

Relation between feeding and egg production in some insects

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Abstract. Food consumption and fecundity of insects vary with life style and feeding pattern. In general, species which feed during the larval and adult stages and maintain a smaller biomass, allocate a higher percentage of the ingested energy to egg production (e.g. *Oryzaephilus surinamensis*; 34.4%). Species which grow larger but feed at lower rates and pass through extended adult life span display very low egg production efficiency (e.g. *Poecilocerus pictus*; 0.7%). A few others feed at faster rates during the larval period, shorten the adult phase and allocate fairly a high percentage of the ingested energy to egg production (e.g. *Bombyx mori*; 5.8%). Food quality regulates food consumption and thereby significantly influences egg production in several polyphagous insects. Prey density influences food consumption and fecundity of predators. Regression of fecundity on blood meal ingested for two hemipterans and two dipterans revealed that the dipterans are autogenous and are relatively independent on adult blood meal for oviposition in comparison with the hemipterans.

Keywords. Feeding pattern; fecundity; egg production efficiency.

1. Introduction

Insects follow a variety of life styles and feeding patterns, which play a major role in determining the strategy of growth and reproduction (Enders 1976; Lawton and McNeill 1979). Southwood *et al* (1974) considered that the generation time of an individual determines its reproductive strategy. Life span of insects varies from a few days in several lepidopterans and parasitic hymenopterans to over 17 years in cicada (Richards and Davies 1977). Some are short lived and are smaller in size (e.g. parasites, aphids, scale insects etc), while a few others are long lived and large sized (e.g. scarabaeid beetles, grasshoppers and locusts etc). A majority of the insects feed throughout life (e.g. most of the ametabolous and hemimetabolous insects and a few holometabolous insects), while several lepidopterans, ephemeropterans and chironomids feed only during the larval period. While a few sanguivores are unautogenous and require an adult blood meal to commence oviposition (e.g. *Aedes aegypti*), several others are autogenous and are independent of adult blood meal for oviposition. Egg production is ultimately an aspect of conversion of ingested food. Therefore, biotic and abiotic factors, which are known to alter the rate and efficiency of food utilization in females also influences her fecundity (Muthukrishnan and Pandian 1987). Although a good number of publications report fecundity of insects, very few alone relate to feeding with energy allocation to egg production. This paper aims to critically evaluate the impact of feeding on egg production in some insects.

2. Materials and methods

Following the gravimetric procedure described by Waldbauer (1968), food consumption, growth and egg production in *Mantis religiosa*, *Coccinella*

Table 1. Food consumption and energy allocation to egg production in few insects.

Insect	Food consumption (J/insect)		Growth (J/insect)	Egg production (J/insect)	Egg production efficiency (%)	Remarks	Reference
	Larva	Adult					
Collembola <i>O. cincta</i>	—	—	38.3	3.334	1.87	4.9	Moults and feeds throughout life Testerink (1982)
<i>T. minor</i>	—	—	38.8	4.467	2.80	7.2	Moults and feeds throughout life Testerink (1982)
Orthoptera <i>O. velox</i>	10208	15967	26175	2180	1077	4.1	Feeds throughout life: grows to about 300 mg in 240 days Delvi and Pandian (1971)
<i>P. pictus</i>	717587	1211704	1929291	48704	13053	0.7	Feeds throughout life: grows to about 6.9 g in 267 days Delvi (1972)
Dicyoptera <i>M. religiosa</i>	39678	55327	95005	14630	5413	5.7	Feeds throughout life: grows to about 2.2 g in 131 days Muthukrishnan (1980)
Homoptera <i>A. fabae</i>	—	—	62	32.3	26	41.9	Feeds throughout life: grows to about 1.0 mg in 39 days Llewilyn and Qureshi (1978)
Lepidoptera <i>B. mori</i>	59469	0	59469	18245	3467	5.8	Feeds only during larval period (25 days), spins an expensive pupal case Hiratsuka (1920)
<i>C. leucosticta</i>	189083	0	189083	33773	7160	3.8	Feeds only during larval period (107 days) and attains a maximum body weight of 5.1 g Mackey (1978)
Coleoptera <i>C. transversalis</i>	226	964	1190	345	29.0	29.0	Feeds throughout life: 4 days larval period; 28 days adult period Muthukrishnan and Senthamizhselvan (unpublished results)

