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Biology of *Dicondylus americanus* (Perkins) (Hymenoptera: Dryinidae) *

Dicondylus americanus (Perkins), a native parasite of delphacid planthoppers, was first described as a *Haplogonatopus* by PERKINS (1905) from Ohio. GIRI & FREYTAG (1982), after studying its morphological characteristics, transferred it to the genus *Dicondylus* Curtis.

PERKINS (1905) reared and studied some aspects of its biology while attempting to use this species to control the sugarcane planthopper. FENTON (1918) also studied the biology of some species of dryinids including *D. americanus* and failed to observe mating of *D. americanus* or *Gonatopus erythrodes* (= *bicolor* Ashmead). WALOFF (1974) observed mating in only 1 pair of *Dicondylus bicolor* (Haliday). PERKINS (1905) observed mating of *Echthrodelphax* sp. Perkins and reported that the male died a short time after mating. RAATIKAINEN (1961) studied development of *Dicondylus helleni* Raatikainen. The developmental stages of *D. americanus* have been studied by GIRI & FREYTAG (in press). CHANDRA (1980) and KITAMURA (1982) have reported behavior and development of dryinids including those that parasitized planthoppers. PONOMARENKO (1975) studied some spp. of *Gonatopus* Ljung and *Neogonatopus* Perkins which parasitized leafhoppers and noted that after oviposition, the development of the host nymphs stopped.

FENTON (1918) obtained a total of 13 eggs/female and the greatest number of eggs/female/day was 6. Little has been reported on the host range of *D. americanus* except that PERKINS (1906) reported rearing this on *Perkinsiella saccharicida* (Kirkaldy) as a host and it was reared on *D. lutulenta* (Van Duzee) and *D. campestris* (Van Duzee) from Ohio. The

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purpose of this study was to determine mating, predatory behavior, fecundity and the host range of *D. americanus*.

MATERIALS AND METHODS

Field collected *D. lutulenta* and *D. americanus* were colonized in the greenhouse according to the methods described by GIRI (1982). The hosts and parasites, used in the following experiments were taken from such colonies.

Courtship and mating behavior - To ensure the parasites were vergin, pupae were removed from the colony and placed individually in gelatin capsules (No. 00, Eli Lilly and Co.) for emergence and were checked twice daily. Failure to effect mating in four dram vials suggested use of smaller arena. As the adults emerged, individual male and female parasites were placed together in a gelatin capsule and watched for 1 h. These observations were made between 9 to 12 AM over a period of about 4 weeks. In a similar experiment, 3 males were placed with each female to see whether the mating incidence increased. When mating occurred, its duration was recorded.

Fecundity - Twenty five *D. lutulenta* nymphs were exposed to each female parasite (N = 20) for oviposition in individual cages daily and the number of progeny produced were counted. The cages were same as those used by GIRI & FREYTAG (1983). A regular supply of 3rd instar host nymphs was obtained from greenhouse colony of delphacids (GIRI, 1982). In the first set, 6 parasites, which had emerged within 24 h, were placed with 25 such nymphs/pair of male and female parasite/cage. The parasites were transferred to similar new cages in every 24 h until the female parasite died.

This experiment was repeated for a 2nd (N = 6) and 3rd (N = 8) set of female parasites, respectively. In the 2nd set, the delphacid nymphs were 24 days old and the male parasites were replaced as they died. In the 3rd set, the delphacid nymphs were 22 days old and 5 male parasites were initially placed with each female parasites. These changes were made to facilitate mating.

Fecundity was calculated as the number of larval sacs produced on the total number of hosts used. Then, the fecundity of the parasites of each set was compared by Duncan's multiple range test. The average fecundity, survival of the 3rd and 4rth instar larvae, pupae and the total longevity for the male and female parasites were calculated from the total of 3 sets.

The dead nymphs within each cage, after the parasite was transferred, were taken out and checked for feeding signs under a binocular microscope. The ones with broken terga were recorded as fed upon and killed. Such victims looked collapsed and dried, because the parasite removed most of the host's body fluid.

