# Biological Observations of *Menochilus sexmaculatus*,[1] Reared on *Schizaphis graminum*[2,3]

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**ABSTRACT**

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When *Menochilus sexmaculatus* (F.) was reared upon the greenbug, *Schizaphis graminum* (Rondani), females laid an average of 11.4 eggs/day with a mean fertility of 70%; mean fecundity was 779.8 eggs. The mean number of days from egg to adult was 12.25 while average longevity for adults was 63.68 days. The amount of $CO_2$ expired for adults was found to increase with age. Males expire more $CO_2$/unit body weight than females and the rate of $CO_2$ expiration increases exponentially with increasing temperatures. Middle aged adults could not be induced to enter diapause by an abrupt reduction in photoperiod. Additionally, the greenbug was found to be a very satisfactory food source.

Insects of the family Coccinellidae are predacious to many species of aphids, spider mites, and scale insects. *Menochilus sexmaculatus* (F.), an aphidophagous coccinellid, is native to southeast Asia.

The aphid prey of *M. sexmaculatus* were reviewed by Cartwright et al. (1977); however, *M. sexmaculatus* also feeds on non-aphid hosts, including mealybugs (Pattarudriah and Basavanna 1953), the white cane fly and a fulgorid (Butani 1958), a delphacid (Patel 1968) and the sorghum stem borer (Jotwani and Verma 1969). In preliminary laboratory studies, we observed *M. sexmaculatus* feeding on *Heliothis zea* Boddie; however, longevity was shortened and reproduction was inhibited.

Biological studies of *M. sexmaculatus* with aphid prey include those by Maxwell-Lefroy (1909), Modawal (1941), Bagal and Trehan (1945), and Azim and Ahmed (1966). Rajamohan and Jayaraj (1973) compared fecundity of this predator when fed on 4 aphid species, while Gawande (1966) studied temperature effects on the biology of *M. sexmaculatus*.

Respirometry has been utilized to monitor the diapause condition (Parker et al. 1977, Sakurai 1969, Tadmor and Applebaum 1971). Most respiratory studies have utilized standard manometric techniques (Umbreit et al. 1964), while more convenient methods use gas chromatography (Tadmor et al. 1971) and infrared absorption techniques (Hamilton 1959, Turner and Charity 1971).

*M. sexmaculatus* was imported to the Department of Entomology at Oklahoma State University in 1975 (Cartwright et al. 1977). This strain was reported to be active on wheat infested with the greenbug *Schizaphis graminum* (Rondani) until snow fall in November (Ghani 1975). Because of its long activity period, *M. sexmaculatus* was selected for introduction into the United States to determine its effectiveness as a biological control agent against the greenbug, a major pest of small grain crops. Since colonization and establishment of the imported species is a major goal for biological control, biological information on introduced species is needed to determine if the goal is feasible. We present biological and respiratory observations of *M. sexmaculatus* reared on the greenbug under controlled laboratory conditions and the effects of a change in photoperiodic regime on non-diapausing adults of *M. sexmaculatus*.

## Methods

### *Laboratory Life History Observations*

All laboratory life history observations were made at 27°±5° C and 45–65% RH with 16:8 LD cycle. Each larva or adult pair of *M. sexmaculatus* was reared separately in a covered 29.6 ml plastic cup and was fed daily an excess of live greenbugs of varying age which were reared on *Sorghum bicolor* L. Also, adult pairs were provided daily with small honey droplets on the sides of the cups and with a cotton ball moistened with water.

Twenty adult pairs, taken from laboratory stock cultures, were used as the parent generation. Date of emergence from the pupa were recorded for each adult and this was counted as day 1 of the adult life cycle. Female beetles used were less than one day old and the males were less than 3 days of age.

Each adult pair was changed to a new cup every other day. Daily observations were made; mating and the onset of oviposition were recorded. Each egg cluster was identified and the number of eggs in the cluster was recorded for each female until death. If the male died first it was replaced with a new male less than 3 days old. If the female died first, the male was kept alone until death. Egg fertility was taken for each egg cluster laid by each female for the first 7 days of oviposition and once a week thereafter. Fertility was determined by graying of the pale yellow eggs and the appearance of dark rings of the developing larval segments visible through the egg.

