

Oviposition Behavior and Development of Immature Stages of *Parasierola swirskiana*, a Parasitoid of the Lesser Date Moth *Batrachedra amydraula*

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Parasierola swirskiana Argaman (Hymenoptera: Bethyridae) is a parasitoid of the moth *Batrachedra amydraula* Meyrick, a pest of unripe fruits of the date palm, *Phoenix dactylifera* L. The parasitoid is most commonly found in the field on second-generation host larvae. Its biological characteristics were studied in the laboratory. Adult longevity averaged 34.9 and 20.5 days for females and males, respectively. Clutch size ranged between 1 and 13 eggs per host, and was positively correlated with host weight. Females laid an average of 60.4 eggs on 11.6 hosts, with a maximum of 152 eggs on 29 hosts in 53 days. Parasitoids were observed standing motionless upon 52% of the paralyzed hosts, and active brood defense was occasionally observed. Immature development is described. Total development time from egg to adult averaged 13.6 days at $26 \pm 2^\circ\text{C}$ and 30-50% r.h. The potential for utilizing *P. swirskiana* for biological control of *B. amydraula* is discussed.

KEY WORDS: *Parasierola*; *Batrachedra*; *Goniozus*; oviposition behavior; clutch size; brood guarding; immature development; biological control.

INTRODUCTION

The lesser date moth *Batrachedra amydraula* Meyrick (Lepidoptera: Batrachedridae) is a major pest of unripe fruits of the date palm, *Phoenix dactylifera* L., in Iran, Iraq, Libya, Egypt and Israel (1,17,19), causing up to 75% yield loss (17). In the Arava Valley of southern Israel, *B. amydraula* has at least three generations per year (19). First-generation larvae are observed from late March until early May, and second-generation larvae from May until mid-June. There may be considerable overlap of generations. Population densities and consequent damage are usually much higher during the second generation. Much lower numbers of *B. amydraula* larvae are observed until mid-August, apparently representing at least one additional generation. Each larva may feed upon several fruits, the number of fruits per larva apparently decreasing as the season progresses and fruit size increases.

Parasierola swirskiana Argaman 1992 (Hymenoptera: Bethyridae) (2) parasitizes *B. amydraula* larvae in the southern Arava Valley. This ectoparasitoid has been collected in most date orchards in the region. It is found in all major date varieties, but is most prominent in 'Deglet Nour', less so in 'Zahidi' and 'Hdrawi', and comparatively rare in 'Medjoul'. Adults are observed from early May until August, with the largest numbers

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of parasitoids seen in late May and early June, on second-generation *B. amydracula* larvae. The level of parasitism is usually low. Parasitism of above 10% has been observed only at very high densities of second-generation larvae or during July–August, when *B. amydracula* populations decrease sharply (personal observations).

Various *Parasierola* and *Goniozus* species have been considered as potential biological control agents of Lepidoptera. With this in mind, several species were studied under laboratory conditions (6,16, and references therein). *Goniozus emigratus* (Rohwer) and *G. legneri* Gordh were introduced in California for the control of *Amyelois transitella* (Walker) (14). Similarly, *G. legneri* was imported to Israel to control *Ectomyelois ceratoniae* (Zeller) (8). The establishment of *G. legneri* in California was followed by a decrease in population densities of its host (13).

Evans (4) regarded the genus *Parasierola* as a subjective junior synonym of *Goniozus*. However, in this paper we follow Argaman (2) in regarding *Parasierola* as a separate genus.

The objective of this investigation was to gather biological data on *P. swirskiana* as a basis for an assessment of its potential to control *B. amydracula* populations. It includes quantitative studies of oviposition behavior and immature development, along with some qualitative observations.

MATERIALS AND METHODS

Batrachedra amydracula larvae were collected from field-infested fruits. Additional larvae were obtained from eggs laid by adult moths in the laboratory. The *P. swirskiana* colony was established using nine adult females collected in the date orchards of Eilot, Ketura, Yahel and Yotvata, plus four females which emerged from two parasitized *B. amydracula* larvae from Eilot and Yotvata.

All female parasitoids used in the study were given the opportunity to mate. Females from mixed (male and female) broods copulated with their siblings, and those from all-female broods were exposed to males after emergence.

Sixteen female parasitoids, five collected in the field and 11 which emerged in the laboratory, were placed individually in plastic petri dishes (diam 85 mm), with honey streaks applied to the inner surface of each lid. A single *B. amydracula* larva was weighed and then placed with each parasitoid. The lid of the petri dish was secured with two rubber bands.

