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REARING *GLYPTA FUMIFERANAE* [*HYM. : ICHNEUMONIDAE*] ON A MULTIVOLTINE LABORATORY COLONY OF THE WESTERN SPRUCE BUDWORM (*CHORISTONEURA OCCIDENTALIS*) [*LEP. : TORTRICIDAE*]

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Methods were developed for rearing *Glypta fumiferanae* Viereck on a nondiapausing laboratory colony of the western spruce budworm, *Choristoneura occidentalis* Freeman. Both host and parasite are univoltine and undergo diapause in nature. In this study, the parasite's voltinism was synchronized with that of a nondiapausing host. *G. fumiferanae* mated readily in the laboratory, and 5 consecutive generations were reared with an average generation time of less than 8 weeks-much less than the 23 weeks needed for 1 generation to develop in the field. Developmental times are reported, and some aspects of behavior described.

KEY WORDS : *Glypta fumiferanae, Choristoneura occidentalis,* western spruce budworm, rearing, parasites, parasitoids.

The ichneumonid *Glypta fumiferanae* Viereck is an important larval endoparasite of both the spruce budworm (*Choristoneura fumiferana* [Clemens]) [*Lep. : Tortricidae*] and the western spruce budworm (*C. occidentalis* Freeman) throughout their ranges in North America (**Dowden** *et al.,* 1948 ; **Wilkes** *et al.,* 1948 ; **Carolin & Coulter,** 1959 ; **Krombein** *et al.,* 1979). In nature, *Glypta fumiferanae* diapauses in overwintering 2nd instar host larvae. Attempts have been made in the past to rear this insect without diapause (**Shon & Shea,** 1975 ; **D. Johnson,** pers. comm., 1980) in order to provide a year-round supply of parasites for laboratory testing. **Shon & Shea** (1975) succeeded in rearing 1 generation of male progeny on a nondiapausing laboratory colony of the western spruce budworm, but were unable to mate the parasites successfully. *G. fumiferanae* is arrhenotokous, so unmated females produce only male progeny. **Johnson** (pers. comm., 1980) was unable to rear progeny of either sex, apparently because of nutritional reasons.

This paper describes techniques used successfully to rear 5 consecutive generations of *G. fumiferanae* on a multivoltine laboratory colony of western spruce budworms. Normally an unparasitized host has a generation time of about 7 1/2 weeks. Our methods reduced average generation time for the parasites from 23 weeks to less than 8 weeks.

MATERIALS AND METHODS

Glypta fumiferanae pupae were reared from field-collected spruce budworms (*C. fumiferana*) in July, 1980 at Rhinelander, Langlade Co., Wisconsin. The adult parasites that emerged were sent to Berkeley, California, in 1/2-liter paper cartons. In July 1981, *G. fumiferanae* pupae were collected after emergence from western spruce budworm (*C. occidentalis*) larvae in the Jemez Mountains, Sandoval Co., New Mexico. Pupae were sent to Berkeley in gauze-filled 1/4-liter paper cartons.

A nondiapausing colony of western spruce budworms with a generation time of about 7 1/2 weeks (**Robertson,** 1979) was used to rear the parasites. Insects were reared at 17-24°C and 44-84 % RH under a natural photoperiod (L:D = 9:15 to 14.5:9.5). As adult parasites eclosed, they were transferred to 1/4-liter paper cartons with nylon mesh screen on both ends, similar to ones used by **Ryan** (1980) to rear several parasites of the larch casebearer, *Coleophora laricella* (Hübner) (*Lep. : Coleophoridae*). We modified Ryan's method by placing a water-saturated cotton wad and a drop of honey on the top of the upper screen of each carton. Adults of *G. fumiferanae* fed and drank readily through the screen, eliminating the need to open the containers repeatedly. Fresh water was squirted onto the cotton each day.

Within 1 to 2 days after emergence, each parasite female was sequestered with from 1 to 3 males in a 2-liter paper carton. Females seemed most receptive to 2- to 4-day-old males. Initial tests showed that a steady air flow through the mating cages to produce an odor gradient (as described by **Finney & Fisher,** 1964 and **Ryan,** 1980) was not necessary for mate location and successful mating.