Sex ratio and longevity - The sex ratio of progeny was calculated only for those mated females which produced both sexes. Longevities for the male and female parasites were calculade as the periods, from adult emergence to death.

Predation vs parasitism - We tested whether the parasite fed and parasitized the same host by placing newly emerged parasite in a small petri dish, 3.5 cm diam., with 10 3rd to 4th instar nymphs. The initial times to capture a host and the duration of feeding or ovipositing were recorded.

Host preference - It has been observed in the field that several species of delphacids were parasitized by *D. americanus* (GIRI, 1982). Therefore, *D. lutulenta, D. campestris, Liberniella ornata* (Stal) and *Sogatella kolophon* (Kirkaldy) were tested for host preference by giving free choice of above mentioned hosts. Six nymphs of each species, approximately of equal size, were placed in a cage and female parasite was introduced for 3 h

(N = 25 cages/sp.). Delphacids which were dead within 24 h were checked for sing of feeding by the parasite and the remainder of the delphacids were checked after 3 weeks for parasitism. The total number of delphacids killed either by feeding or parasitizing in each species were combined and compared using Duncan's multiple range test (DMRT).

RESULTS AND DISCUSSION

Courtship and mating behavior

Male parasitic Hymenoptera usually display courtship by fanning wings (VINSON, 1978; GIRI *et al.*, 1982). When the male and female *D. americanus* were placed 1:1 in a capsule only 38% male responded by wing fanning, sometimes this was inconspicuous. No other courtship was observed. Newly emerged receptive females seemed to withdraw their antennae and remain motionless for 5 to 10 s. Mating between 24 h old adults were less frequent than that described for braconid parasites (VINSON, 1978; GIRI *et al.*, 1982). Of 100 pairs observed 31 attempted mating within 10 s to 31 min. for 1 to 7 times. Only 12% (of 100 pairs) mated for a period of 10 to 90 s. When wing fanning was observed the male pursued the female for a distance of 1 to 2 cm. When 3 males were placed with each female, 22% (N = 50) mated. In one case, a male attempted 7 times within the observation period and mated for a total period of 3 min. and 55 s. This mated female produced five female progeny before any male emerged. This indicated that multiple mating may increase the famale ratio. However, further data will be needed to confirm this.

Fecundity

When the number of larval sacs produced on the parasitized hosts in 3 different sets were compared (Table 1), 1st set had significantly ($P < 0.05$) greater number of parasitism than the 3rd set. Although all 3 sets of experiments were run at same place, same conditions but different times. However, in the 2nd and 3rd sets, hosts were older than in the 1st set. Beside this, in the 3rd set, among 8 females used, 3 females produced 41, 44 and 65 progeny while other 5 produced between 150 to 287. These data are close to 2nd set (193 to 312 progeny), however significantly different ($P < 0.05$) than 1st set (270 to 373 progeny). This time difference between the 1st and the 3rd sets was one year. So, was this the effect of long term greenhouse rearing, is yet to be determined.

When progeny produced in all three sets were combined the average production of progeny/female/day increased after the 1st day, peaked on the 9th day and declined thereafter (Fig. I). The reproductive potential of the parasite remained statistically similar ($P > 0.05$) from the 2nd to the 13th day after emergence as shown by DMRT.

TABLE 1 - Longevity of female parasite, average number of host nymphs used and different stages of *Dicondylus americanus* (Mean±se).

Sets [1]	Longevity of female parasite	Mean number of		Mean number of parasite [2]		
		Host Nymphs	Parasitized Hosts	4th instar	Pupae	Adults
I	23.3±1.4	554.2±28.5	332.3±17.1	288.5±16.5	240.3±14.4	185.7±12.4 a
II	21.0±1.5	525.0±37.2	259.5±24.3	211.0±20.8	171.5±19.2	96.8±11.6 b
III	19.9±2.2	496.9±50.6	161.9±29.0	146.3±32.2	128.7±24.2	104.5±20.4 b
Mean [3]	20.9±1.1	522.5±27.7	242.2±22.9	208.4±19.8	175.0±16.9	123.8±14.0

1 - Sets I and II are average of 6 females in each, and set III is an average of 8 females.