Each host and parasitoid was examined daily. Parasitoid behavior, including host feeding, host attack and oviposition, and position relative to the host, were recorded. Whenever the parasitoid failed to oviposit on the host within 2 days of its introduction, the latter was removed. When it was parasitized and the wasp not observed nearby, the host was removed and placed in a no. 1 gelatin capsule. When it was parasitized and the wasp observed on or near it, we assumed that the parasitoid may have not yet completed its oviposition, and the host was therefore left in the petri dish for one additional day. The parasitized host was removed to a capsule no later than 2 days after the first eggs were observed even if the parasitoid remained upon it. This was done in order to (i) prevent unnecessary damage to developing parasitoid larvae during transfer of the host to the capsule; and (ii) enable the wasp to parasitize another host so that it would more fully realize its oviposition potential. In all cases, removal of the host was followed immediately by introduction of a fresh *B. amydracula* larva. Each host larva was exposed to only one parasitoid, so that all eggs on any given host were progeny of a single wasp.

The immature parasitoid stage was determined daily. Duration of the immature stages was determined using data for the most mature individual of each brood which produced at least one adult wasp. Longevity was determined by placing individual males or females in petri dishes as described above. Results are given as mean \pm SE. Temperature was maintained at $26 \pm 2^\circ\text{C}$ and relative humidity ranged between 30% and 50%.

RESULTS AND DISCUSSION

Adult longevity Females lived 34.9 ± 3.1 days (range 4–72 days; $n=46$). There was no significant difference in longevity between females provided with, or deprived of, hosts (with hosts 33.3 ± 5.1 days, $n=12$; without hosts 35.4 ± 3.9 days, $n=34$; Student's t -test, $t=0.29$, $P>0.77$). Males lived 20.5 ± 4.9 days (range 2–57 days; $n=15$).

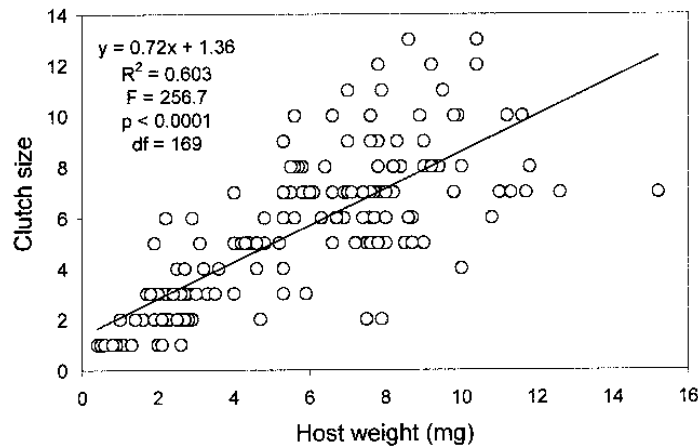


Fig. 1. Relationship between weight of *Batrachedra amydraula* hosts and number of eggs deposited by *Parasierola swirskiana* females.

Adult behavior *Host attack and oviposition:* Upon encountering the host, the female immediately stands on it, attaching its mandibles to the dorsum of the host's thorax, and attempts to sting its venter between the head and thorax, *i.e.*, in the vicinity of the subesophageal ganglion. If successful, this causes the immediate and permanent immobilization of the host. The female usually leaves the host after several seconds and begins grooming. Alternatively, it may remain attached to the host with its mandibles without movement. After resting for several minutes, the parasitoid returns to the host and begins to walk upon it back and forth, moving its antennae constantly. This behavior may be interpreted as assessment of the paralysis and size of the host. If paralysis is incomplete, the wasp may sting the host again in the thorax or abdomen. Even hosts on which eggs had already been deposited were observed to be stung in this manner.

Oviposition usually commenced within 24 h of paralysis, and within 48 h of completion of oviposition on the previous host. Egg deposition on a single host may last several hours,

during which time the parasitoid usually remains upon the host. Laying of a single egg lasts approximately 4 min.

The egg is usually laid parallel to the longitudinal axis of the host. In general, the female's ovipositional stance is random: 52% of the eclosing larvae faced the anterior end of the host, while 48% faced the posterior end. However, eggs on a particular host are usually laid with the same orientation: on 31% of the hosts all eclosing larvae faced the anterior end, on 31% all larvae faced the posterior end, and on 38% of the hosts the parasitoid larvae faced either direction (n=144).

TABLE 1. Position of *Parasierola swirskiana* eggs on *Batrachedra amydraula* larvae

Segment ^z	Aspect			Total
	Dorsal	Lateral	Ventral	
T1	0	1	0	1
T2	0	4	0	4
T3	11	8	1	20
A1	31	28	1	60
A2	70	48	2	120
A3	114	81	4	199
A4	138	114	5	257
A5	98	78	1	177
A6	47	37	5	89
A7	18	16	1	35
A8	3	1	0	4
Total	530	416	20	966

^zT = Thoracic segment; A = Abdominal segment.