### *Respiratory Observations*

The effects of an abrupt reduction in photoperiod on actively reproducing *M. sexmaculatus* adults were investigated. Rearing procedures for this group of beetles were the same as indicated above. The experimental group consisted of 30 mating pairs between 20 and 30

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days old. All 30 females had oviposited for at least 2 days. Mating pairs were randomly divided into 3 groups of 10 pairs. Each group was then placed in a Sherer® Model CEL 8 controlled environmental chamber with the photophase adjusted to 11, 13, 15 h. The temperature in all three chambers was 15.5°C in the scotophase and 21°C in the photophase. Relative humidity was not controlled and varied from 40–70%. The initiation of the experiment was designated Day 0 and was continued until Day 50. As above, all pairs were provided an excess of live greenbugs daily and were given a moistened cotton ball and honey droplets.

Daily ovipositional data were obtained for each pair. In addition, weekly egg fertility data were obtained. Twice weekly, individual pair weights and weight specific $CO_2$ expiration rates were determined.

An infrared absorption method for $CO_2$ quantification was chosen, using a Beckman® model 865 infrared $CO_2$ analyzer coupled to a Beckman® model 1005 strip chart recorder. This instrumentation allowed the rapid determination of a large number of samples by injection of each sample into a continuous stream of $N_2$ flowing through the analyzer. Samples were obtained utilizing a series of gas sampling chambers consisting of standard 29.6 ml polypropylene bottles. Each bottle had the bottom removed and replaced with the index finger from a Tru-Touch® vinyl medical glove. This served as a diaphragm allowing the removal of some of the gas mixture without causing a partial vacuum in the chamber. Each bottle had the cap replaced with a rubber stopper so that sampling could be performed using a syringe. After construction the volume of each chamber was determined for use in later calculations. Volumes were determined by measuring the volume of distilled $H_2O$ required to fill the chamber to capacity. Values were determined from chart recordings by comparison with a commercial standard gas mixture of 300 ppm $CO_2$ in $N_2$.

Prior to use each sampling chamber was ventilated and filled with normal atmospheric air having a $CO_2$ concentration of ca 330 ppm. Immediately after introduction of the *M. sexmaculatus* mating pair to be tested, the sampling chamber was sealed and an initial gas sample of 5 ml withdrawn. Each chamber was then left unagitated for 15 min, at which time a final 5 ml gas sample was withdrawn and analyzed. All sampling was performed at a laboratory temperature of 22°–24°C. Beetle weights were determined after the respiration tests using a Mettler® Model $H_2O$ balance accurate to 0.01 mg. Computer analysis of initial and final $CO_2$ concentrations, beetle pair weights, and gas chamber volumes allowed the calculation of $CO_2$ expiration rates in units of ml $CO_2$ expired/g pair weight/hour for each beetle pair on each sampling date.

Determination of the effects of different temperatures on $CO_2$ expiration rates were determined using a different group of beetles, 10 ♂ and 10 ♀ that had eclosed within a 5-day period. At the time of testing the beetles were ca. 14 days old. They were reared and maintained using a 15-h photoperiod. Sexed beetles as evidenced by mating were tested individually using the materials described above except that a test period of 45 min was utilized. The temperatures attained with a controlled environmental chamber for use in the study were 1°, 10°, 19°, 28°, and 37°C with RH of 40–70%. One replicate consisted of this entire sequence of temperatures which began with 1°C then transferred to each temperature until reaching 37° or began with 37° moving to lower temperatures until reaching 1°C. One replicate was performed each day. Three replicates of each high to low and 3 replicates of each low to high sequence were performed. The beetles were allowed to adjust to each temperature for 1 h prior to sampling.