<i>M. sexmaculatus</i>	292	1424	1716	1264	389	22.7	Feeds throughout life: 4 days larval period: 32 days adult period	" "
<i>C. cautena</i>		5547	5547	385	296	5.3	Larval consumption not estimated: adult life span 25 days	Senthamizhselvan (1987)
<i>R. verreauxi</i>	124880	0	124880	11140	5414	4.3	Feeds only during larval period (924 days): attains maximum growth of 3.3 g	Cairns (1982)
<i>O. surinamensis</i>	38	273	311	120	107	34.4	Feeds during larval (13 days) and adult period (60 days): attains maximum growth of 25 mg	White and Sinha (1981)
<i>S. granarius</i>	331	1189	1520	87	39.4	2.6	Feeds during larval (19 days) and adult periods (30 days): attains maximum growth of 7 mg	Campbell <i>et al</i> (1976)
<i>C. ferrugineus</i>	25.5	310	336	3.2	21	6.0	Feeds during larval (20 days) and adult periods (123 days): attains maximum growth of about 0.7 mg	Campbell and Sinha (1978)
<i>Callasobruchus maculatus</i>	386	0	386	87	21.0	5.4	Feeds only during larval period (16 days); oviposits for 8 days: attains maximum growth of 4 mg	Chandranantha (1985)

transversalis, *Monochilus sexmaculatus* and *Cicindela caudata* were estimated in terms of energy. However, rest of the information presented in this paper were collected from pertinent publications. From a survey of over 100 publications, about 30 were selected; the others which do not provide quantitative (mass or energy) data for both food consumption and fecundity were not considered. Information presented here pertain to a wide range of insects following different life styles and feeding patterns. The data collected have been discussed in the light of theoretical information provided by Calow (1977).

3. Effect of life style and feeding pattern

Table 1 presents data on food consumption and energy allocation to egg production in a few insects, which follow different life styles and feeding patterns. Egg production efficiency is expressed as percentage of ingested energy allocated to egg production; the efficiency ranges from 0.7% in the grasshopper *Poecilocus pictus* to 34 and 42% in the granivorous *Oryzaephilus surinamensis* and the juice feeding *Aphis fabae*, respectively. The wide range in the efficiency may partly be attributed to the life style (living for longer or shorter durations, and growing smaller or larger) and feeding pattern (feeding throughout or part of the life span). The primitive collembolans *Orchesella cincata* and *Tomocerus minor* moult throughout life comprising intermoult periods of active feeding and reproduction, and short non-feeding moult periods. About 5 and 7% of the ingested energy (ca 38 J) is allocated by them respectively, to egg production. *T. minor* is metabolically less active than *O. cincata* and hence affords to allocate a higher percentage of ingested energy to egg production (Testerink 1982). Of the two species of grasshoppers considered, *Oxya velox* displays egg production efficiency of 4.1% as against 0.7% by *P. pictus*. Although their life span is around 250 days, energy costs of growing larger (6.9 g in *P. pictus* vs 0.3 g in *O. velox*) and maintenance of a larger adult biomass for a longer duration (>105 days in *P. pictus* vs <75 days in *O. velox*) have restricted the egg production efficiency of *P. pictus* to the lowest level (0.7%). Metabolic cost of maintenance of larger biomass of adult for a longer duration depletes the energy available for egg production (Calow 1977). Although the scarabaeid beetle *Rhopaea verreauxi* lives longer (924 days) than *P. pictus* and attains a biomass of 3.3 g, it allocates 4.8% of the ingested energy to egg production. It does not feed as adult but converts most part of the energy accumulated during the larval period into egg. On the other hand, *P. pictus* allocates a part of the ingested energy during nymphal period to somatic growth and depends mostly on the energy ingested during the adult period for maintenance and egg production. The strategy of the moth *Cyclophragma leucosticta* is similar to that of *R. verreauxi*. Despite growing as large as 5.1 g and passing through a larval period of 107 days, *C. leucosticta* allocates 3.8% of the ingested energy to egg production. *Bombyx mori* spins an expensive pupal case and yet manages to spare 5.8% of the ingested energy for egg production. Granivorous beetles like *Sitophilus granarius*, *O. surinamensis* and *Cryptolestes ferrugineus* adopt a different strategy. They resort to shorten the larval period susceptible to parasitic infection and prolong the adult period to acquire sufficient energy and nutrients and maximise egg production. Shortening the larval period to 4 days and decreasing the adult biomass to 13.9 mg have helped the aphidophagous

ladybird beetles *C. transversalis* and *M. sexmaculatus* to allocate as much as 29.0 and 22.7% of the ingested energy to egg production. Ingestion of amino acid-rich phloem sap enables *A. fabae* to enhance its egg production efficiency to 41.9%.