After 5 to 7 days, each mated female was transferred to a 150-x-15 mm plastic Petri dish containing 100-150 1st and 2nd instar western spruce budworms. The Petri dish bottom was lined with filter paper to provide traction for ovipositing parasites. Honey was streaked on the underside of the Petri dish lid to feed the adult parasite, and a slice of artificial diet (**Robertson,** 1979) was provided to feed the budworm larvae. The budworm larvae spun hibernacula in a 4-x-12 cm strip of sterile gauze draped over the diet. A 1-cm diam hole was ground through the Petri dish lid and was plugged with a water-saturated cotton wad to provide water for the parasite. We prevented the escape of small host larvae by removing the air vent lugs from the Petri dish lids and tightly closing the Petri dishes with rubber bands. Approximately every 5 days the host larvae were transferred to 100-x-15 mm Petri dishes containing artificial diet to complete their development, and another 100-150 fresh host larvae were provided. This procedure was performed until the parasite died.

Searching and ovipositing normally began immediately and continued until the female parasite died. Contrary to the results reported by **Lewis** (1960) and **Shon & Shea** (1975), the parasites in our study probed and apparently oviposited in both freemoving larvae and larvae in hibernacula, although they had some difficulty in immobilizing the freemoving larvae. This difference may be attributable to the traction provided by the filter paper used in our study. No cases of host-feeding were seen.

After the oviposition period, Petri dishes containing host larvae were checked daily for parasite larvae, which emerge from 5th and occasionally 6th instar budworms. Newly-emerged parasite larvae were transferred individually to 50-x-90 mm snapcover Petri dishes to complete development. Larvae of *G. fumiferanae* pupated soon after emergence from the host. The Petri dishes were checked each day, and dates of pupal and adult molts were recorded. Newly-emerged adult male ichneumonids were transferred to 1/4-liter cartons to await the emergence of females. Newly-emerged adult females were mated immediately.

RESULTS AND DISCUSSION

No elaborate courtship behavior was witnessed during observations of 9 copulations. Copulation usually took place within the first 30 minutes after the female was introduced into the mating container, or presumably not at all. Females mated up to 3 times in quick succession, apparently once with each of the 3 males present, after which they became refractive to further attempts at copulation. There was no apparent long-range attraction of males ; the male typically moved randomly about the container until he happened to come within a few centimeters of the female. He then moved in rapidly with wings vibrating and, if she were receptive, mounted the female and copulated quickly. Copulation lasted from less than 1 to 3 1/2 minutes, during which time wing vibrations ceased completely. At least 2 polyandrous females produced viable female progeny, which was evidence of successful insemination. Some parasitic Hymenoptera have low rates of insemination if they copulate more than once because the spermatophore does not align properly in the spermathecal duct (**Flanders,** 1946b ; **Finney** *et al.,* 1947), but this was apparently not the case with our colony of *G. fumiferanae*. Whether *G. fumiferanae* females mate more than once under natural conditions is not known.

Developmental times, number of progeny per generation, number of progeny per female parasite, sex ratios of parasite progeny, percent parasitism, mean rearing temperatures, and mean percent humidities were documented for 6 generations (table 1). Mean developmental times (egg to adult), which ranged from 43 to 54 days for both sexes combined, were inversely proportional to mean rearing temperatures ($r = -0.57$). The males' mean development time was 1.1-7.6 days less than the females', which coincided with the females' observed preference for slightly older males. This phenomemon has been noted frequently in Hymenoptera (**Finney & Fisher,** 1964).

When fed honey and water, adult females lived from 19-73 days after eclosion ($\bar{x} = 38.0 \pm 13.4$ days), which was considerably longer than the period reported by **Stairs** (1983) in his study of fecundity and longevity in *G. fumiferanae* reared from *C. fumiferana*. Perhaps this difference can be attributed to the wider range of temperature fluctuations in Stairs' study, the difference in host species, or the fact that we provisioned our parasites with water as well as honey.