2 - Sets followed by similar letters are not significantly different ($P > 0.05$) according to Duncan's multiple range test.

3 - Mean of I, II and III (3 sets).

Of 10,450 host nymphs used in all 3 sets, 4845 (46.3%) were parasitized (Table 1). We consider this is still a conservative number, because GIRI & FREYTAG (in press) observed that some eggs either failed to develop and show sacs, or developed within the body of the host and ulti-

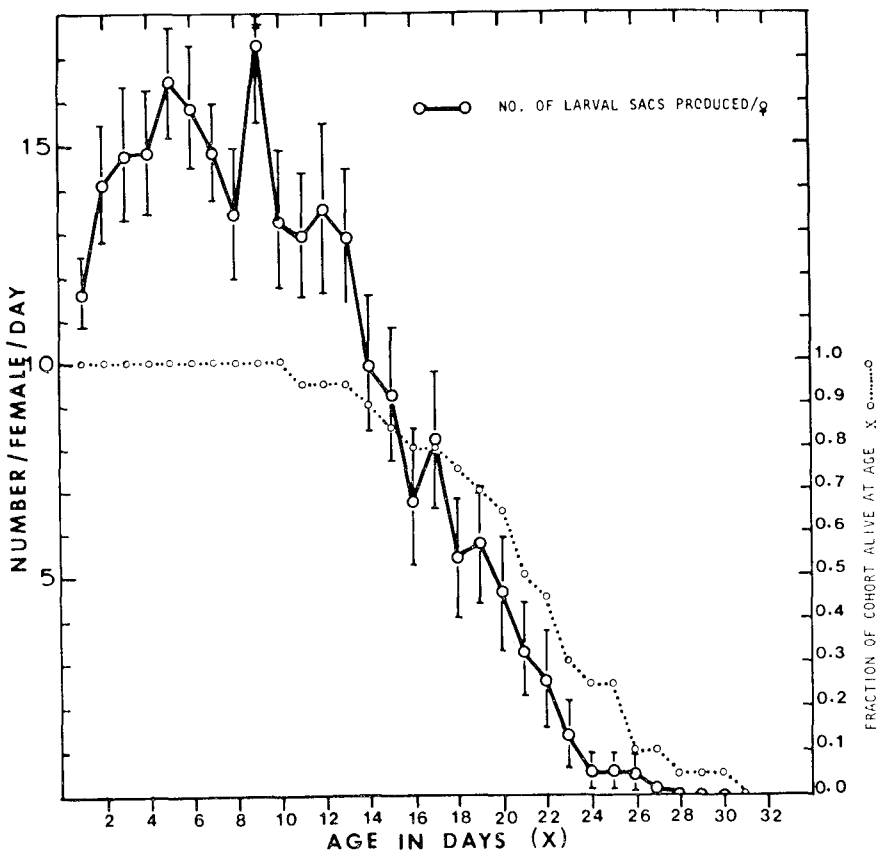

Fig. I - Production of progeny (larval sacs) by, and survivorship of a cohort of 20 *Dicondylus americanus* females in a greenhouse at 26-30°C when provided with 25 *Delphacodes lutulenta* nymphs/day. (Bar = ±se).

mately died. Such cases are unaccounted for in our data. Therefore, the actual fecundity may be higher than that obtained by observing larval sacs. When the data taken for predation (6.8/female) were added to the parasitism data (Fig. II) the number of *D. lutulenta* killed/female was 53.2%. Of the total number of observed larval sacs (4845), 52.3% emerged as adult (Fig. III). KITAMURA (1982) observed similar results that *Haplogonatopus atratus* Esaki and Hashimoto had about 18% predation and 36% parasitism

on each of the 2 hosts, *Sogatella furcifera* Horvath and *Laodelphax striatellus* Fallen.

