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FOOD CONSUMPTION, FOOD UTILIZATION, AND METABOLIC RATES OF *GEOCORIS PUNCTIPES* [*HET. : LYGAEIDAE*] FED *HELIOTHIS VIRESCENS* [*LEP. : NOCTUIDAE*] EGGS(¹)

ALLEN C. COHEN

Biological Control of Insects Laboratory
2000 East Allen Road, Tucson, AZ 85719, U.S.A.

Food consumption and utilization were measured in *Geocoris punctipes* (Say) from 1st instar nymphs to adults that were fed eggs of *Heliothis virescens* (Fabricius). Growth in both sexes was similar until the final portion of the last nymphal period, when female growth rose sharply over that of males. Food absorption efficiency was 95.2 % ; growth efficiency (ratio of weight ingested) was 52.9 %, and metabolic efficiency was 55.6 %. RQ was 0.93, and oxygen consumption rates were 0.84, 1.37, and 1.80 μl O_2 mg body weight h^{-1} at 24 °C, 30 °C and 35 °C, respectively. Q_{10} for O_2 consumption was 2.14 (25-35 °C).

Since the appearance of **Waldbauer**'s (1968) and **Gordon**'s (1968) definitive treatments of quantitative nutrition of insects, numerous studies have appeared reporting consumption and utilization values in many kinds of insects and several kinds of food. However, **Slansky & Scriber**'s (1982) review of this subject reveals that there has been remarkably little attention to food consumption and utilization in predaceous terrestrial insects. This is especially true of predators with sucking mouthparts. Some recent reports have implicated *Geocoris punctipes* (Say) as an important predator of eggs of several species of agricultural pests (**Crocker & Whitcomb**, 1980, **Ragsdale** *et al.*, 1981). The present study was undertaken to examine the quantitative aspects of nutrition in the predaceous hemipteran *G. punctipes* and includes measurements of food consumption, growth, metabolic and digestive efficiencies and metabolic rates of this predator fed eggs of the lepidopterous pest, the tobacco budworm, *Heliothis virescens* (Fabricius).

MATERIALS AND METHODS

Geocoris punctipes used to initiate cultures for these tests were collected from 2 alfalfa farms in the Avra Valley ca. 32 km northwest of Tucson, AZ. They were kept in ca. 4 L card-

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(¹) Mention of a commercial product does not constitute a recommendation by the U.S. Department of Agriculture.

board cartons covered with organdy and were fed coddled beet armyworms *Spodoptera exigua* (Hübner) and whole green beans *Phaseolus vulgaris* L. Flattened cotton matting was used as an oviposition site. Newly hatched 1st instar nymphs were caged individually in 10 mm diameter X 10 mm long cylindrical plastic cages topped with fine mesh screen ; they were provided with food and water *ad libitum,* as previous experiments (**Cohen & Debolt**, 1983) revealed that water was required for survival in developing *G. punctipes.*

Freshly laid eggs of *H. virescens* were removed from waxed paper oviposition sites and provided each day in groups of 5, 10, 15 or 20/*G. punctipes* nymph, the number depending upon size of the *G. punctipes* being fed. There was always an excess of food to allow *ad libitum* feeding. Water was provided by insertion of vials stoppered with an organdy covered sponge. Eggs were weighed collectively to the nearest 0.1 μg (on a Cahn 25 Microbalance ® , Cahn Instruments, el Cerritos, CA) before and after being presented to the *G. punctipes* nymphs. Moisture contents of similarly treated eggs were determined gravimetrically with eggs dried at 105 °C until equilibrium weights were measured. Correction for natural weight losses of eggs fed the *G. punctipes* was made by calculations with the following formula from **Waldbauer** (1968).

$$\text{Corrected wt. of food eaten} = \left[1-\frac{a}{2}\right]\left[W-(L+bL)\right]$$

where : a = ratio of loss (in controls) to original wt.
b = ratio of loss (in controls) to final wt.
W = original weight of food.
L = final weight of food.

Daily, individual nymphs were anaesthetized with CO_2 and weighed to the nearest 1.0 μg. Exuviae from all molts were left in the cage and weighed after final ecdysis.

