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Effect of Quantitative Nutrition on Adult Characters and Reproductive Fitness in Tropical Tasar Silkworm *Antheraea mylitta*

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Nutrition is very essential for growth, development and reproduction. The quantitative impetus of nutritional factor on adult characters and reproductive fitness was studied in *Antheraea mylitta* by providing fresh leaves of *Terminalia tomentosa* for 1 to 4 times a day to 5th instar larvae. All the characters have improved on giving fresh diet more times over the single diet. The adult weight has strong effect on the reproductive potential *i.e.*, female pupa and moth weight, survivability, pupation rate, emergence percentage, fecundity, fertility, egg weight and hatched out larval weight. The improvement recorded to the tune of 70%, 77.1%, 115.4%, 36.7%, 45.9% and 218.3% in larval weight gain, survivability, pupation rate, female pupa weight, moth weight and fecundity respectively when fresh diets were provided 4 times a day against single diet. The adult emergence percentage has increased from 66.4% to 96.2% and fertility rose from 52.2% to 93.6%. The weight of eggs and the larvae hatched out of it also found to be significantly higher in 4 diets a day condition. The study revealed that optimization of fresh diet frequency should be maintained to obtain higher egg production and fertility in order to get vigorous larvae to continue the generation.

Key words: *Antheraea mylitta*, Quantitative nutrition, Reproductive fitness

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Introduction

Lepidopteran larvae consume almost 100% of its total food requirements during its larval stages to accumulate sufficient food energy to tide over the non-feeding pupal and adult stages and to lay eggs (autogeny). Larval feeding in non-feeding adult insects is an active and dynamic process and hence the amount, rate and quality of food consumed has an immense effect on growth, developmental time, final weight, survival and reproductive potential as well (Slansky and Scriber, 1985). As nutrients can influence all aspects of insect performance, adequate amount of necessary nutrients must be ingested by the larvae to achieve maximum potential fitness. Decreased food abundance in nature has an adverse effect on development, metabolism, and reproduction (Slama, 1964; Slansky, 1980; Grabstein and Scriber, 1982). Food deprivation has extended the larval period and had a negative impact on the growth and fecundity in many insects including sericigenous species (McGinnis and Kasting, 1959; Bhanot and Kapil, 1973; Muthukrishnan *et al.*, 1978; Srivastava *et al.*, 1982; Nath *et al.*, 1990; Rath *et al.*, 2004). It is understood that insects has to reach the intake target to achieve their growth targets in order to attain functional optima (Raubenheimer and Simpson, 1999) and any change in intake and growth target will be leads to physiological disturbance affecting the performance level.

Antheraea mylitta Drury is a wild sericigenous insect of polyphagous nature. A good number of studies have been reported on the aspect of food consumption and utilization in this species (Ojha *et al.*, 2000; Rath *et al.*, 2000; Sinha *et al.*, 2000) but the results cited by the authors revealed differential ingestion and hence growth owing to single or double feeds a day they have opted for feeding purpose to the larvae. By adopting two feeds/day, the ingestion increases by 1.4 to 2 times and the growth by 1.8 to 2.1 times over one feed/day. The results indicate that optimum number of feeds/day needs to be found out to enable the larvae to reach their optimum growth so that the adult can achieve the normal reproductive potential, which is the aim of the present study.

Materials and Methods

Experimental silkworm larvae, *Antheraea mylitta* (Lepidoptera: Saturniidae) were reared in their natural habitat on the most suited host plant, *Terminalia tomentosa* (Rath, 2000; Rath *et al.*, 2000) till the larvae completed 4th stadium. Soon after 4th moult out the selected 5th stadium larvae (average weight 11 g) were shifted to indoor condition (temp. 26 – 30°C, 70 – 77% R.H. and 11L:13D) and fed on fresh and pre-weighed leaves of *T. tomentosa* to allow the larvae to mature and spin the cocoons (Rath *et al.*, 2003). The 5th stadium larvae were selected for the study because *81 – 83% of total food intake is ingested during* this stadium alone (Rath *et al.*, 2000), and any change in quantum of intake will affect the physiological potential of the insect.

