Perilitus coccinellae (Hymenoptera: Braconidae): Parasitization and Development in Relation to Host-stage Attacked

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ABSTRACT The braconid *Perilitus coccinellae* (Schrank), generally regarded as a parasitoid of adult coccinellids, oriented toward and inserted its ovipositor (stung) into all four larval stages and pupae of *Coleomegilla maculata* (DeGeer). Pupae and fourth instars elicited more responses from female parasitoids than the early larval stages. *P. coccinellae* successfully parasitized all immature stages, except the first instar. However, there was a direct relationship between the rate of successful parasitization and the maturity (stage) of the host at the time of attack. The egg-larva development time of *P. coccinellae* was inversely related to the stage of the host attacked. Development (±SE) averaged 17.1 ± 0.4 days when an adult was parasitized and 25.0 ± 3.2 days when a second instar was stung. Rather than solely a parasitoid of adult coccinellids, *P. coccinellae* may be classified as a "larval/pupal/adult-adult" parasitoid.

THE BRACONID *Perilitus coccinellae* (Schrank) parasitizes many coccinellid species throughout the Holarctic. One of its most common hosts in North America is *Coleomegilla maculata* (DeGeer), a polyphagous coccinellid predator (Hagen 1962, Cartwright et al. 1982).

Various studies have reported that *P. coccinellae* attacks adult coccinellids (see Hodek 1973). Subsequently, laboratory investigations showed that this parasitoid also accepts immature stages and then emerges from the adult beetle (David and Wilde 1973, Semyanov 1979). However, this phenomenon is not restricted to the laboratory; field collections of immature *C. maculata* in Canada and of *Coccinella septempunctata* L. in the USSR, showed that *P. coccinellae* parasitized a small percentage of immatures (Smith 1960, Semyanov 1979).

All instars of *Hippodamia convergens* Guerin are acceptable for oviposition and suitable for successful development of *P. coccinellae* (David and Wilde 1973). As part of a series of studies on the host–parasitoid interaction between *C. maculata* and *P. coccinellae* (Obrycki and Tauber 1978, 1979), we investigated the relative acceptance and suitability of immature (larvae and pupae) and adult *C. maculata* for *P. coccinellae*. We also examined *P. coccinellae*'s developmental time in relation to the host stage attacked.

Materials and Methods

Adult *C. maculata*, from the Ithaca, N.Y., area, were maintained at a photoperiod of 16:8 (L:D), 24 ± 1°C, and provided with water, a honey–sugar–Wheast-protein mixture, and living aphids, *Acyrthosiphon pisum* (Harris) and *Myzus persicae* (Sulzer). After egg masses were collected, larvae were reared on *A. pisum* and *M. persicae*. Adult female *P. coccinellae* were obtained from field-collected *C. maculata* adults and maintained at a photoperiod of 16:8, 24°C, with water, a honey–sugar–Wheast-protein mixture, and honeydew from *M. persicae*. *P. coccinellae* females 2–7 days old were used in all tests.

Individual *C. maculata* (four larval stages, pupae, and adults) were exposed to randomly selected individual *P. coccinellae* females for 5 min in 0.24-liter (½-pint) cages; 5 min is sufficient time for *C. maculata* to attack *P. coccinellae*. The behavior of the parasitoid was recorded as 1) no response, 2) assuming the ovipositional stance—abdomen and ovipositor extended ventrally and

Table 1. Behavioral responses of *P. coccinellae* females exposed to *C. maculata* larvae, 5-min observation period, 0.24-liter cages, 23 ± 1°C

	No response (%)	Ovipositional stance,[a] no stinging (%)	Ovipositional stance[a] and stinging (%)
Exposed instar (*n*)			
4th Instar (20)	0	5	95
3rd Instar (18)	17	17	66
2nd Instar (21)	5	19	76
1st Instar (13)	23	31	46

[a] Abdomen and ovipositor extended ventrally and cephalad between legs (*see* Richerson and DeLoach 1972).

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Table 2. Developmental times (days; $\bar{x} \pm SE$) of *P. coccinellae* parasitizing *C. maculata* life stages 24 ± 1°C, photoperiod of 16:8 (L:D)

C. maculata stage parasitized	Parasitoid developmental time Egg-larval (*n*)	Pupal (*n*)	Total (*n*)
Adult	17.1 ± 0.4 (8)	10.0 ± 0.8 (8)	27.1 ± 0.5 (8)
Pupa	18.8 ± 0.6 (9)	9.6 ± 0.2 (7)	27.9 ± 0.6 (7)
4th Prepupa	19.9 ± 0.5 (7)	9.2 ± 0.3 (6)	28.8 ± 0.4 (6)
3rd Instar	22.0 ± 0.8 (5)	8.4 ± 0.4 (5)	30.4 ± 0.7 (5)
2nd Instar	25.0 ± 3.2 (5)	10.0 ± 1.0 (2)	33.5 ± 1.5 (2)

cephalad between legs (see Richerson and DeLoach 1972) without stinging host (inserting ovipositor), or 3) stinging host. We did not test host preference via choice tests because we exposed each stage individually; we demonstrated acceptability (stinging) and suitability (development), not preference.