## Results and Discussion

### *Life History Observations*

Newly emerged females had a mean preoviposition period of 5.6±0.86 days ($\bar{x}$ ±SE). Copulation was frequently observed before egg laying, with mating recorded in females as young as 2 days. During most of the adult life span, females deposited eggs daily, but oviposition in young and old females, oviposition was sporadic, with eggs laid singly or in small clusters. Eggs of *M. sexmaculatus* are cigar-shaped and pale yellow, and attached to the substrate in clusters, standing on end. Towards the end of the second day, fertile eggs turn grayish, with dark horizontal rings. *M. sexmaculatus* females averaged 11.4 ± 0.30 ($\bar{x}$ ±SE) eggs/day, with 74 the maximum number laid in one day. Clusters averaged 4.8 ± 0.8 eggs. Mean fecundity for all females was 779.8 ± 102.2 eggs, with 2388 the maximum number for one ♀. The oviposition period averaged 68.6 ± 6.64 days. Seventy % of the females laid fertile eggs.

*M. sexmaculatus* has 4 larval stages. Bagal and Trehan (1945) gave a detailed description of each stage. Table 1 gives the mean duration of each stage, weight in g and length in mm for *M. sexmaculatus* reared on the greenbug The mean number of days from egg to adult was 12.2±0.5.

Longevity for the adult (both sexes) averaged 63.67±5.2 days (Table 1); males lived a mean of 53.60±6.45 days, females 73.75±7.64 days. The longest longevity (143 days) was for a female.

### *Effects of Reduction in Photoperiod on Middle Aged Adults*

An analysis of variance showed no significant differences between treatment groups subjected to the different L:D regimens ($P = 0.05$). Data from all groups were therefore pooled to provide overall means.

Egg laying was highly variable from day to day but a gradual decline in ovipositional ability was evident after Day 20 (20 days after mating pairs were placed together) of the study (Fig. 1). This corresponds to a beetle age of ca. 45 days. The overall ovipositional mean was 10.9 eggs/♀/day (± 0.54). Day 20 seems to be near the midpoint of the period of maximum ovipositional ability. Interestingly, this same period is also the period of maximal egg fertility (Fig. 2). As expected, egg fertility also gradually declined with increasing age.

Mean pair weight declined very gradually in time but the magnitude of the decline was insufficient to solely account for the significant rise ($P = 0.05$) in $CO_2$ expiration (Fig. 3). A linear rise in temperature produced an exponential increase in $CO_2$ expiration rates (Fig. 4). As expected, smaller males exhibit a significantly ($P = 0.05$) higher respiration rate than females in all temper-

**Table 1.—Means and standard errors of live weight, length, and duration of life stages of *M. sexmaculatus* reared on greenbugs.[a]**

| Life Stage | | Weight (mg) | Length (mm) | Duration (days) |
|---|---|---|---|---|
| Egg | | | | 2.04±0.03(55) |
| I | $\bar{x}$ | 0.1±0.01(44) | 1.96±0.16(22) | 1.43±0.08(56) |
| II | $\bar{x}$ | 0.5±0.03(45) | 2.95±0.15(22) | 1.34±0.07(56) |
| III | $\bar{x}$ | 1.6±0.10(45) | 4.16±0.12(22) | 1.41±0.08(56) |
| IV | $\bar{x}$ | 4.1±0.30(44) | 5.80±0.14(22) | 2.98±0.12(56) |
| Pupa | $\bar{x}$ | 9.5±0.30(45) | 3.74±0.06(22) | 3.05±0.09(56) |
| Adult (Both sexes) | $\bar{x}$ | 7.7±0.30(45) | 4.73±0.12(22) | 63.68±5.19(40) |
| Adult (Males) | $\bar{x}$ | 7.4±0.30(11) | 4.39±0.15(11) | 53.60±6.45(20) |
| Adult (Females) | $\bar{x}$ | 9.2±0.60(11) | 5.07±0.10(11) | 73.75±7.64(20) |

[a] Values in parentheses are numbers of insects.

