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Faecal weight as an index of development rate and energy content of imago of lepidopterous insects

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Abstract. Statistically significant correlation coefficients were obtained for the relation between defecation rate and development rate as well as energy contents of pupa and imago of the noctuid moth *Achaea janata*. Using simple regression equations, the dependent variables development rate, pupa and imago were predicted against values of defecation rate obtained in a factorial design of experiment. The predicted and observed values did not significantly differ from each other indicating the possibility of predicting these parameters from easily estimatable faecal weight. The validity of the concept was tested using the data available in literature.

Keywords. Faecal weight; development rate; pupa; imago; *Achaea janata*.

1. Introduction

An innate tendency of all organisms is to acquire and accumulate sufficient energy to sustain and propagate. Although food is considered to be a less limiting factor for herbivores than for carnivores, owing to rapid and wide population oscillations, herbivores are likely to be exposed to abundance and scarcity of food under natural conditions (White 1978). This has become true for most lepidopterous insects for whom natural selection seems to have set a premium for faster rates of consumption and utilization of food especially during the final instar larval period to tide over the non-feeding pupal and adult stages (Waldbauer 1968; Muthukrishnan and Pandian 1983a). Maximization of energy accumulation can be achieved either by enhancing feeding rate with simultaneous shortening of growth period or by increasing the efficiency of conversion of food (Calow 1977). Available information points out that insects facing restricted availability of food adopt the strategy of prolonging their feeding larval period and emerging as miniature adults (Muthukrishnan and Delvi 1974; Mathavan and Muthukrishnan 1976; Muthukrishnan *et al* 1978; Muthukrishnan and Pandian 1984). Beddington *et al* (1976) and Hassell (1978) have substantiated the dependence of development rate (expressed as the reciprocal or larval duration) and fecundity of predatory insects on prey density. Statistically significant correlations have been reported for the relations between food consumed and development rate as well as pupal weight in the armyworm *Pseudaletia unipuncta* (Mukerji and Guppy 1973) and *Mamestra configurata* (Bailey 1976). The present communication aims to examine whether faecal weight can be used as a reliable index of development rate (D_r) and energy contents of pupa (Pe) and imago (Ie) of lepidopterous insects. Prediction of these parameters especially for lepidopterous pests will find useful application in contemplating pest management strategies. Use of faecal weight for the prediction of bioenergetics components of the predatory wasp *Sceliphron violaceum* and a few lepidopterous insects has been already substantiated by Marian *et al* (1982) and Muthukrishnan and Pandian (1983b), respectively.

2. Materials and methods

In a factorial design of experiment, freshly moulted final instar larvae of *Achaea janata* (Lepidoptera: Noctuidae) (hatched and acclimated at 22, 27, 32 and 35°C) were reared separately on wide range of restricted rations as well as *ad libitum* level on fresh leaves of the castor *Ricinus communis* at their respective acclimation temperatures. The chosen ration levels were 50, 100, 200, 400 and 500 mg fresh leaf/larva/day. As the larvae receiving 50 mg restricted ration at 32 and 35°C suffered high mortality, the lowest ration at these temperatures was raised to 100 mg/larva/day. The highest submaximal ration at 22 and 27°C was 400 mg/larva/day; it was 500 mg/larva/day at 32 and 35°C. Faeces egested and left over leaf bits were collected separately and dried to weight constancy at 80°C. The duration required for the completion of the final instar at the tested temperatures and feeding schedules was noted. Samples of fresh Pe and Ie from each feeding schedule and temperature were weighed and dried. Energy content of these samples was estimated in a Parr 1421 semi-micro bomb calorimeter. Considering the initial and final live weight of the larvae, defecation rate was calculated as mg dry wt/g live wt of the larva/day; the following formula was used:

$$\text{Defecation rate } (F_r) = \frac{\text{Faeces (mg dry wt) egested during the final instar}}{\text{Live mid-body wt (g) of the larva} \times \text{duration (day)}}.$$

D_r was calculated as the reciprocal of the final instar duration. Mean F_r of the larvae reared at the tested conditions was related to D_r, energy contents of the Pe and Ie and separate regression equations were developed. Using these equations, the dependent variables were predicted for the observed rates of defecation. Goodness of fit of the predicted values with the observed values was tested using the chi-square test (Zar 1974).