The exposed *C. maculata* were reared at 24 ± 1°C, a photoperiod of 16:8 on *A. pisum* and *M. persicae*. We recorded the number of *C. maculata* adults emerging from each life stage exposed to *P. coccinellae*, the number of *P. coccinellae* adults from each host life stage, and the developmental time for *P. coccinellae*. Dead *C. maculata* were dissected, and the presence of immature *P. coccinellae* was noted. Groups of unexposed *C. maculata* were reared to determine the influence of *P. coccinellae* on host survival. Specimens of *C. maculata* and *P. coccinellae* are in the Cornell University Insect Collection, Lot #1138.

Results

Within the 5-min exposure period, *P. coccinellae* females reacted to all immature stages (eggs were not tested) of *C. maculata*. In each condition female parasitoids responded by showing an ovipositional stance at least 75% of the time; 100% of the females responded to fourth instars (Table 1). The lowest percentage of *P. coccinellae* females stinging (46%) was observed when first-instar *C. maculata* were available to the females. The percentage of hosts stung increased to 95% when fourth instars were available (Table 1).

Lengths of egg and larva development of *P. coccinellae* were inversely related to the age of host attacked (Table 2). A one-way analysis of variance indicated significant differences between these developmental times ($F = 5.96$; df = 4,29; $P = 0.05$). *P. coccinellae* pupae developmental time ranged from 8.4–10 days. Although there were significant differences between the pupae developmental times ($F = 3.81$; df = 4,23; $P = 0.05$), the variation was not consistently related to the age of the host.

The highest percentage of successful parasitization (production of an adult *P. coccinellae*) occurred when adult *C. maculata* were attacked (Table 3). This percentage decreased when younger host stages were attacked; no *P. coccinellae* were produced when first instars were exposed to the parasitoid, even though 46% of them were stung (Table 3). One *P. coccinellae* larva emerged from a fourth-instar *C. maculata*, which had been parasitized as a second instar; this parasitoid larva did not spin a cocoon.

Dissections of immature *C. maculata* revealed from 0–70% parasitism (Table 3). Dead beetle larvae contained both early and late stage parasitoid larvae.

Discussion

Our results indicate that *P. coccinellae* attacks all larval stages and pupae, in addition to adults, of *C. maculata*. However, there are stage-specific influences on both the attack rate and on the percent successful parasitization. Early instars were less acceptable for stinging than later ones, and the younger host stages were less suitable for successful parasitoid development. We had no successful parasitization of first instars. This differs from David and Wilde's (1973) results when *H. convergens* was the host.

These studies provide some clues for characterizing aspects of successful parasitization by *P. coc-*

Table 3. Suitability of *C. maculata* for *P. coccinellae*, 24 ± 1°C, photoperiod 16:8 (L:D)

C. maculata life stage	Exposed (*n*)	% *C. maculata* adults produced (*n*)	% *C. maculata* adults from controls (*n*)	% Successful parasitization[a]	No. dead immature *C. maculata* (% with *P. coccinellae*)[b]	No. dead adult *C. maculata* (% with *P. coccinellae*)[b]
Adult	20	—	—	40	—	2 (0)
Pupa	25	100 (25)	100 (7)	28	0	4 (75)
4th Prepupa	38	82 (31)	90 (10)	26	7 (47)	6 (67)
3rd Instar	27	93 (25)	90 (10)	19	2 (0)	2 (50)
2nd Instar	26	62 (16)	100 (5)	8	10 (70)	0 —
1st Instar	13	77 (10)	80 (5)	0	2 (50)	1 (0)

[a] % Successful parasitization = (no. *P. coccinellae* adults emerging/no. *C. maculata* hosts exposed) × 100.

[b] Dead *C. maculata* were dissected, the presence of immature *P. coccinellae* was recorded.

cinellae (see Vinson 1984). This parasitoid is usually abundant in habitats where coccinellids are commonly found (Richerson and DeLoach 1973), but the factors regulating host-habitat finding by *P. coccinellae* are unknown. Once in the appropriate habitat, the parasitoid uses visual cues to locate its host (Walker 1961, Richerson and DeLoach 1972). Subsequent host examination and oviposition appear to be regulated by olfactory cues (Richerson and DeLoach 1972, Semyanov 1981). *P. coccinellae* females responded to filter paper exposed to live *C. septempunctata* and also attempted to sting several fractions of whole beetles (e.g., adults without elytra, a head and pronotum only, or fractions of the elytra) (Semyanov 1981).

Our experiments indicate that *C. maculata* larvae, pupae, and adults share common features in that they elicit an ovipositional stance by *P. coccinellae* females. However, oviposition stimuli differ qualitatively or quantitatively among the stages, because stinging increased in older host stages.

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