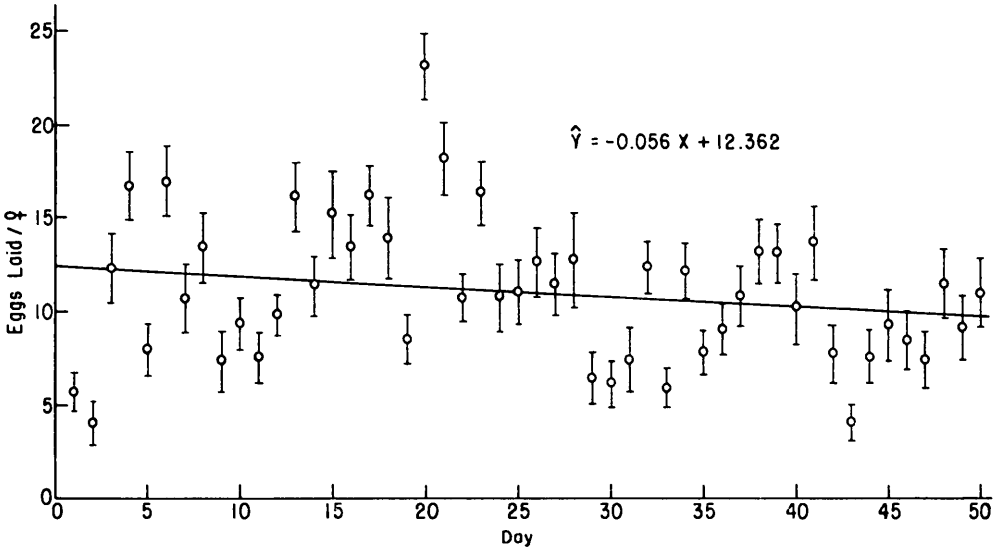


FIG. 1.—Average daily oviposition of 30 mating pairs of *M. sexmaculatus*. Vertical lines represent two standard errors.

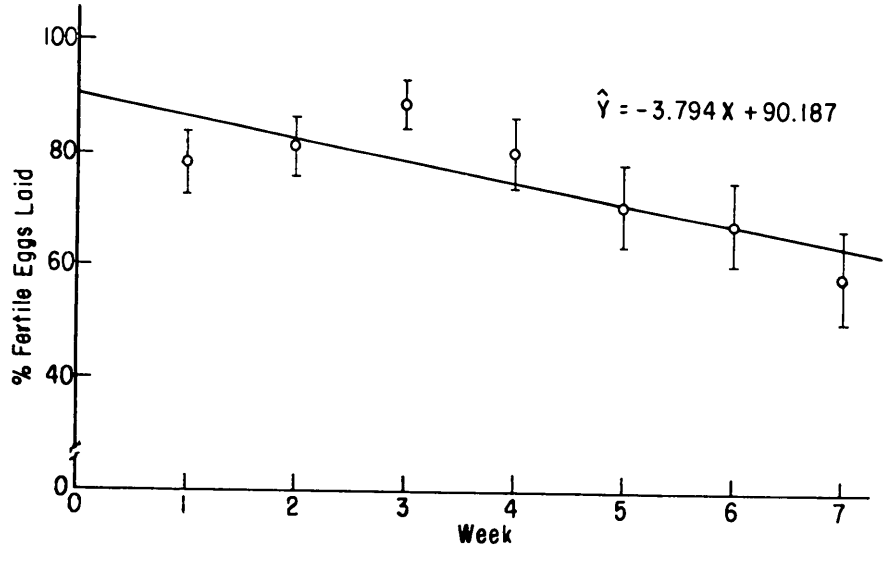


FIG. 2.—Average weekly egg fertility values of 30 mating pairs of *M. sexmaculatus*. Vertical lines represent two standard errors.