Within the total number of progeny (1845), there were losses of 14.07, 13.75 and 19.97% individuals due to mortality in the 3rd, 4th instar larvae

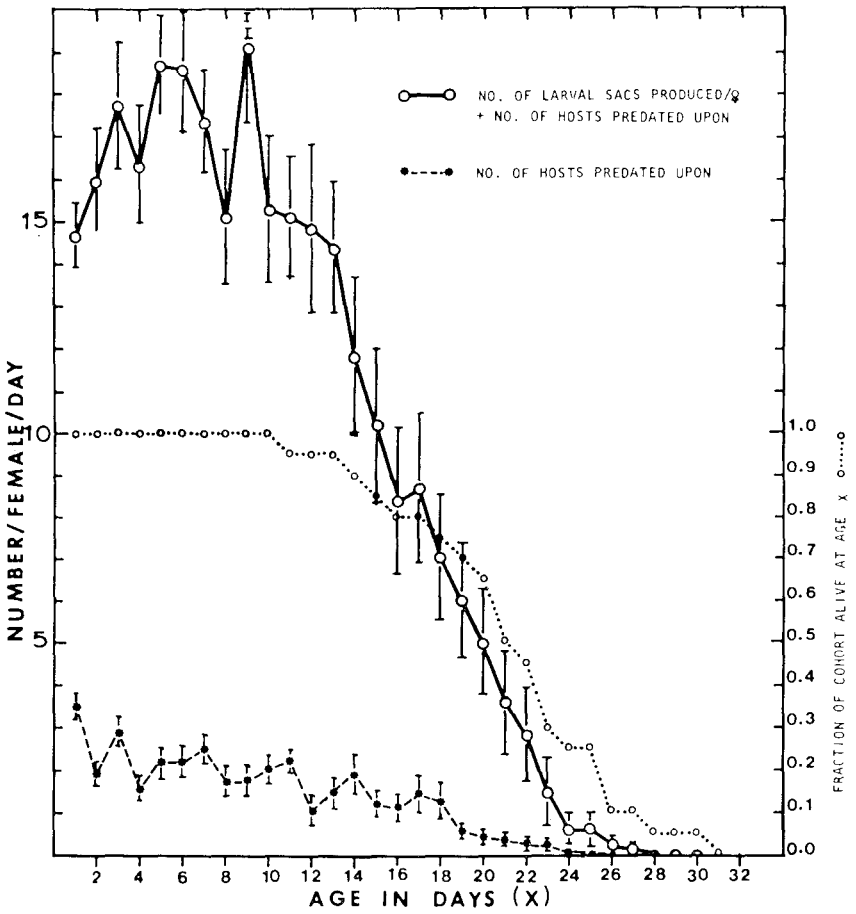

Fig. II - The number of *Delphacodes lutulenta* that can be killed by, and survivorship of a cohort of 20 *Dicondylus americanus* females in a greenhouse at 26-30°C when provided with 25 host nymphs/day. (Bar = ±se).

and pupae, respectively (Table I; Fig. III). The mortality of the 3rd instar larvae may have been due to dehydration, or the host not being able to feed properly. Some of the 4th instar larvae died after emergence from the sacs because they either got entangled in honeydew produced by the delphacids and could not move or the larvae became dehydrated after a long search for a suitable pupation site and died. We also believe dehydration to be the primary cause of pupal mortality.

PONOMARENKO (1975) and CHANDRA (1980) have observed that once a dryinid parasite oviposited on leafhopper hosts, the host development was inhibited. Our observations in this species suggested that the development of the delphacid host was not inhibited. KITAMURA (1982) has also repor-

