parasite cocoons, consistently showed lower parasitism rates than did dissection for parasitized larvae. Overwintering survival of caged *C. 7-punctata* near Stillwater, OK, varied between years averaging 53,5 %. Infection of overwintering *C. 7-punctata* by *Beauveria bassiana* (BALSAMO) was 1,6 % in 1978-1979.

Coccinella septempunctata L., a Paleartic coccinellid, is well recognized as a valuable aphid predator (HODĚK, 1973 ; CLAYHILLS & MARKKULA, 1974). Introduction to North America began in the 1950's with beetles being found in the Hackensack Meadowlands of Eastern New Jersey in 1973 (ANGALET & JACQUES, 1975). Subsequent efforts were made to colonize *C. 7-punctata* in Oklahoma, Georgia, New Mexico and Texas from beetles collected in the Hackensack Meadowlands (ANGALET *et al.*, 1979). As a result, CARTWRIGHT *et al.* (1979) reported the establishment of *C. 7-punctata* in Oklahoma.

The effectiveness of *C. 7-punctata* in limiting aphid populations will ultimately determine the value of these introductions in areas where the predator is recently

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established. However, mortality of the predator from biotic sources may influence the effectiveness of this predator. Thus, the purpose of this study was to quantify certain sources of mortality, including parasitism by *Perilitus coccinellae* (SCHRANK) and infection by *Beauveria bassiana* (BALSAMO) in overwintering adults. Additionally, this paper compares the impact of *P. coccinellae* on several indigenous species of coccinellids at several locations with its impact on *C. 7-punctata.*

P. coccinellae has received attention from a number of old world authors including IPERTI (1964), HODEK (1973) and GHORPADE (1977). HODEK (1973) found that *C. 7-punctata* is the predominant host in Europe, while in N. America, BALDUF (1926) observed *Coleomegilla maculata* (DEGEER) to be the most heavily parasitized coccinellid. He also investigated the biology of *P. coccinellae* in association with *Hippodamia convergens* (GUERIN-MENEVILLE) as well as other native coccinellids. He estimated that the overall predatory capability, i.e. voracity, fecundity, etc., was reduced by one-eighth by *P. coccinellae.*

In Europe, infection by the fungal pathogen, *B. bassiana* is reported by LIPA *et al.* (1975) to occur at relatively low levels in *C. 7-punctata.* By contrast, HODEK (1973) indicates an infection rate of 50 % in hibernating adult *C. 7-punctata.* In view of the broad range of infection rate of *B. bassiana,* an attempt was made to determine the incidence of this pathogen during this study.

METHODS AND MATERIALS

Three methods were used. First, monthly dissections for the presence of *P. coccinellae* larvae were conducted from December 1978 to October 1979 in the laboratory on at least 50 adult *C. 7-punctata.* These beetles were collected randomly from various habitats at the Hackensack Meadowlands near Rutherford, NJ. Secondly, the rate of parasitism was determined by dissecting 200 adults each of *C. 7-punctata, C. maculata* and *C. 11-punctata* collected in 3 overwintering habitats : Scotch pine (*Pinus sylvestris* L.), redtop (*Agrostis alba* L.) and common mullein (*Verbascum thapsum* L.). Finally, rates of parasitism by *P. coccinellae* were determined both by dissection and rearing hosts for parasite cocoons, for 100 adults each of 5 coccinellid species collected in the Hackensack Meadowlands on 3 dates in 1979. The parasitism rate was similarly determined at 2 other sites, near Tinicum Marsh, PA and at Newark, DE, where coccinellid populations were much smaller. Comparison among sites can only be made for 3 species since all coccinellids observed for parasitism were not available at all sites.

Adult coccinellids reared to determine success of development of parasite larvae were provided an excess of *Acyrthosiphon pisum* (HARRIS) nymphs and adults for 30 days (at 27° C, 50 % RH, 16 h photophase) or until *P. coccinellae* had formed cocoons. Identification of adult parasites was confirmed by Dr. P. M. MARSH of the Systematic Entomology Laboratory, USDA-SEA, Beltsville, MD. Chi-square tests for equality of percentages was used for testing for differences among percentages of parasitism (GRIZZLE *et al.,* 1969).

A comparison was made for parasitism of *C. maculata* collected at Rancocas, NJ, during the winters of 1967 through 1970 by dissecting 100 adults for each collection date. Populations of adult *C. maculata* and probable aphid hosts were monitored during each year and categorized as low or high.