The details of feeding treatments were: 1FD = one feed/day, 2FD = two feeds/day, 3FD = three feeds/day and 4 FD = four feeds/day. The representatives of all the treatments were run concurrently, with the experiment being replicated 10 times to yield a trial of 100 larvae per treatment. Buffer stocks were also maintained for each treatment to compensate mortality. During the course of experimentation data on ingestion and growth (Waldbauer, 1968), survivability, stadium duration, pupa and moth weight, emergence percentage, fecundity, egg weight and hatched out larvae weight and fertility were recorded for further computation. Ingesta requirement for growth and egg mass were calculated to assess production efficiency.

Data analysis was undertaken using ANOVA, correlation coefficient and regression to assess the effect of feeding treatment on different parameters.

Results and Discussion

The results indicated that all the parameters studied had improved upon increase in feed times (Table 1, 2). The

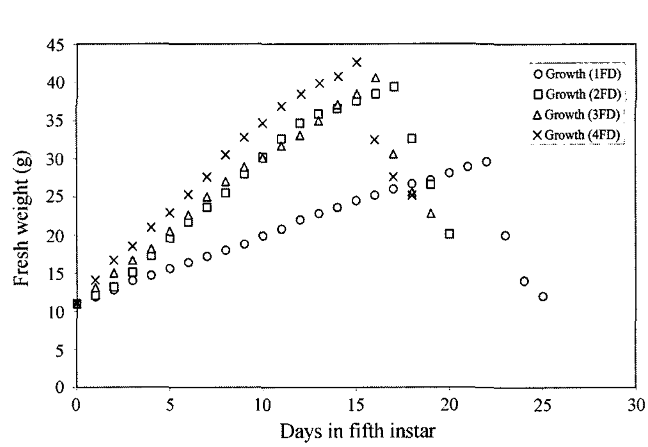

Fig. 1. Growth pattern in *A. mylitta* larva under different feeding treatment.

Table 1. Regression coefficient of number of feedings per day on different parameters in *A. mylitta* (d.f. 1, 36)

Parameters	Regression equation	R^2	F-value	P
Gain in body wt. (g)	16.984 + 4.0373X	0.7431	109.9325	< 0.00001
Final wt. (g)	27.9840 + 4.0373X	0.7405	108.4602	< 0.00001
Instar duration (days)	26.0500 – 2.3900X	0.7540	116.4859	< 0.00001
Survivability (%)	37.4200 + 9.9890X	0.7584	119.258	< 0.00001
Pupation rate (%)	42.9000 + 15.6800X	0.6338	65.7712	< 0.00001
Male pupa wt. (g)	7.0150 + 0.6055X	0.7647	123.4812	< 0.00001
Female pupa wt. (g)	10.7475 + 1.3777X	0.8803	279.3961	< 0.00001
Emergence (%)	65.4450 + 9.0690X	0.6280	64.1487	< 0.00001
Male moth wt. (g)	1.6760 + 0.4527X	0.8777	272.7458	< 0.00001
Female moth wt. (g)	4.4220 + 0.6987X	0.8501	215.4300	< 0.00001
Fecundity (nos.)	49.6500 + 75.0600X	0.9164	416.7127	< 0.00001
Fertility (%)	46.8150 + 13.1410X	0.7678	125.6814	< 0.00001
Total egg wt. (g)	0.3115 + 0.7871X	0.9277	487.3804	< 0.00001
Hatched out larvae wt. (g)	-0.3198 + 0.7656X	0.9686	1170.9010	< 0.00001
Production efficiency of egg (%)	0.7328 + 0.2169X	0.7704	127.5000	< 0.00001
Production efficiency of neonate larvae (%)	0.1104 + 0.2968X	0.9169	419.4300	< 0.00001