Position of eggs on the host is detailed in Table 1. There is a clear preference for the host's dorsum (55%) and sides (43%), with only 2% of eggs laid ventrally. Egg deposition upon the host's dorsum is typical of *Parasierola* species (5). Sixty-six percent of the eggs were deposited on abdominal segments 3–5 (n=966).

Wasps parasitized third to fifth instar *B. amydraula* larvae (*i.e.*, the last three instars) weighing a minimum of 0.5 mg, but no progeny completed development on hosts weighing less than 1.0 mg. Clutch size ranged from 1 to 13 eggs per host, and correlated positively with host weight (Fig. 1). Similar relationships between clutch size and size of the host have been demonstrated for other bethylids (5,11,12,15). Females laid an average of 60.4 ± 10.2 eggs on 11.6 ± 1.9 hosts in their lifetime, or 2.0 ± 0.2 eggs on 0.36 ± 0.03 hosts per day (n=16). A field-collected female was the most fecund, depositing 152 eggs on 29 hosts in 53 days.

Host feeding Parasitoids were frequently observed feeding upon *B. amydraula* larvae that they had paralyzed, often before and occasionally after the depositing of eggs. Some hosts were used only for feeding and not for oviposition. Females provided with hosts apparently utilized them as their sole food source, and were never observed feeding on the honey streaks.

Brood guarding Parasitoids were observed standing motionless upon 97 of 186 hosts (52%). At the time of observation, 29 hosts were paralyzed without parasitoid eggs, 61 with parasitoid eggs, and seven with developing parasitoid larvae. In most cases the wasp left the host temporarily if disturbed, *e.g.* due to handling of the petri dish, as reported for *Parasierola nigrifemur* (Ashmead) (5). Oviposition of a full clutch often

lasts for several hours. Thus, passive standing upon the host may simply be due to a physiological requirement to wait for the complete development of a sufficient number of eggs to complete the clutch. However, the presence of the parasitoid in the vicinity of the host may enable the wasp to prevent or deter superparasitism, multiparasitism or hyperparasitism of the host (9,18).

Active defense of the host was occasionally observed, with the parasitoid spreading its mandibles and biting objects presented to it such as a small brush. Such behavior was reported also for *Parasierola bicarinata* (Brues) (3). Active defense or standing upon hosts on which oviposition had been completed may be considered brood guarding. Apparent brood guarding was also observed in field-collected dates.

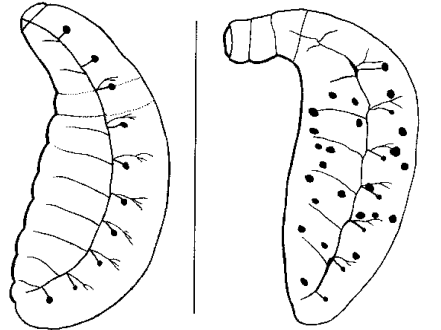


Fig. 2. a (left). Mid-stage *Parasierola swirskiana* larva. b (right). Late-stage *Parasierola swirskiana* larva. Each bar represents 1 mm.

Development of immature stages The *P. swirskiana* egg is white, sausage-shaped, and hatches 1.3 ± 0.05 days after deposition (n=92). The larva begins feeding immediately after eclosion, before freeing itself from the chorion. Thus it is difficult to distinguish between the egg and the newly eclosed larva, and impossible to record the exact time of eclosion. The larva remains attached to the host throughout its development, and detaching it causes the larva's death. The larva grows from less than 0.5 mm long at eclosion (equal to the size of the egg) to over 2 mm long when fully developed. At first the larva is transparent and pear-shaped, the mandibles attached to the host's integument. Eventually it assumes a yellow color, and develops a 'neck' which protrudes into the host's body. This protrusion becomes apparent when the larva is ~ 1 mm long (Fig. 2a), and when fully developed is comprised of the larva's head and thorax (Fig. 2b). The parasitoid's body external to the host lacks nearly any sign of segmentation, except for a slight appearance of segmentation in the mid-stage larva (Fig. 2a). The head and thorax which project into the host's body in the late-stage larva are clearly segmented (Fig. 2b).