4. Effect of quantity of food

In most hemimetabolous insects, quantity of food ingested during the adult period plays a major role in reproduction and hence restriction of adult feeding is likely to affect egg production efficiency. Table 2 provides data on food consumption and egg production by the milkweed bug *Oncopeltus fasciatus* receiving 100, 50 and 25 mg dry seeds/week/pair (Slansky 1980). A female in 100 mg ration group passed through interoviposition periods of 2.3 days and oviposited 1217 eggs weighing 119 mg in total. Owing to the extension of the interoviposition period to 4.7 and 10.0 days and the consequent increase in the metabolic cost of maintenance, egg production efficiency of females in the 50 and 25 mg ration groups decreased to 21.1% and 7.7%, respectively. Corpora allata of females receiving restricted rations are also likely to have not been sufficiently activated resulting in decreased fecundity (Ralph 1976). Restriction of ration may also directly interfere with egg production and decrease fecundity (Walker 1976). Mathavan (personal communication) has obtained a highly significant correlation between feeding rate and fecundity on the one hand and faeces egested and fecundity on the other for the silkworm *B. mori*. The simple linear regression equations especially the one between faeces egested and fecundity developed may be useful to predict fecundity of *B. mori* (figure 1).

Discussing stability and resilience in predator—prey models, Beddington (1976a, b) showed that prior to commencement of oviposition, a predator should consume sufficient energy to meet its metabolic demand; once this demand is met, fecundity of the predator holds a definite relation to prey ingested by it. For instance, *Coccinella undecimpunctata aegyptiaca* consumes about 25 aphids/day before commencing oviposition; thereafter, with increasing prey consumption to 40 and 75 aphids/day, fecundity increases to 60 and 160 eggs/female (table 3). Dixon (1959) has also reported similar relation for the beetle *Adalia decempunctata* (table 3).

5. Effect of food quality

In addition to differences in chemical composition, natural food materials differ in their capacity as phagostimulants. Consequently, quantities of food consumed,

Table 2. Effect of ration levels on food consumption and egg production in *O. fasciatus* fed on air-dried seeds of *Asclepia syriaca* for a period of 13 weeks after eclosion (from Slansky 1980; modified).

Parameters	Ration (mg/seed/week/♀ ♂)		
	100	50	25
Consumption (mg dry wt/♀ ♂)	422.4	268.2	189.8
Inter-oviposition period (day)	2.3	4.7	10.0
Fecundity (egg/female)	1217	576	131
Biomass of eggs produced (mg dry wt/♀)	119.0	59.4	14.6
Egg production efficiency (%)	27.9	21.1	7.7

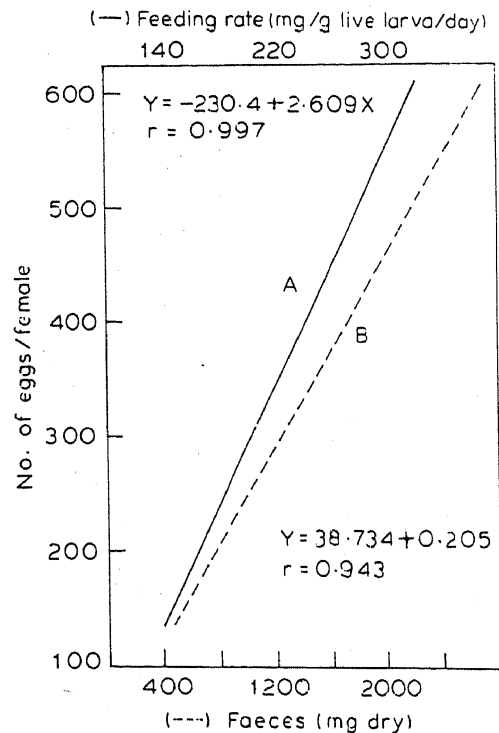


Figure 1. Fecundity of *B. mori* as functions of (A) feeding rate and (B) faeces egested (Mathavan, personal communication).

Table 3. Fecundity in relation to prey density in *C. u. aegyptiaca* and *A. decempunctata*.