In the falls of 1975 and 1978, diapausing adults of *C. 7-punctata* (27,000 and 36,000, respectively) that were collected at the Hackensack Meadowlands were placed in field cages consisting of a wooden frame (2,5 × 1,5 × 1,8 m) covered with screen

wire and a plywood cover. These cages were left for the winter in an ungrazed pasture on the south side of a juniper grove located near Stillwater, OK. Cages contained pine clippings, artificial pine branches, dried mullein leaves, excelsior, styrofoam packing and wood chips. These materials were included to provide a suitable overwintering habitat for the beetles. Winter mortality was determined by counting the remaining beetles in the cages. The dead beetles were checked for mycelial growth characteristic of the fungal pathogen, *B. bassiana.* Infection of each beetle was confirmed by culturing the pathogen in the laboratory, by placing suspect beetles in 1 % sodium hypochlorite for 30 s and observing growth emanating from the beetle on protease peptone No. 2 dextrose agar medium. Microscopic examination of spores removed from these plates allowed positive identification of the pathogen.

RESULTS AND DISCUSSION

SEASONAL OCCURRENCE OF *P. COCCINELLAE*

Figure 1 shows the occurrence of *P. coccinellae* larvae in adult *C. 7-punctata* from December 1978 to October 1979 in the Hackensack Meadowlands. Peak occurrence of

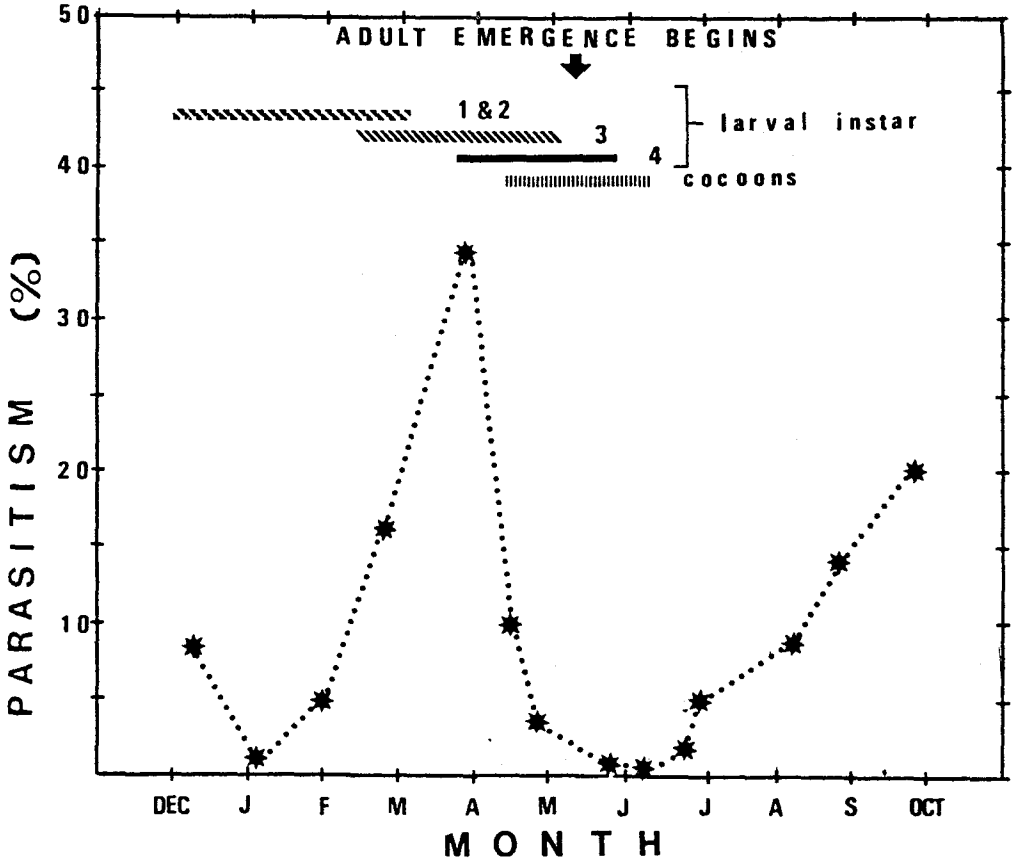

FIG. 1. Occurrence of *Perilitus coccinellae* larvae in *Coccinella septempunctata* collected at the Hackensack Meadowlands, Bergen County, NJ, 1978-1979 ($n \geq 50$).

parasite larvae occurred in April 1979, declined during the summer and increased again in the fall of 1979. These data suggest that *P. coccinellae* parasitizes *C. 7-punctata* twice yearly, corresponding to the period of adult emergence and periods of peak larval occurrence, once as beetle overwintering begins and again in late spring as new adults emerge. *C. maculata* is also parasitized similarly (OBRYCKI & TAUBER, 1979 ; RICHERSON & DELOACH, 1972), with 4-5 generations of the parasite occurring in a year. Parasites emerging in the spring may parasitize F_1 adult *C. 7-punctata* or other suitable hosts which are available, then complete several generations during the summer on a multivoltine host or series of hosts.