absolute body weight increased with advancement of the stadium in all treatment groups. While the larvae in 1FD attained its maximum growth on 22nd day, in 2FD it attained on 17th, in 3FD on 16th and in 4FD on 15th day of development (Fig. 1). The average increases in weight were 846 mg/day, 1671 mg/day, 1852 mg/day and 2111 mg/day in 1FD, 2FD, 3FD and 4FD respectively. Larval body weight fell as they stop feeding to 12 g, 20.1 g, 22.8 g and 25.2 g in 1FD, 2FD, 3FD and 4FD respectively before commencement of spinning. Gain in body weight and final weight were significantly increased ($P < 0.001$) with increase in number of feeds/day (Table 2). Regression ANOVA revealed a profound difference in growth and final weight with number of feeds/day (Table 1). Significant difference in growth and final weight among treatment groups were also apparent. Development period

Table 2. Effect of number of feedings per day on growth, survival and reproductive potential of *A. mylitta*

Parameters	Number of feeds/day (FD)				Correlation coefficient (r)
	1	2	3	4	
Initial wt. (g)	11.00 ± 0.23[a]	11.00 ± 0.19[a]	11.00 ± 0.14[a]	11.00 ± 0.23[a]	
Gain in body wt. (g)	18.61 ± 2.03[a]	28.41 ± 1.68[b] (+52.66%)	29.63 ± 1.28[c] (+59.22%)	31.66 ± 1.04[d] (+70.12%)	0.8620*
Final wt. (g)	29.61 ± 2.12[a]	39.41 ± 1.61[b] (+33.10%)	40.63 ± 1.39[c] (+37.22%)	42.66 ± 1.03[d] (+44.07%)	0.8605*
Instar duration (days)	24.6 ± 1.0[a]	19.9 ± 1.5[b] (-19.11%)	18.8 ± 1.8[b] (-23.58%)	17.0 ± 0.8[c] (-30.895)	-0.8683*
Survivability (%)	41.17 ± 1.88[a]	65.40 ± 3.98[b] (+58.85%)	70.10 ± 2.69[c] (+70.27%)	72.90 ± 2.83[d] (+77.07%)	0.8708*
Pupation rate (%)	44.70 ± 7.17[a]	92.70 ± 3.83[b] (+107.38%)	94.70±2.36[b] (+111.86%)	96.30 ± 2.00[b] (+115.44%)	0.7961*
Male pupa wt. (g)	7.67 ± 0.39[a]	8.20 ± 0.27[b] (+6.91%)	8.75 ± 0.34[c] (+14.08%)	9.50 ± 0.53[d] (+23.86%)	0.8745*
Female pupa wt. (g)	11.70 ± 0.44[a]	14.09 ± 0.56[b] (+20.43%)	14.99 ± 0.41[c] (+28.12%)	15.99 ± 0.29[d] (+36.67%)	0.9382*
Emergence (%)	66.42 ± 4.48[a]	94.25±1.90[b] (+41.90%)	95.60 ± 1.35[b] (+43.93%)	96.20 ± 1.55[b] (+44.84%)	0.7925*
Male moth wt. (g)	2.26 ± 0.12[a]	2.40 ± 0.12[a] (+6.19%)	3.00 ± 0.17[b] 32.74%)	3.57 ± 0.19[c] (+57.96%)	0.9369*
Female moth wt. (g)	4.84 ± 0.08[a]	6.22 ± 0.22[b] (+28.51%)	6.55 ± 0.16[c] (+35.33%)	7.06 ± 0.03[d] (+45.87%)	0.9220*
Fecundity (nos.)	104 ± 11[a]	223 ± 11[b] (+114.42%)	292 ± 20[c] (+180.77%)	331 ± 20[d] (+218.27%)	0.9573*
Fertility (%)	52.15 ± 7.21[a]	82.95 ± 2.17[b] (+59.06%)	89.95 ± 2.20[c] (+72.48%)	93.62 ± 0.90[d] (+79.52%)	0.8763*
Total egg wt. (g)	0.89 ± 0.10[a]	2.12 ± 0.11[b] (+138.20%)	2.83 ± 0.20[c] (+217.98%)	3.28 ± 0.19[d] (+268.54%)	0.9632*
Hatched out larvae wt. (g)	0.35 ± 0.05[a]	1.29 ± 0.08[b] (+268.57%)	2.10 ± 0.16[c] (+500.00%)	2.63 ± 0.16[d] (+651.43%)	0.9842*
Production efficiency of egg (%)	0.87 ± 0.13[a]	1.26 ± 0.10[b] (+44.83%)	1.42 ± 0.13[c] (+63.22%)	1.54 ± 0.12[d] (+77.01%)	0.8777*
Production efficiency of neonate larvae (%)	0.35 ± 0.07[a]	0.77 ± 0.06[b] (+120.00%)	1.06 ± 0.10[c] (+202.86%)	1.24 ± 0.09[d] (+254.29%)	0.9575*