Because the atmosphere in the cage was dry (< 40 % RH), liquid frass deposited on the sides of the cage and organdy bottom dried rapidly; therefore it was assumed that there was negligible weight loss of the frass due to microbial decomposition. Analyses of frass samples (**Cohen**, 1983) of known weight collected from *G. punctipes* treated similarly to the experimental animals revealed that 25.12 % (± 4.07 SE) of dried fecal material is purine waste (xanthine, hypo-xanthine and uric acid). Fecal and urinary output were measured as follows : Cages were carefully washed with a total of 250 μl of Li_2CO_3/H_2O (0.5 %) solution. Aliquots of 20 μl were injected into an Altex-Beckman Model 320 ® HPLC equipped with an Ultrasphere ® 10μ C_{18} column. The solvent was 900 H_2O : 100 methanol and 0.005 M tetrabutylammonium phosphate (PIC-A® reagent from Waters Associates, Milford, MA) pumped at 2000 psi at 1.0 ml/min. Detector setting was 254 nM. The values measured for total purine concentration from the individual *G. punctipes* cages were multiplied by 1/2512 to calculate the total dry weight of the frass. Total frass weight minus weight of purines was used in calculating metabolic and absorption efficiencies (**Waldbauer**, 1968).

Combined groups of 3rd, 4th or 5th instar nymphs (10 of each) were placed collectively in a cylindrical 10 mm diameter X 12 mm length organdy-covered plastic cage and inserted into a 19 ml respirometry reaction flask and allowed to equilibrate to the desired temperature in a Gilson differential respirometer. Each experiment lasted for 3 h after a 1 h period of temperature equilibration. Five replications were made for each experimental group. Standard manometric procedures were used for O_2 consumption measurements and respiratory quotient (RQ) measurements as described by **Umbreit** *et al.* (1972).

RESULTS AND DISCUSSION

Of 50 1st instar nymphs used in this experiment, 17 reached the adult stage (10 ♂♂ : 7 ♀♀). Because there was no significant difference ($P > 0.05$, Student's-t test) in the performance of the 2 sexes in terms of growth or metabolic efficiencies, data for both sexes were pooled together for calculation of growth efficiency (ECI = 52.9 ± 14.17 S.D.), metabolic efficiency (ECD = 55.6 ± 14.53 S.D.), and absorption efficiency (AD = 95.2 ± 2.29 S.D.) measurements. Although there was no significant difference between sexes in either dry food consumption or weight gain for the whole feeding period, it appeared that there was a trend toward higher consumption and greater weight gain in females than there was in males (table 1). This trend was further indicated by the greater daily food consumption (fig. 1) and wet weights (fig. 2) of

TABLE 1

Means of food consumed and weight gained on a dry weight basis by 7 females and 10 male Geocoris punctipes *reared from 1st instar nymphs to the adult stage* (a)

	Weight of food consumed (mg)	Weight gained (mg)
♀♀	2.31 (0.54)	1.27 (0.25)
♂♂	1.94 (0.52)	0.93 (0.06)

(a) Means tested and found not significantly different ($P > 0.05$) by a Student's-t test.

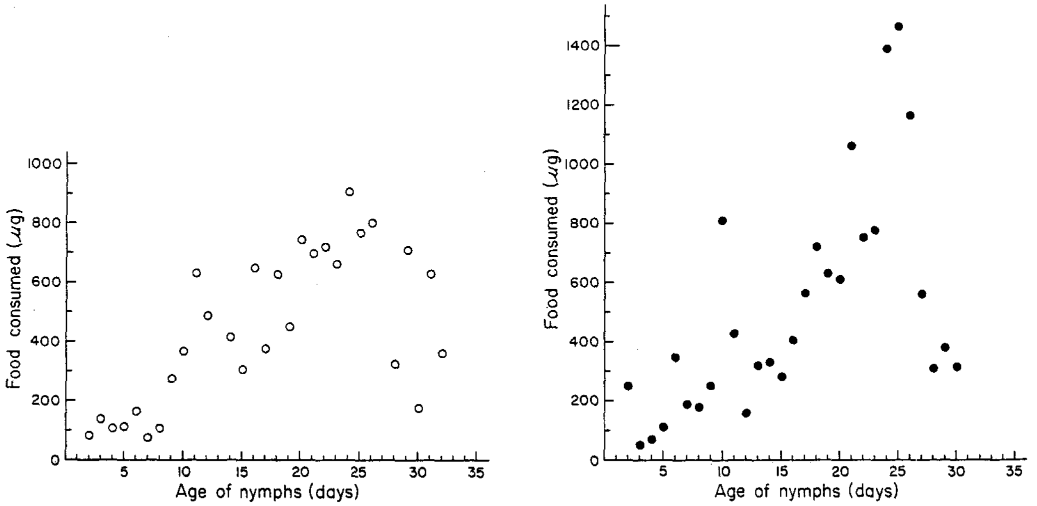

Fig. 1. Mean daily wet food consumption in 10 *Geocoris punctipes* males (open circles) and 7 *Geocoris punctipes* females (solid circles) fed *Heliothis virescens* eggs corrected for natural losses.