The average percentage of *C. 7-punctata* from the Hackensack Meadowlands containing *P. coccinellae* larvae was 11 % (from data in figure 1). Since *C. 7-punctata* were quarantined at the time of their introduction, this rate of parasitism represents the adaptation of indigenous parasites to an introduced host. With additional time for temporal synchrony to occur, the rate of parasitism may increase to the levels found in Europe where both the host and parasite are indigenous (HODEK, 1973 ; LIPA *et al.*, 1975).

Of all parasites dissected from adult *C. 7-punctata* a significantly higher ($p = 0,05$) percentage were found in ♀ hosts (64 % -- 91 of 142 total parasite larvae) as compared to ♂ hosts (36 % -- 51 of 142 total parasite larvae), even though the sex ratio of the host was nearly equal. This preference by *P. coccinellae* for ♀ was also reported by HODEK (1973) and PARKER *et al.* (1977). PARKER further found that among superparasitized hosts, a higher percentage were female. In our studies, only 2 *C. 7-punctata* contained more than 1 parasite larva, both hosts being ♀. In each case, the host contained 1 large and 1 small parasite larva. HODEK (1973) suggested that in superparasitized hosts, only 1 larva will survive, while the smaller larvae are consumed by the largest. Preference for ♀ hosts may have an adaptive advantage for *P. coccinellae* since the larger body size of ♀ *C. 7-punctata* allows more space for larval growth and ♀ generally have a greater amount of adipose tissue, a food source for developing larvae, than do ♂ (HODEK 1973). All the parasite adults were ♀ which is consistent with the conclusion of BALDUF (1926), BRYDEN & BISHOP (1945) and HODEK (1973), that *P. coccinellae* reproduces by thelytokous parthenogenesis.

HOST PREFERENCE, EFFECT OF HABITAT AND HOST POPULATION DENSITY

Parasitism of 3 coccinellid species was not significantly different among 3 overwintering habitats, scotch pine, redtop and mullein, within the same host species (table 1). Lack of differences among habitats may be explained by the beetles being parasitized prior to their selection of overwintering habitat. Differences were apparent among species within the same habitat with *Coccinella 11-punctata* L. being the most highly parasitized, followed by *C. maculata* and *C. 7-punctata.*

TABLE 1

Percentage of adult coccinellids containing Perilitus coccinellae *larvae collected from 3 habitats at the Hackensack Meadowlands, NJ, 24 Sept. 1979* (a)

Species	Scotch Pine	Redtop	Mullein
Coccinella 7-punctata L.	17.5	13.5	19.5
Coleomegilla maculata (DEGEER)	25.0	19.5	28.0
Coccinella 11-punctata L.	48.5	41.5	54.5

(a) Percentages for the same species are not significantly different ($p = 0.05$, chi-square test) between habitats ; $n = 100$.

The percentage parasitism by *P coccinellae* for various coccinellids at 3 locations is given in table 2. Not all coccinellids listed were available from each site. With *C. 7-punctata, C. maculata and C. 11-punctata,* parasitism at the Hackensack Meadowlands which had a much larger host population, was significantly greater than at either Tinicum Marsh or Newark, where host densities were much smaller.

Table 2 also shows that *C. undecimpunctata* is the most highly parasitized species at the Hackensack Meadowlands, whereas parasitism was fairly equal among species at the low host density sites.

TABLE 2

Percentage of various adult coccinellids containing larvae of Perilitus coccinellae *with respect to coccinellid density* (a)

	Location (b)			
	Hackensack Meadowlands, NJ		Tinicum Marsh, PA	Newark, DE
Population density (per sweep) →	>5		<5	<5
Species	dissection	rearing	dissection	dissection
Coccinella 7-punctata L.	19*	11	8 (25)	6 (50)
Coleomegilla maculata (DEGEER)	20*	16	8 (50)	10 (20)
Coccinella 11-punctata L.	48*	20	10 (20)	5 (20)
Adalia bipunctata (L.)	12	0	—	—
Olla sp.	28	11	—	—
Hippodamia convergens GUERIN-MENEVILLE	—	—	5 (20)	4 (25)
Coccinella novemnotata HERBST	—	—	8 (50)	5 (20)

(a) Numbers in parentheses indicate the number of beetles dissected if different than 100. A chi-square test was performed for dissection percentages to test for differences in the high density site from the low density sites ; significance ($p = 0.05$) is indicated by an « * ».