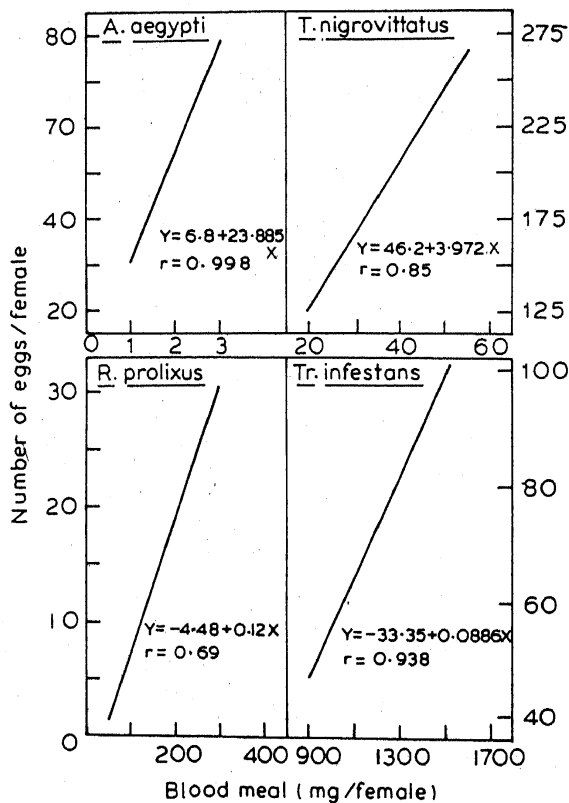
<i>C. u. aegyptiaca</i> ^a		<i>A. decempunctata</i> ^b	
Prey density (No./♀)	Fecundity (egg/♀)	Prey density (No./♀)	Fecundity (egg/♀)
30	10	3	3
35	30	7	13
40	60	15	18
55	120	23	15
60	130		
75	160		

^aData from Beddington *et al* (1976a). ^bData from Dixon (1959).

assimilated and converted by polyphagous insects vary with quality of food (Soo Hoo and Fraenkel 1966; Muthukrishnan and Rajeeva 1979). Such differences in food utilization account for the variations in the fecundity of a number of polyphagous insects. For instance, fed ad libitum on *Solanum tuberosum* and *Mamestra configurata* consumed 388 mg (dry) of food and produced 279 eggs after emergence (Bailey 1976). Feeding on *Brassica campestris* enhanced its consumption to 498 mg and fecundity to 756 eggs (table 4). Young *et al* (1950), East (1977) and Ottens and Tood (1979) have reported wide variations in the fecundity of whitefringed beetles *Graphognathus* spp. fed on leguminous and graminaceous plants. Fecundity of the beetle varied from 4–26 eggs/female while feeding one or the other of 12 different species of grass to 153–631 or 1450 eggs/female for those feeding leguminous or malvaceae plants

Table 4. Effect of food quality on food consumption and fecundity of *M. configurata* (from Bailey 1976; recalculated).

Host plant	Food consumption (mg dry wt/larva)	Fecundity (egg/♀)
<i>S. tuberosum</i>	388	279
<i>Cheuopidium album</i>	448	411
<i>B. campestris</i>	498	756
<i>Brassica napus</i>	494	838
Artificial diet	—	1367

**Figure 2.** Fecundity of some sanguivorous insects as a function of blood meal consumed. (A) *A. aegypti* (Roy 1936); (B) *T. nigrovittatus* (Magnarelli and Stoffolano 1980); (C) *R. prolixus* (Patterson 1979); (D) *T. infestans* (Regis 1979).

(Ottens and Tood 1979). However, food consumption in the beetles feeding on different host plants was not estimated by the authors and hence fecundity could not be related with quantity of food consumed.

6. Autogeny

By feeding the stable fly *Stomoxys calcitrans* on a blood meal mixed with soybean trypsin inhibitor, Spates (1979) demonstrated the importance of protein for egg production in sanguivores. However, arctic mosquitoes such as *Aedes impiger* and *A. nigriceps* as well as *A. detritus* inhabiting the deserts of Sahara and Tunisia, where

chances of finding mammalian host are remote are autogenous and produce eggs without having to consume a blood meal after emergence (Corbet 1964). Larval nutrition is one of the major factors controlling autogeny in insects (Friend *et al* 1965). For instance, the bug *Rhodnius prolixus* fed on full blood meal at each nymphal instar oviposits 51 eggs after ingesting first adult blood meal compared with 18 eggs by that fed on partial meals during nymphal period (Patterson 1979). Fecundity of the bug *Triatoma infestans* ingesting 930–1510 mg of blood meal after eclosion varies from 50–95. On an average about 16.6 mg of blood is required for the production of an egg (Regis 1979). Magnarelli and Stoffolano (1980) fed *Tabanus nigrovittatus* on different quantities of blood (0–60 mg) and observed a linear relation between quantity of meal and fecundity. They have demonstrated that the autogenous and anautogenous fecundity of the fly do not differ significantly. Figure 2 shows the relation between blood meal ingested and fecundity for two dipterous and two hemipterous sanguivores. The negative intercept on y of the regression lines for the hemipterous *R. prolixus* and *T. infestans* clearly indicates that blood consumption after eclosion is obligatory for the initiation of oviposition; on the other hand, the positive intercept for the dipterous *A. aegypti* and *T. nigrovittatus* indicates their relative independence on adult blood meal for oviposition of at least a few eggs.

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