The larva detaches from the exsanguinated host 2.3 ± 0.06 days after eclosion (n=92). The prepupa is clearly segmented throughout and lacks the narrowing of the thoracic segments found in the feeding larva. It normally begins to spin a cocoon shortly after detachment from the host, usually adjacent to the shriveled host integument. Of 350 parasitoids that reached the adult stage, 26 males and 7 females never formed cocoons. A blackish meconium is formed at one end of the cocoon 1.5 ± 0.06 days after detachment from the host (n=91). Meconium formation is concluded with lighter-color secretion from

the gut 1.2 ± 0.08 days later (n=27). Apolysis occurs at this stage and a pharate pupa is formed. Some pigmentation of the pupal eye is already apparent through the larval integument. Ecdysis occurs 1.1 ± 0.08 days after apolysis (n=27). Pigmentation of the compound eye begins at its posterior margin, gradually spreading to the whole eye. Simultaneously, pigmentation of the ocelli occurs. Both the eye and ocelli are at first pinkish-red, later darkening until becoming brownish-black. 4.6 ± 0.09 days after apolysis (n=86), the head and thorax become dusky and then black. Pigmentation is initially most prominent dorsally in the propodeum, and ventrally in the head and anterior margin of each thoracic segment. Pigmentation of the gaster begins only when the head and thorax are almost totally black, spreading from the posterior margin forward in each abdominal segment. This latter sequence of pigmentation is similar to that described by Gordh (5) for *Goniozus gallicola* Fouts. Twenty-four hours after appearance of the first signs of pigmentation, the whole body is black, except for the legs and antennae, and the most posterior abdominal segment – which remains light until shortly before adult emergence.

Up to 13 individuals develop successfully to the adult stage on a single host larva. The adult emerges 2.9 ± 0.12 days after the onset of cephalic and thoracic pigmentation (n=91), or 7.4 ± 0.15 days after apolysis (n=87). Total development time from egg to adult is 13.6 ± 0.2 days (range 11–18 days; n=87).

Adult emergence Males emerge from their cocoon approximately one day before females of the same brood and chew a hole in the females' cocoons, which they enter. Copulation takes place inside the cocoons. However, since females emerging from all-female broods and later exposed to males produced both male and female progeny, it is assumed that copulation may also occur after females emerge from their cocoons.

Of 16 females producing adult progeny, two probably unfertilized females produced only males. In almost all broods that produced both sexes, the majority of progeny were female. For example, the largest brood produced three males and ten females. Full analysis of the sex ratio was not performed, due to the high developmental mortality (see below).

One field-collected female, after depositing 110 eggs in the first 37 days that she was held in the laboratory, began to deposit eggs that produced only males. This may have been the result of sperm depletion, as reported for *G. legneri* (7).

Survival of immature stages Mortality of the immature stages was high. Only 94 of 186 parasitized hosts (51%) produced adult parasitoids. Of 966 eggs deposited, 260 (27%) died as eggs, 175 (18%) as feeding larvae, 101 (10%) as prepupae, 11 (1%) as pharate pupae, 51 (5%) as pupae, and 17 (2%) as adults which did not emerge from the cocoons, with only 351 (36%) producing active adults. Compared with developmental mortality of only 28% for *Goniozus nephantidis* (Muesebeck) (10), this suggests that the rearing procedure may not have been suitable.

Biological control potential *Parasierola swirskiana* is uncommon on first-generation larvae of *B. amydraula*, appearing in the field only on the last of these larvae, in early May (personal observations). Population levels of the parasitoid may be too low to be detected before this time. Alternatively, *P. swirskiana* may avoid earlier-season parasitism because of the size of the date fruits, which may be too small to accommodate both the host larva and the parasitoid. Small fruit size early in the season similarly forces *B. amydraula* larvae to leave the fruits and pupate in their fourth rather than fifth instar (personal observations). *P. swirskiana* attacks late-instar larvae, thus contributing to a reduction in infestation only

in the subsequent generation. As few first-generation larvae are parasitized, *P. swirskiana* has little immediate impact on the damage-inflicting second generation.

The combination of adult female longevity (maximum > 70 days), short generation development time (mean 14 days), laying of several (mean 5) eggs per host, and brood guarding, results in a relatively high parasitoid population density in the summer months which may be sufficient to suppress third-generation *B. amydracula* populations. Many second-generation *B. amydracula* larvae enter diapause to emerge the following year (personal observations), possibly to avoid a high probability of parasitism of their progeny as third-generation larvae.

The generally low natural levels of parasitism by *P. swirskiana* are in themselves insufficient to provide decisive short-term control. However, augmentative releases of *P. swirskiana* on first-generation *B. amydracula* larvae may be considered in the future as an alternative to the current practice of chemical treatments. Further studies are necessary before the implementation of such releases, including evaluation of whether the parasitoid develops successfully within small fruits, and development of a method for mass-rearing.

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