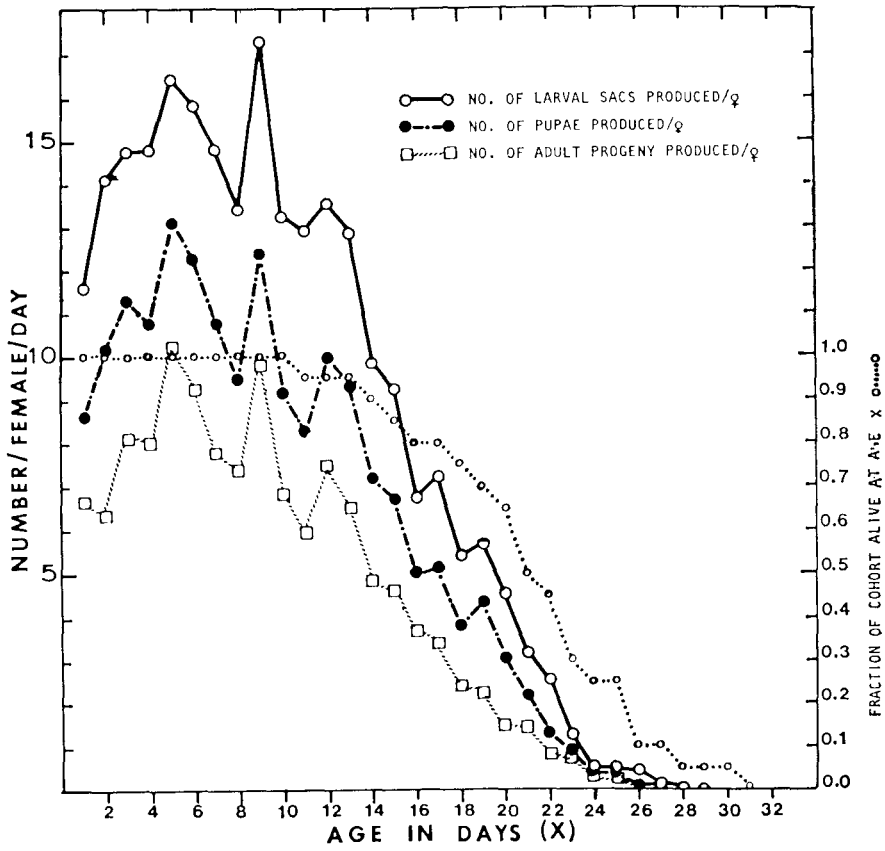

Fig. III - Relative numbers of progeny (larval sacs) pupae and adults produced by, and survivorship of a cohort of 20 *Dicondylus americanus* females in a greenhouse at 26-30°C when provided with 25 *Delphacodes lutulenta* nymphs/day.

ted similar observation. There may be a critical age of a host before which, if parasitized, the host's development is inhibited. This was evidenced by our data that 33, 87 and 80% of the parasitized *D. lutulenta* nymphs became adults in the 1st, 2nd and 3rd sets, respectively. In the 1st set the nymphs were 3rd instar or younger and in the other 2 sets the nymphs were 3rd instar or older at the time of parasitization.

Sex ratio and logevity

Unmated female produced only male progeny. Not all parasites that were usede in the experiments were mated. In each of the 1st and 2nd sets only female mated as indicated by production of female progeny. However, in the 3rd set, all of the females mated. The reason for unsuccess-ful mating between 1:1 male and female ratio is unknown. It may be possible that because of smaller size of males (GIRI & FREYTAG, 1982), not all males could readily mate.

The sex ratio among the progeny of mated females was 3 males to 1 female. The male longevity was 2.2±1 days and was significantly ($P < 0.05$) less than female longevity 20.9±1 days (Table I). The males were not seen to feed and their only function seemed to be mating. The females fed on water or honeydew produced by delphacids, and actively searched for hosts.

Predation vs parasitism

The parasites were seen to capture a host and bite between 2nd and 3rd terga of the host and feed through the wound. The initial time for capture of a prey by a newly emrged female parasite varied from less than 1 min. to 10 min. and the mean±se was 3.5±0.2 min. ($N = 30$). This time was longer (19 to 15 min.) when the newly emerged female was exposed to 5th instar nymphs or adults. All the female ($N = 30$) fed on the 1st host caught. 90% of the females fed on the 2nd host caught, 60% of the females fed on the 3rd host caught and all females oviposited on the 4th host caught. First 3 or 4 ovipositions were made in quick succession within a few min., then the period between ovipositions increased. The feeding period (4.8±0.4 min) was significantly longer ($P < 0.05$, t-test) from oviposition period (2.9±0.3 min.). None of the parasites ($N = 30$) fed and oviposited on the same host. Positions of holding the host while feeding or ovipositing were similar to that described by (CHANDRA (1980) for *Pseudogonatopus nudus* (Perkins). It can easily be distinguished by the grip of the parasite on the host, whether she is feeding or ovipositing. There were some cases of superparasitism as evidenced by the presence of two or more larval sacs on a parasitized host, but this usually occurred when the number of hosts in the cage were less than 25/day.

