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Energy transfer efficiency in three hymenopteran egg parasitoids of *Homoeocerus prominulus* (Tagus) (Insecta : Heteroptera : Coreidae)

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Abstract. Energy budgets of the solitary egg parasitoids, *Anastatus ramakrishnae* (Mani) and *Trissolcus* sp., and a gregarious egg parasitoid, *Xenoencyrtus* sp. near *niger* Riek on the eggs of *Homoeocerus prominulus* have been compared. Energy allocation for consumption, assimilation and metabolism were greater in the gregarious parasitoid than in the solitary parasitoids; on the other hand, higher production efficiency and lower assimilation efficiency were noticed in the solitary parasitoids than in the gregarious parasitoids. The rate of consumption, assimilation, production and metabolism of gregarious and solitary parasitoids have been compared in the light of their reproductive efficiencies.

Keywords. Bioenergetics; hymenopteran parasitoids; coreid host.

1. Introduction

Food utilization efficiency among parasitoids is high because they consume limited food resource of a seemingly high nutritional quality and their presumed relative inactivity within the host (Slansky and Scriber 1985). In general, gregarious parasitoids inevitably entail internal competition for food resource provided by the host, and this is a physiologically intricate interaction. In the host-parasitoid systems where a single parasitoid larva consuming the nutrients present in the whole body of the host is relatively simpler in terms of energy allocation, ingestion can be estimated from the energy content of the host (Howell and Fisher 1977). Arthur and Wylie (1959), Varley (1961) and Weseloh (1969) have discussed the food conversion efficiency of hymenopteran parasitoids which are generally known to be very efficient in utilizing and assimilating the biomass of their hosts into their tissues. Only in a few cases energy budget have been made for solitary parasitoids (Chlodny 1968; Edgar 1971; Cameron and Redfern 1974; Howell and Fisher 1977) and hyperparasitic parasitoids (Prakash and Pandian 1978). The present study aims at determining energy budget of 3 hymenopteran chalcidoidean parasitoids, *Anastatus ramakrishnae* (Mani) (Eupelmidae) and *Trissolcus* sp. (Scelionidae), solitary parasitoids and *Xenoencyrtus* sp. near *niger* Riek (Encyrtidae), a gregarious parasitoid, of the eggs of *Homoeocerus prominulus*.

2. Materials and methods

A. ramakrishnae, *Xenoencyrtus* sp. and *Trissolcus* sp. were reared in the laboratory by providing cotton wads soaked in dilute honey. To maintain a constant supply of host eggs for the parasitoid, *H. prominulus* was reared *en masse* in the laboratory by providing fresh host plants (*Prosopis spicigera* L.) daily.

The eggs of the coreid bugs were exposed in closed plastic vials (10 × 8 cm) to enable parasitisation. Newly emerged adult parasitoids were collected and their live weights were taken, and dried at $60 \pm 5°C$. The parasitoids that emerged from host egg shells were dissected and the meconia were separated. The particles of the meconia and the egg shells were weighed and dried for the calorific determination as follows:

Following the gravimetric method of Waldbauer (1968), food consumption (C), egestion (FU) and growth (P) were estimated. Energy contents of the normal egg, meconia, empty parasitised egg shells of the host as well as that of the adult parasitoids were estimated in a Parr 1421 semi-micro bomb calorimeter, following the standard procedure. Using these energy values, the mass budget involving C, FU and P was evaluated into energy budget in J/mg/individual.

Bioenergetic parameters were estimated following the IBP formula of Petrusewicz and MacFadyen (1970):

$$C = FU + P + R.$$

Assimilation was calculated as the difference between food consumed and that of faeces:

$$A = C - FU.$$

Whereas metabolism was calculated as the difference between assimilated energy and that of growth:

$$M = A - P.$$

Rates of consumption (Cr), assimilation (Ar), production (Pr) and metabolism (Mr) were calculated by dividing the respective quantitative values expressed on per insect basis by the mid-body weight of the insect (mg)—in this study it was based on the weight of the host egg (mg), and duration of the immature stage expressed in J/mg live insect/day. The following formulae were used to compute the rates and efficiencies:

$$Cr = \frac{\text{Consumption (J/insect)}}{\text{Mid-body weight (mg)} \times \text{duration of the insect/stage}}.$$

$$Ar = \frac{\text{Assimilation (J/insect)}}{\text{Mid-body weight (mg)} \times \text{duration of the insect/stage}}.$$