females compared to males, especially around day 25 for food consumption and after day 30 for weight. During days 20-30 the females consumed significantly more food than did males over the same period ($P < 0.05$, Student's-t test). Mean oxygen consumption (in μl mg wet weight^{-1} h^{-1}) ranged from 0.84 at 25 °C to 1.80 at 35 °C with an RQ of 0.93 and a Q_{10} (25-35 °C) of 2.14 (table 2). Cumulative exuviae was 97 (± 20.0) μg.

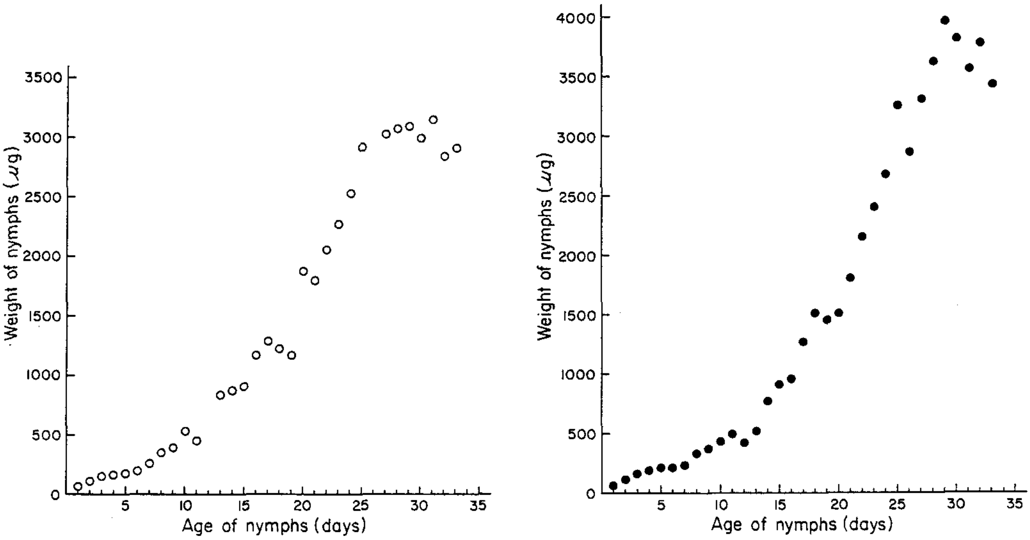

Fig. 2. Mean daily wet weights of 10 *Geocoris punctipes* males (open circles) and 7 *Geocoris punctipes* females (solid circles) fed *Heliothis virescens* eggs and water.

TABLE 2

Oxygen consumption at 3 temperatures, RQ at 30 °C and Q_{10} *(25-35 °C) measured in 5 replicated groups of 3rd, 4th and 5th instar nymphs (10 of each) of* Geocoris punctipes *fed* Heliothis virescens *eggs (± S.D.)*

Temp. (°C)	$\bar{X}$ μl O_2 mg^{-1} h^{-1}	$\bar{X}$ RQ	Q_{10}
25°	0.84 (0.15)		
30°	1.37 (0.07)	0.93 (0.03)	2.14
35°	1.80 (0.09)		

It is evident that food consumption increased as nymphal age advanced except for the last few days before final ecdysis, when food consumption decreased. Sharp decreases in food consumption are most likely correlated with periods preceding ecdysis. The very high consumption by late female 5th instar nymphs compared to males was evidently correlated with production of reproductive materials or energy reserves to be incorporated into reproductive materials, as indicated by the sharp increase in weight of females over males at this time. It should be noted that mean adult fresh weights of *G. punctipes* of both sexes in these experiments 3.55 (± 0.50) mg was evidently lower than the weights of *G. punctipes* reared on *H. virescens* eggs 4.53 (± 0.29) as reported by **Cohen & Debolt** (1983). The most plausible explanation for this discrepancy is that the daily anaesthetization and other handling of the insects in this study had a slightly adverse effect either upon food consumption or utilization.