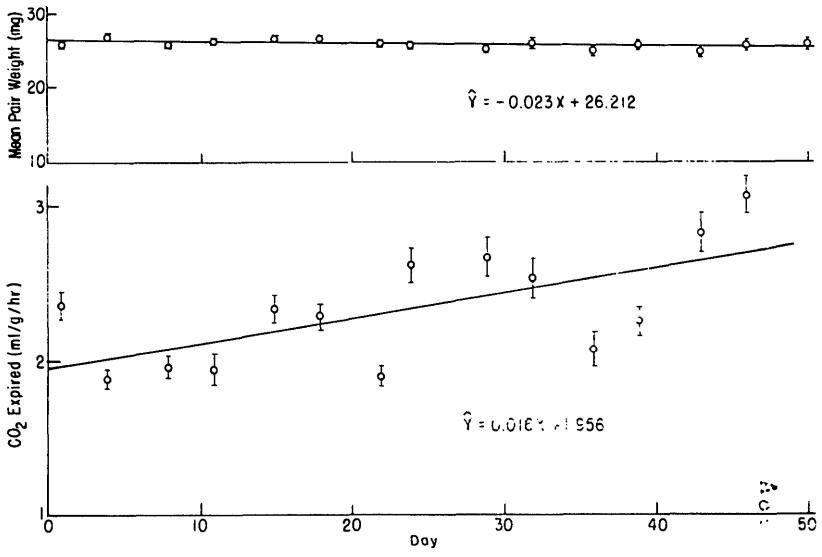


FIG. 3.—Mean pair weights (above) and $CO_2$ expiration values (below) for 30 mating pairs of *M. sexmaculatus*. Vertical lines represent two standard errors.

ature ranges. Furthermore, the increase in the respiration rate at the higher temperatures for males is greater than the increase for females, as seen in the significant divergence of the curves in Fig. 4. The sequence at which beetles were subjected to various temperatures did not produce any significant differences in responses.

Values for $CO_2$ expiration in *M. sexmaculatus* were slightly higher than values reported for *Chilocorus bipustulatus* (Tadmor et al. 1971, Tadmor and Applebaum 1971). This was true even though mean live weight values were comparable.

Hodek (1973) hypothesized that food sources for coccinellids can be divided into 3 groups; essential, alternative, and toxic. There can be degrees of suitability among the 1st 2 groups and degrees of harmfulness in the last group. Essential foods allow the completion of larval development and oviposition while alternative foods are used as energy sources for survival as opposed to starvation. *M. sexmaculatus* has been successfully reared in the laboratory through many generations on the greenbug. Using the before stated criteria the greenbug is an essential prey for *M. sexmaculatus*.

Success of establishment depends on suitable prey as well as suitable habitat. *M. sexmaculatus* is eurytopic, thus tolerates a wide range of temperatures, humidities, and flora. The habitats offered by the grain-producing states of the United States fall well within the range required by this predator. Presence of prey is then the prime factor for the successful establishment of *M. sexmaculatus*. Comparison of preoviposition, oviposition, and fecundity data from this study with data for *M. sexmaculatus* fed on different aphid hosts (Rajamohan and Jayaraj 1973) demonstrates that the greenbug is a highly suitable essential food source. These factors make *M. sexmaculatus* a logical choice for colonization as a biological control agent for the greenbug, *S. graminum*.

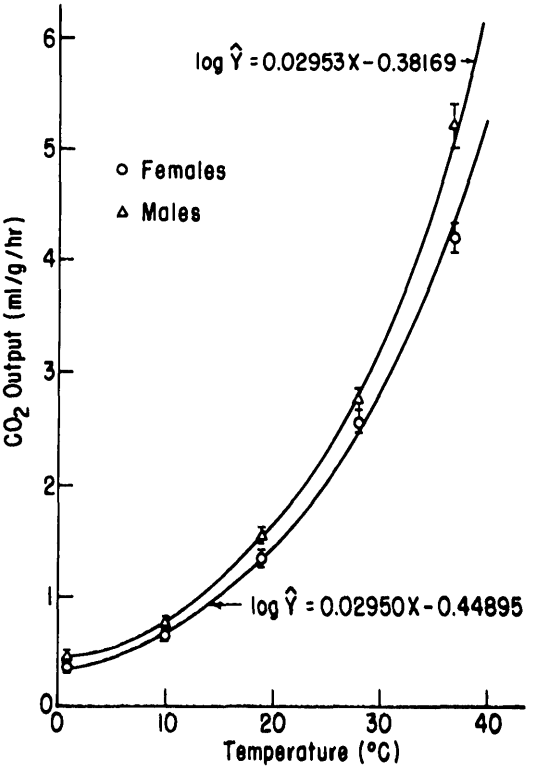


FIG. 4.—Average $CO_2$ expiration values for 10 males and 10 females of *M. sexmaculatus* at various temperatures. Vertical lines represent two standard errors.

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