Mean ± SD. Significant differences within rows are indicated by different superscripts (one way ANOVA at 5%, d. f. 36). Figures in parentheses indicate percentage change over 1FD.
*Significant at 0.1% level (d. f. 38).

of the larvae reduced from 24.6 days in 1FD to 19.9, 18.8 and 17 days in 2FD, 3FD and 4FD respectively and were found significant. Significant difference among treatment groups were also observed except between 2FD and 3FD (Table 2). Decline in weight increase and prolongation of development are also reported in many insects suffering from either starvation and/or reduction in number of feeding times per day (Slama, 1964; Mathavan and Muthukrishnan, 1976; Muthukrishnan *et al.*, 1978; Slansky, 1980; Grabstein and Scriber, 1982; Srivastava *et al.*, 1982; Mathavan *et al.*, 1987; Nath *et al.*, 1990; Rath *et al.*, 2004) corroborate our findings. The prolongation of larval period which might become necessary to reach their intake and growth targets to attain functional optima (Raubenheimer and Simpson, 1999).

Larval survivability increased significantly upon increase in number of feeds/day (Table 1 and 2). The increases were to a tune of 58.9%, 70.3% and 77.1% in 2FD, 3FD and 4FD groups respectively over 1FD. Difference in survivability percentage among the treatment groups were also found significant. Survivability in *B. mori* with 8 feeds/day is 97%, which becomes zero by reducing the number of feed to 1 feed/day, corroborate our findings (Haniffa *et al.*, 1988).

All the parameters related to adulthood and reproduction (pupation rate, pupa weight, emergence, moth weight, fecundity, fertility, egg weight and weight of hatched out larvae) increased significantly with increase in number of feeds/day (Table 1 and 2). Pupation rate was 44.7% in 1FD which was increased upon increase in number of feeds/day to 92.7% in 2FD, 94.7% in 3FD and 96.3% in 4FD. While male pupa weight was increased by 23.9% the female pupa weight increased by 36.7% upon providing four feeds/day, so also the adult weight which was increased by 58.0% and 45.9% respectively for male and female. Fecundity was 104 in 1FD condition but increased significantly to 223, 292 and 331 in 2FD, 3FD and 4FD conditions respectively. Although pupation rate and emergence did not differ significantly among 2FD, 3FD and 4FD, but other parameters like pupa weight, moth weight and fecundity did (Table 2). Starvation and/or decrease in number of feeds/day lead to lower down the fecundity in many insects (Newmann, 1976; Ives, 1981; Haniffa *et al.*, 1988; Nath *et al.*, 1990; Rath *et al.*, 2004) supports our findings. Reproductive potential of autogenous insects depend upon larval nutrition. Reduced fecundity following food shortage might be due to lack of a proper nutritional and neuroendocrine interaction leading to lowering of functional status of corpus allatum (Calow, 1973; DeWilde and DeLoof, 1973b; Engelmann, 1970) or, diversion of high proportion of assimilated food for maintenance of life activities instead of production of eggs (Slansky, 1980). Quantity of mulberry leaves ingested is intimately related to the growth of larva (Sunioka *et al.*, 1982) and consequently to the egg weight (Samson and Krishnaswamy, 1980). This is also evident from the present study that the ingestion declined significantly upon reducing the number of feeds/day resulting decrease in growth of larvae and consequently pupal and adult weight were affected resulting in lowering the fecundity and fertility. It may be presumed that the adult fails to attain the functional optima following non-achievement of intake and growth targets (Raubenheimer and Simpson, 1999). The adult weight is reduced following qualitative and quantitative deterioration in food resulting lowering the fecundity (Slansky and Scriber, 1985) seems to be true.