The rates of oxygen consumption were comparable to those measured in insects of similar size as reviewed by **Keister & Buck** (1974). The RQ of 0.93 suggested that the main fuel utilized for growth and other energy requirements by the *G. punctipes* in this study was carbohydrates. If the sole fuel were carbohydrates, an RQ of 1.0 would have been measured. Since a mean of 19.75 (± 6.25 SE) μg of purine was produced over the entire development period, approximately 40 μg of protein was catabolized. This amount of protein catabolism would require about 39 μl of O_2 (**Schmidt-Nielsen**, 1975). Since total projected O_2 consumption for the full development period was about 1700 μl, at least 1600 μl were devoted to carbohydrate and lipid catabolism, and since the RQ was closer to 1.0 than to 0.76, most oxygen was used for carbohydrate catabolism. However lipid catabolism was significant and must account for a substantial amount of the energy budget of developing *G. punctipes.*

The Q_{10} between 25-35 °C was 2.14. Since the rearing temperature for these individuals was 27 °C, the temperature range used in the respiration experiments was well within boundaries of acclimatization. Yet the oxygen consumption rate more than doubled with a 10 °C increase. A doubling of oxygen consumption rate would concomitantly double energy utilization and other metabolic functions. This helps explain the sharp drop in nymphal survival, egg production and egg hatch described by **Champlain & Sholdt** (1967) in their study of temperature effects on development of *G. punctipes.* These authors showed that the optimal rearing conditions for *G. punctipes* were between 25 °C and 30 °C. Evidently metabolic rates demanding O_2 consumption between 0.84 and 1.37 μl O_2 mg body weight^{-1} h^{-1} are most suitable for development and adult reproductive functions in *G. punctipes.*

Slansky & Scriber (1982) summarized utilization efficiencies of 11 species of predaceous insects as follows : absorption efficiency (AD) = 86 % (range : 37-98) ; growth efficiency (ECI) = 39 % (range : 4-75), and metabolic efficiency (ECD) = 34 % (range : 4-64). In all 3 parameters, *G. punctipes* compares favorably with values of 95.2 %, 52.9 % and 55.6 % respectively for AD, ECI and ECD.

Fraenkel (1981) argued that under the best conditions a growing insect could convert a maximum of 2/3 of its ingested food to body materials with 1/3 going to metabolic processes. He said, further, that this seems to be the limit of efficiency in insects in general. **Calow** (1977) and **Schroeder** (1981) provided much the same argument regarding conversion efficiency. **Mukerji & Le Roux** (1969) reported a wide range of efficiencies of energy conversion from food to body material in the hemipteran predator, *Podisus maculiventris* (Say), nymphs ranging from 19.27 % to 74.53 %. The variation in conversion efficiency was related both to food quality and age of nymphs with younger nymphs tending to be more efficient than older ones. This age relationship has been observed frequently (e.g. **Waldbauer**, 1968, **Cohen & Patana**, 1983). The efficiency of conversion of ingested material to body mass by the *G. punctipes* in this study is close to the limit set by **Fraenkel** (1981) and is equal to or greater than all but the highest values reported by **Mukerji & Le Roux** (1969).

It seems reasonable that the high conversion efficiency is associated with the feeding apparatus possessed by hemipteran predators. The piercing-sucking mouthparts allow selection of soft, highly digestible materials ; and the possibility of injection of digestive enzymes that help predigest egg materials may add to this efficiency. Furthermore, the use of eggs as a food source also leads to high efficiencies because of the high nutrient density inherent in this type of food.

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RÉSUMÉ

Consommation des aliments, utilisation des aliments et taux métabolique chez *Geocoris punctipes* [*Het. : Lygaeidae*] nourri avec des œufs de *Heliothis virescens* [*Lep. : Noctuidae*]

La consommation et l'utilisation des aliments ont été évaluées chez *Geocoris punctipes* (Say) nourri d'œufs de *Heliothis virescens* (Fabricius) depuis le premier stade de nymphose jusqu'à l'insecte adulte. La croissance chez les 2 sexes s'est avérée similaire jusqu'à la dernière période de la nymphose où la croissance des femelles a brusquement dépassé celle des mâles. Le taux d'absorption des aliments a été évalué à 95.2 % tandis que celui de croissance était de 56 %. Le coefficient respiratoire était de 0.93 et le taux de consommation d'oxygène de 0.84, 1.37 et 1.80 μl O_2/mg de poids corporel et par heure à 24 °C, 30 °C, et 35 °C respectivement. Le Q_{10} pour la consommation de l'oxygène était de 2.14 (25-35 °C).

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