$$Pr = \frac{\text{Production (J/insect)}}{\text{Mid-body weight (mg)} \times \text{duration of the insect/stage}}.$$

$$Mr = \frac{\text{Metabolism (J/insect)}}{\text{Mid-body weight (mg)} \times \text{duration of the insect/stage}}.$$

$$Ase\ (\%) = \frac{\text{Assimilation (J/insect)}}{\text{Consumption (J/insect)}} \times 100.$$

$$Pe_1\ (\%) = \frac{\text{Production (J/insect)}}{\text{Assimilation (J/insect)}} \times 100.$$

$$Pe_2\ (\%) = \frac{\text{Production (J/insect)}}{\text{Consumption (J/insect)}} \times 100.$$

3. Results

Energy budgets for the adult, meconium and empty host egg shell of *A. ramakrishnae*, *Trissolcus* sp. and *Xenoencyrtus* sp. and zero day egg of host, *H. prominulus* are summarised in table 1. Efficiency to utilize the available energy content of host egg (0·541 J/mg/individual) varied with the parasitoids. The energy values obtained for the meconium were strikingly different; the meconia of *A. ramakrishnae* (dark brown coloured, single and folded mass) had an energy value of 0·203 J/mg/individual while it was 0·216 J/mg/individual in *Trissolcus* sp. (pale yellowish, single mass without fold), and 0·169 J/mg/individual in *Xenoencyrtus* sp. (pale brown with orange tinged, small granules in appearance).

Comparing consumption, assimilation, metabolism and efficiencies of assimilation and production among the 3 species (tables 2 and 3), maximum food consumption of 0·484 J/mg/individual/day was evident in *Xenoencyrtus* sp. as compared to *A. ramakrishnae*, while it was least in *Trissolcus* sp. (0·447 J/mg/individual/day). Assimilation of energy by parasitoids also followed a trend similar to that of consumption. More energy assimilation was recorded for *Xenoencyrtus* sp. (0·315 J/mg/individual/day) while it was comparatively low in *A. ramakrishnae* and *Trissolcus* sp. (0·278 J/mg/individual/day and 0·261 J/mg/individual/day respectively).

Table 1. Energy budgets for the eggs of *H. prominulus* and their parasitoids.

Material	Energy value (J/mg/individual)
Host	
Freshly laid egg	0·541 ± 0·18
Parasitoids	
Anastatus ramakrishnae	
Adult	0·262 ± 0·086
Meconia	0·203 ± 0·09
Empty host egg shell	0·060 ± 0·012
Xenoencyrtus sp.	
Adult	0·183 ± 0·126
Meconia	0·169 ± 0·11
Empty host egg shell	0·057 ± 0·019
Trissolcus sp.	
Adult	0·247 ± 0·072
Meconia	0·216 ± 0·096
Empty host egg shell	0·064 ± 0·015

Table 2. Energy budgets of 3 parasitoids in the host eggs of *H. prominulus*.

Parameters	Energy value (J/mg/individuals/day)		
	A. ramakrishnae	*Xenoencyrtus* sp.	*Trissolcus* sp
Consumption	0·481 ± 0·012	0·484 ± 0·019	0·477 ± 0·015
Assimilation	0·278 ± 0·090	0·315 ± 0·110	0·261 ± 0·096
Metabolism or respiration	0·016 ± 0·007	0·132 ± 0·017	0·014 ± 0·006

Table 3. Assimilation and production efficiencies of 3 parasitoids of the host eggs of *H. prominulus*.

Parameters	Energy value (%)		
	A. ramakrishnae	*Xenoencyrtus* sp.	*Trissolcus* sp.
Assimilation efficiency (Ase)	57·80 ± 8·16	65·08 ± 18·21	54·72 ± 10·18
Production efficiency			
Pe_1	54·47 ± 12·04	37·81 ± 20·13	51·78 ± 13·24
Pe_2	94·25 ± 4·62	58·10 ± 24·07	94·64 ± 4·13

Table 4. Rate of energy transfer in 3 egg parasitoids of *H. prominulus*.