Fertility rate was also increased from 52.2% in 1FD to 83.0% in 2FD, 90.0% in 3FD and 93.6% in 4FD. Significant differences in fertility among the treatment groups were also observed (Table 2). In contrast, the hatching of eggs is cent per cent in under fed groups and decreased to 93% in maximum fed individuals in *B. mori* (Haniffa *et al.*, 1988). This might be due to the fact that food shortage has an immense effect on the female as compared to male (Slansky, 1980). The single egg weight laid by the moth developed from the larvae under 1FD was 9 mg but that of 2FD, 3FD and 4FD it was 10 mg but

Table 3. Effect of number of feeds per day on ingesta requirement for growth and egg production in *A. mylitta*

Parameters	Number of feeds/day (FD)				Correlation coefficient (r)
	1	2	3	4	
Ingesta / g larva	5.55 ± 0.33 [a]	5.95 ± 0.51 [b]	6.73 ± 0.38 [c]	6.73 ± 0.18 [c]	0.7812*
Ingesta / g female pupa	8.81 ± 0.89 [a]	11.97 ± 0.69 [b]	13.29 ± 0.38 [c]	13.32 ± 0.49 [c]	0.8579*
Ingesta / g female moth	21.27 ± 2.01 [a]	27.09 ± 1.11 [b]	30.42 ± 1.74 [c]	30.23 ± 1.86 [c]	0.8358*
Ingesta / g egg	116.72 ± 17.43 [a]	79.81 ± 6.66 [b]	70.71 ± 6.25 [c]	65.21 ± 5.20 [d]	-0.8207*
Ingesta / 100 eggs	100.42 ± 15.12 [a]	75.83 ± 6.30 [b]	68.58 ± 6.09 [c]	64.60 ± 5.14 [d]	-0.7831*

Mean ± SD. Significant differences within rows are indicated by different superscripts (one way ANOVA at 5%, d. f. 36).
* Significant at 0.1% level (d. f. 38).

the hatched out single larva weight were 6 mg, 7 mg, 8 mg and 8 mg for 1FD, 2FD, 3 FD and 4FD, respectively.

Food requirement for unit weight (g) of larva, pupa and moth increased significantly ($P < 0.001$) with increase in number of feeds/day. The said parameters also differ significantly among the treatment groups except between 3FD and 4FD (Table 3). In contrast, the ingesta requirement for unit growth significantly decline upon starvation (Rath *et al.,* 2004). This might be due to diversion of more assimilated food towards maintenance rather than for growth. Food requirement for production of 1g egg and 100 eggs were declined significantly ($P < 0.001$) with increase in number of feeds/day. The gross production efficiency of egg (total egg weight/ingestion × 100) and neonate larvae (total weight of newly hatched larvae/ ingestion × 100) remained significantly high (1.54% and 1.24% respectively) in 4FD condition and decreased to 0.87% and 0.34% respectively in 1FD (Table 3). Production efficiency in *B. mori* also declined with lowering the number of feeds/day confirms our findings (Haniffa *et al.,* 1988).

In the present study nutritional stress was applied through number of feeds/day in order to find out the optimal growth of *A. mylitta* larva so that the reproductive fitness can be restored. The findings also support the reciprocal interaction between nutrient intake and egg production (Engelmann, 1970; DeWilde and DeLoof, 1973a, b; Walker, 1976; Slansky, 1980).

It is evident from the present study that more number of feeds/day must be supplied to the larvae in order to support the growth, survivability and adult fitness for normal reproduction. Hence it is urged that both intake and growth target of the species should be given due care for achieving the functional optima.

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