3. Results

The simple correlation coefficient ($r = 0{\cdot}954$) obtained for the relation between F_r and D_r of the final instar *A. janata* larva at the tested conditions was statistically significant ($P < 0{\cdot}005$; $N = 25$). The following regression equation explains the relation between the two variables:

$$D_r = 0{\cdot}03772 + 0{\cdot}001453\ F_r. \tag{1}$$

Values of D_r predicted for the observed F_r using this equation are provided in table 1. Several predicted values were close to the observed values. The total chi-square value obtained for the differences between the observed and predicted D_r values (table 1) was statistically not significant (chi-square $= 0{\cdot}0394$; $P > 0{\cdot}5$; $D_f = 22$) showing that the predicted values come from the population of observed data.

Although the correlation coefficients obtained for the relation between F_r, Pe and Ie at all the tested temperatures and feeding schedules were statistically significant,

Table 1. Observed (D_r1) and predicted (D_r2) values of D_r of final instar *A. janata* as functions of defecation rate (mg/g larva/day). D_r2 values were predicted by using the equation (1).

Temperature/ration[a]	F_r	D_r1	D_r2
22°C			
50	25·95	0·0658	0·0754
100	41·20	0·0885	0·0976
200	69·40	0·1370	0·1385
300	88·70	0·1538	0·1666
400	105·70	0·2000	0·1913
Ad libitum	123·80	0·2000	0·2176
27°C			
50	38·30	0·0952	0·0934
100	61·40	0·1220	0·1269
200	98·90	0·1818	0·1814
300	117·10	0·2222	0·2079
400	132·80	0·2300	0·2306
Ad libitum	170·40	0·2300	0·2853
32°C			
100	64·40	0·1250	0·1313
200	92·70	0·1786	0·1724
300	116·60	0·2326	0·2071
400	129·30	0·2500	0·2255
500	147·80	0·2788	0·2525
Ad libitum	161·60	0·2788	0·2725
35°C			
100	68·30	0·1250	0·1370
200	97·10	0·1887	0·1788
300	117·50	0·2439	0·2084
400	142·00	0·2703	0·2440
500	153·50	0·2500	0·2607
Ad libitum	168·70	0·2500	0·2828

[a] mg fresh leaf/larva/day; total chi-square value for D_r1 and $D_r2 = 0{\cdot}0394$; $P > 0{\cdot}5$ at D_f 22.

the regression equations given below were found to be less precise for the prediction of either of the dependent variables.

$$\text{Pe (J/individual)} = 0{\cdot}0856 + 0{\cdot}0226\ F_r;\ r = 0{\cdot}858 \quad (2)$$
$$\text{Ie (J/individual)} = -0{\cdot}0986 + 0{\cdot}0141\ F_r;\ r = 0{\cdot}830. \quad (3)$$

Therefore, separate regression equations were developed for the relation between F_r and Pe as well as Ie for each temperature and provided in table 2. Figure 1 presents the regression lines for Pe and Ie drawn by using the equations in table 2. Most of the observed values fall on the regression lines showing the adequacy of these equations for prediction purposes. Total chi-square values for the differences between the observed and predicted values at each temperature were also statistically not significant.

4. Discussion

Values on D_r and F_r for the final instar larva of the monarch butterfly *Danaus chrysippus* exposed to different restricted rations (Mathavan and Muthukrishnan

Table 2. Regression equations for the relation between F_r and energy content (kJ/individual) of Pe and Ie of *A. janata.*

Temperature (°C)	Regression equation	N	r	Equation number
22	$Pe = +0{\cdot}153 + 0{\cdot}0331\ F_r$	6	0·990	2
27	$Pe = -0{\cdot}457 + 0{\cdot}0264\ F_r$	6	0·993	3
32	$Pe = -0{\cdot}767 + 0{\cdot}0277\ F_r$	6	0·984	4
35	$Pe = -1{\cdot}289 + 0{\cdot}0300\ F_r$	6	0·988	5
22	$Ie = -0{\cdot}136 + 0{\cdot}0218\ F_r$	6	0·996	6
27	$Ie = -0{\cdot}441 + 0{\cdot}0168\ F_r$	6	0·988	7
32	$Ie = -0{\cdot}722 + 0{\cdot}0180\ F_r$	6	0·982	8
35	$Ie = -1{\cdot}031 + 0{\cdot}0190\ F_r$	6	0·982	9