The number of progeny per generation ranged from 23 to 292, and the mean number of progeny per *G. fumiferanae* female (excluding nulliparous females) ranged from 7.7 to 45. Progeny sex ratios varied widely (from 55:1-2:1), which is common in arrhenotokous Hymenoptera (**Flanders,** 1946a ; **Doutt,** 1964). The high proportion of male progeny in the 1980 F_1 generation probably resulted from shipment of the parent adults under conditions unconducive to mating. None of those adults were seen to copulate after their arrival, but 1 female must have copulated before shipment or in transit because female progeny ensued. All of the F_1 females were the progeny of a single parent female, so it is unlikely that the other parent females mated.

Percent parasitism was based on the ratio of parasites emerging per surviving host insect, because during late 1980 the host colony developed a protozoan infection (*Nosema fumiferanae* [Thompson]) which greatly reduced the number of hosts surviving to maturity. This may explain the decline in percent parasitism over time (i.e., parasitized hosts may have suffered greater mortality from the infection than unparasitized hosts). The decline may also have resulted from inbreeding, however, since there was apparently only 1 mated female in the parent generation and some subsequent generations yielded very few females. Whatever the cause, the F_5 generation failed to yield any progeny. Fresh parasites were obtained from the field in the summer of 1981, and rearing efforts were immediately successful.

TABLE 1

Biological data for 6 generations of laboratory-reared Glypta fumiferanae

Year and generation number	Progeny sex ratio, ♂ : ♀	Total no.of prog.	Mean prog. per female	Mean developmental times (a) (Days)			T (°C)	Rel. hum. (%)	Number surviv. hosts	% paras.(b)
				Females $\bar{x}$ ± S.D.	Males $\bar{x}$ ± S.D.	Males + females $\bar{x}$ ± S.D.				
1980 : F_1	55:1	165	16.5	54 ± 6.4	47 ± 4.9	47 ± 5.0	20.6	68	–	–
F_2	8.9:1	79	26.3	59 ± 11	51 ± 8.4	52 ± 8.9	20.6	62	144	55 %
F_3	5.1:1	135	45.0	59 ± 6.1	52 ± 7.0	54 ± 7.3	18.9	55	494	27
F_4	11.8:1	64	11.3	50 ± 4.4	49 ± 5.8	49 ± 5.6	19.4	59	559	11
F_5	7:1	23	7.7	51 ± 2.5	48 ± 5.5	49 ± 5.2	21.1	56	284	8.1
1981 : F_1	2:1	292	29.2	45 ± 3.1	42 ± 4.2	43 ± 4.2	21.7	66	1,032	28

(a) Mean developmental time from egg to adult stage.

(b) Ratio of parasites emerging per surviving host insect.

On the basis of this study, we conclude that a year-round, nondiapausing colony of *G. fumiferanae* could easily be maintained in the laboratory. Fresh infusions of field parasites might be necessary to maintain colony vigor and a sufficient level of parasitism to sustain the colony throughout the year. The type of mating container used was apparently critical to the success of year-round propagation of this parasite. Using these techniques, we were able to rear 5 full generations of the ichneumonid *G. fumiferanae* within 11 months, which is less time than it takes for 1 generation to develop in the field.

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RÉSUMÉ

Méthodes d'élevage du parasitoïde *Glypta fumiferanae* [*Hym. : Ichneumonidae*] sur une souche de laboratoire sans diapause, de la tordeuse occidentale de l'épinette [*Choristoneura occidentalis*] [*Lep. : Tortricidae*]

Les méthodes d'élevage du parasitoïde *Glypta fumiferanae* Vierek [*Hym. : Ichneumonidae*] sur une souche de laboratoire sans diapause de la tordeuse occidentale de l'épinette (*Choristoneura occidentalis* Freeman) sont décrites. Dans la nature le parasitoïde et son hôte sont univoltins et passent tous deux l'hiver en diapause. Dans cette étude, le développement du parasitoïde a été synchronisé avec celui de la souche sans diapause de l'hôte. Les adultes de *G. fumiferanae* s'accouplèrent facilement en laboratoire et 5 générations consécutives, d'une durée moyenne de 8 semaines chacune, comparativement aux 23 nécessaires dans la nature, se succédèrent. Cet article décrit la durée des différents stades de développement et certains aspects du comportement de ces parasitoïdes.

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