Host preference

We reared *D. americanus* from field collected, parasitized *D. lutulenta*, *D. campestris*, *D. puella* (Van Duzee) and *L. ornata*. Our free choice test (Table 2) showed *D. lutulenta* was the preferred host ($P < 0.05$) over *D. campestris* and *L. ornata*. There was no significant difference ($P > 0.05$)

TABLE 2 - Host preference by *Dicondylus americanus* when given free choice of following hosts.

Host spp.	Total nymphs	No. of hosts killed		
		Fed	Parasitized	Total *
Delphacodes lutulenta	152	27	45	72 a
Delphacodes campsetris	152	17	16	33 b
Delphacodes puella [1]	25	5	3	8
Liburniella ornata	152	26	10	36 b
Sogatella kolophon [1]	38	4	1?	4

(*) Totals followed by similar letters are not significantly different ($P > 0.05$) according to Duncans's multiple range test.

(1) Not included in the comparison.

between *D. campestris* and *L. ornata*. Beside these 3 species, we also observed feeding and ovipositing on *S. kolophon* and *D. puella* but because of inadequate supply of nymphs, they were not compared.

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SUMMARY

The biology of *Dicondylus americanus* (Perkins) was studied using *Delphacodes lutulenta* (Van Duzee) as the host. When 1 male was placed with each female (N = 100) 12% mated. When 3 males were placed with each female (N = 50), the mating increased to 22%. The average fecundity calculated from the number of larval sacs produced was 242.25 progeny/female (N = 20). In addition to parasitism, each female fed on and killed an average of 37.7 hosts/female. Survival of all progeny from oviposition to adult emergence was 52.3%. Third instar or older hosts, continued to develop to adulthood even after being parasitized. *Dicondylus americanus* is an arrhenotokous parasite having a sex ratio of 3 males to 1 female among the progeny of mated females. The longevities of male and female parasites were 2.2±1 and 20.95±1 (Mean±se) days, respectively. No female fed and oviposited on the same host (N = 30).

This species parasitized and successfully developed on 3 species of delphacids, *D. lutulenta*, *D. campestris* (Van Duzee) and *Liberniella ornata* (Stal), but *D. lutulenta* was the preferred host ($P<0.05$).

RIASSUNTO

E' stata indagata la biologia di *Dicondylus americanus* (Perkins) usando *Delphacodes lutulenta* (Van Duzee) come ospite. Quando un maschio viene posto a contatto con una femmina (N = 100) il 12% di esse si accoppia. Quando tre maschi sono posti

a contatto con ciascuna femmina (N = 30), la percentuale di quelle accoppiate aumenta al 22%. La fecondità media, calcolata in base al numero dei sacchi larvali prodotti, è stata di 242,25 discendenti/femmina (N = 20). Ogni femmina, oltre a parassitizzare, si è alimentata ed ha ucciso una media di 37,7 ospiti. La discendenza sopravvissuta, dall'ovideposizione all'emergenza degli adulti, è risultata essere il 52,3%. Dal terzo stadio in poi gli ospiti continuano lo sviluppo fino ad adulto nonostante la parassitizzazione. *D. americanus* è un parassitoide caratterizzato da partenogenesi arrenotoca con una sex ratio di tre maschi per ogni femmina, nella progenie di femmine accoppiate. La longevità dei maschi e delle femmine del parassita è stata rispettivamente di 2,2±1 e di 20,95±1 (media±deviazione standard) giorni. Nessuna femmina si alimenta e ovidepone sullo stesso ospite (N = 30). Questa specie parassitizza e si sviluppa con successo su tre specie di delfacidi, *D. lutulenta*, *D. campestris* (Van Duzee) e *Liberniella ornata* (Stal), ma *D. lutulenta* è l'ospite di elezione (P < 0,05).

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