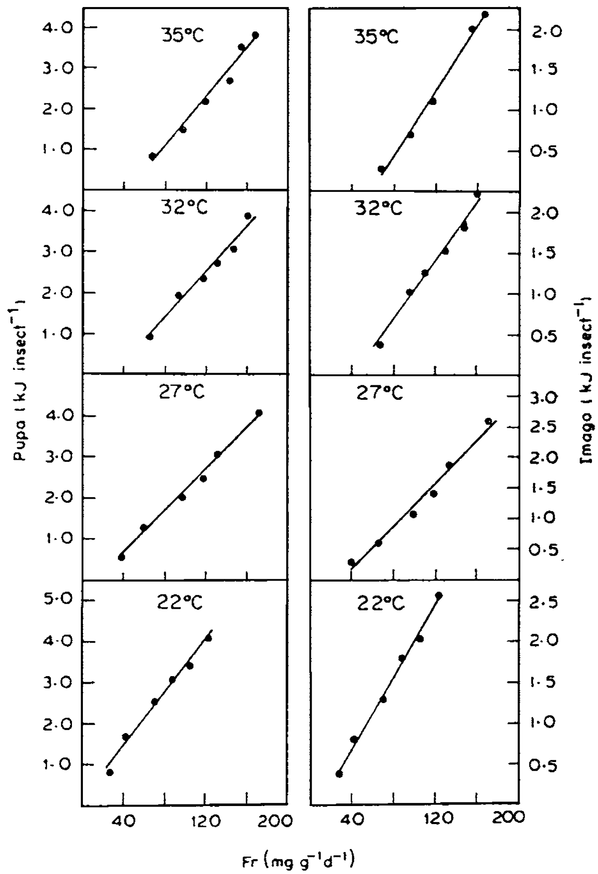

Figure 1. Energy content of Pe and Ie in relation to defecation rate (F_r in mg/g live larva/day) of *A. janata.* The lines were drawn using the regression equations (2–9) provided in table 2. Open circles indicate the observed values. Total chi-square for the difference between the observed and predicted values are:

22°C : Pe = 0·1611; Ie = 0·02469
27°C : Pe = 0·1203; Ie = 0·07490
32°C : Pe = 0·1577; Ie = 0·07556
35°C : Pe = 0·1512; Ie = 0·09720.

For all chi-square values $P > 0{\cdot}5$ at D_f 4.

Table 3. Observed (D_r1) and predicted (D_r2) values of D_r of final instar larva of *D. chrysippus* (Mathavan and Muthukrishnan 1976) and *B. mori* (Muthukrishnan *et al* 1978) as functions of F_r (mg/g larva/day). D_r2 values were predicted from the equation given below (10 and 11).

Feeding schedule	F_r	D_r1	D_r2
Ration[a]		*D. chrysippus*	
200	84·0	0·1923	0·2023
300	107·4	0·2273	0·2304
400	116·8	0·2500	0·2471
500	177·4	0·3125	0·3143
750	177·9	0·3333	0·3149
Ad libitum	234·0	0·3704	0·3821
Feeding duration[b]		*B. mori*	
4	102·4	0·0862	0·0772
6	132·5	0·0909	0·1050
10	164·2	0·1333	0·1342
12	170·0	0·1429	0·1395
18	197·3	0·1667	0·1647
24	198·8	0·1667	0·1660

Total chi-square value for D_r1 and $D_r2 = 0·00223$; $P > 0·5$ at D_r 4
$D_r2 = 0·10171 + 0·0012\ F_r$; $r = 0·986$ (equation No. 10).
[a] mg fresh leaf/larva/day.
Total chi-square value for D_r1 and $D_r2 = 0·0032$; $P > 0·5$ at D_f 4
$D_r2 = 0·01714 + 0·000921\ F_r$; $r = 0·976$ (equation No. 11).
[b] h/day.

1976) and the silkworm *Bombyx mori* restricted to feed for different durations (Muthukrishnan *et al* 1978) were used to test the validity of the concept of predicting D_r from F_r. Table 3 provides the observed and predicted values of D_r against F_r of *D. chrysippus* and *B. mori*. The close proximity of the predicted values with the observed values and the lack of significance of the chi-square values for the differences between them reaffirm the dependance of D_r on F_r. The relation between the two variables implies that processing of some amount of food in the gut is essential for development to proceed. However, the positive intercept on $Y (a = 0·03772)$ of the regression equation (1) indicates that development is possible to a certain extent even in the complete absence of food consumption and faecal output. Relating the D_r of the spider *Linyphia triangularis* to food consumption rate, Turnbull (1962) also obtained a positive intercept on Y indicating that development can be proceeded even without food consumption. But, Beddington *et al* (1976) are of the view that under these conditions the slope and intercept of the line have no simple biological interpretation (Mukerji and Leroux 1969). Although Mukerji and Guppy (1973) and Bailey (1976) have reported significant correlations between food consumption rate during the larval period and the initial or final dry weight of the Pe for a few lepidopterous insects, it is not possible to make use of their data to find support for the prediction of Pe and Ie from F_r, as details of faecal weight and energy content of the Pe and Ie have not been provided by these authors.

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