(b) Beetles collected in field on September 24, 16 and 16, 1979, respectively.

Dissection yielded greater parasitism percentages for all species than did rearing hosts for *P. coccinellae* cocoon formation (table 2). This discrepancy is an indication of the parasite larval mortality within each host species. Difference in percentage parasitism between the 2 methods varied among host species and was much greater (28 %) with *C. undecimpunctata* than all other species. The least parasite larval mortality occurred with *C. maculata* as host. In concert with previous findings (HODEK, 1973), no parasites emerged from *Adalia bipunctata* (L.) adults. Variation in parasite larval mortality among host species could be due to differences in host reaction to the parasite larva or in host suitability, e.g. nutritional preferences.

Observations of the native coccinellid, *C. maculata,* at Rancocas, NJ from 1967 to 1970 show that parasitism by *P. coccinellae* varies yearly and depends on the population density of *C. maculata* (table 3). During 1967 and 1968, aphids were abundant on many different plants and *C. maculata* aggregations overwintering in duff along the edge of a woodlot were very abundant. However, during 1969 and 1970, aphids were scarce and coccinellid populations were greatly reduced.

TABLE 3

Incidence of Perilitus coccinellae *larvae in* Coleomegilla maculata *at Rancocas, NJ, 1967-1970*

			Percentage hosts with parasite larva (a)			
	Density of		Date			
Year	Beetles/Sweep	Aphids/Sweep	Jan. 14-19	Feb. 19-21	Mar. 25-27	Average
1967	high	high	54	49	44	49.0
1968	high	high	51	68	62	60.3
1969	low	low	10	6	10	8.7
1970	low	low	2	4	8	4.7

(a) n = 100 ; "aphids" = *Acyrthosiphon pisum* (HARRIS).

WINTER SURVIVAL OF *C. 7-PUNCTATA*

Overwintering *C. 7-punctata* in cages near Stillwater, OK showed that percentage survival varied significantly (p = 0.05) between 2 years, 59,2 % of 36,000 beetles for 1975-1976 and 45,9 % of 27,000 beetles for 1978-1979. The average survival rate for both winters combined was 53,5 % which is similar to the survival rate in field cages reported by SHANDS *et al.* (1972) in Maine.

In 1978-1979, observations on beetle cadavers showed 569 of 19,479 (2,9 %) to be infected with *B. bassiana,* which amounts to 1,6 % of all beetles in the cages. Estimates of the percentage mycosis from this pathogen are much less than the 50 % mean infection rate reported by IPERTI for *C. septempunctata* in southeastern France (HODEK, 1973).

CONCLUSION

In U.S.A., the occurrence of *P. coccinellae* and *B. bassiana* in *C. 7-punctata* is fairly minor, 11 % and 2 % respectively, compared to that reported in Europe. While this parasite and pathogen may increase as *C. 7-punctata* populations increase, they presently cause only a minor amount of mortality and should provide only minimal impedance to the predator's effectiveness in newly established areas.

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RÉSUMÉ

Parasitisme par *Perilitus coccinellae [Hym. Braconidae]* des coccinelles indigènes hôtes et de *Coccinella 7-punctata* introduite et notes sur la mortalité hivernale

Le parasitisme de *Coccinella 7-punctata* L. par *Perilitus coccinellae* (SCHRANK) varie selon les saisons avec un taux maximum de 11 % chez les coccinelles hivernantes dans la région de Hackensak Meadowlands, ce qui est moindre qu'en Europe. *P. coccinellae* peut parasiter *C. 7-punctata* 2 fois par an. Les femelles de *C. 7-punctata* sont davantage parasitées que les mâles. Le parasitisme par *P. coccinellae* varie de façon significative selon les espèces hôtes mais ne diffère pas dans les 3 habitats étudiés. Une forte densité en hôtes favorise le parasitisme chez 3 espèces de coccinelles. L'élevage pour obtenir les cocons des parasites donne des taux de parasitisme nettement inférieurs à ceux observés par dissection des larves parasitées. La survie pendant l'hiver en cages de *C. 7-punctata*, près de Stillwater, OK, est variable selon les années et en moyenne de 53,5 %. L'infection par *Beauveria bassiana* (BALSAMO) chez les *C. 7-punctata* hivernantes fut de 1,6 % en 1978-1979.

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