Energy parameters	Energy value (J/mg/day)		
	A. ramakrishnae	*Xenoencyrtus* sp.	*Trissolcus* sp.
Cr	5101·52 ± 12·0	3483·33 ± 19·3	3975·0 ± 15·4
Ar	2948·49 ± 90·2	2267·05 ± 11·3	2175·0 ± 96·4
Pr	2778·79 ± 86·0	1940·91 ± 126·0	2058·3 ± 72·0
Mr	169·70 ± 7·3	950·0 ± 17·1	116·67 ± 6·4

Assimilation and production efficiencies (table 3) indicated that efficiency of assimilation was more in the case of gregarious parasitoid than in solitary parasitoids while production efficiency was more in solitary parasitoids than in gregarious parasitoid.

High consumption and assimilation rates were recorded in *A. ramakrishnae* (5101·52 and 2948·49 J/mg/day respectively) and *Trissolcus* sp. (3975 and 2175 J/mg/day respectively) whereas in *Xenoencyrtus* sp. it was only 3483·33 J/mg/day and 2267·05 J/mg/day for the consumption and assimilation rates respectively. While considering the metabolic rate, *Xenoencyrtus* sp. spent more energy (950 J/mg/day) than the other two parasitoids, *A. ramakrishnae* (169·7 J/mg/day) and *Trissolcus* sp. (116·67 J/mg/day) (table 4).

4. Discussion

Energy budgets hold the key for understanding reproductive strategies of individuals (Price 1974; Boggs 1981). Since hymenopteran parasitoids tend to exhibit high food utilization efficiency, it is essential to study the amount of energy being utilized by the parasitoid for their complete development. The results presented in this study reveal the variation between the energy expenditure of two solitary egg parasitoids, *A. ramakrishnae* and *Trissolcus* sp. besides a gregarious parasitoid *Xenoencyrtus* sp. These results support the view of Smith and Smilowitz (1976) that the nutritional demands imposed by the individuals of gregarious parasitoids are greater than those of an individual solitary parasitoid. Since the amount of food ingested by the parasitoid larvae is important for survival, one would expect the mortality rate to increase with both the number of eggs laid per host and the hatching time between larvae. Although parasitising the same host egg, adults of *A. ramakrishnae* and *Trissolcus* sp. completed their development within 14 and 11 days respectively, whereas adults of *Xenoencyrtus* sp. completed its development within 9·5 days itself. This faster post-embryonic developmental period of *Xenoencyrtus* sp. might be advantageous for them to avoid mortality due to the depletion of nutrients during development. The importance of hatching time and survival of the gregarious parasitoid, *Trichogramma embryophagum* and *T. pretiosum* was explained by Klomp *et al* (1980); Strand and Vinson (1985). More energy was spent by the gregarious parasitoid, *Xenoencyrtus* sp. for consumption, assimilation and respiration whereas it was low in the solitary parasitoids. But in this regard Chlodny (1968) found that approximately 70% of *Pieris brassicae* pupa was consumed by a solitary larva of the pupal parasitoid, *Pimpla instigator* or by about 44 larva of the gregarious *Pteromalus puparium*, suggesting relatively high exploitation efficiencies for both solitary and gregarious parasitoids. Quantities of the egesta and assimilated food depend on the efficiency of the digestive and absorptive machinery (Muthukrishnan and Pandian 1986). Therefore, high energy expended in *A. ramakrishnae* and *Trissolcus* sp. for egestion as meconia caused the decrease in the energy value for efficiency of assimilation, whereas in *Xenoencyrtus* sp. low energy expenditure for egestion is presumably due to partitioning of food caused by lesser food consumption resulting in an increase in the energy for assimilation. The energy budget obtained for *Xenoencyrtus* sp. when compared with two species indicates a low production efficiency because of the undersized adults. Egg parasitoids lack the opportunity of increased food intake from the host and if the weight of the host is less than that required by the parasitoid to achieve its ideal body weight, then the resulting adult parasitoids may have a reduced body weight (Slansky 1986). Moreover ovipositing females of some parasitoids and their hyperparasitoids may assess host size and bias the sex ratio of the eggs they lay toward the smaller sized sex (usually males) in smaller hosts (Kfir and Rosen 1981a, b, c) as well as alter the number of eggs they lay per host (Luck *et al* 1982; Charnov and Skinner 1984). High assimilation efficiencies (55–94%, $\bar{x} = 68\%$), have been reported for more than 15 species of parasitoids (Slansky 1986). Results presented in this study, also indicate the higher metabolic rate in *Xenoencyrtus* sp. in comparison to *A. ramakrishnae* and *Trissolcus* sp. and one possible attribute is that the gregarious adults spend more energy for respiration than the solitary ones.

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