Philippine Journal of Science
133 (1): 39-43, June 2004
ISSN 0031 - 7683

Growth and Dietary Efficiency of Mulberry Silkworm (*Bombyx mori* L.) Under Various Nutritional and Environmental Stress Conditions

V.K. Rahmathulla*, V.B. Mathur and **R.G. Geetha Devi**

Central Sericultural Research and Training Institute
Mysore, India

The fifth instar larvae of bivoltine silkworm race (CSR2 x CSR4) were reared under various nutritional and environmental stress conditions to determine growth and dietary efficiency. The data were compared with a control, which was provided with standard feeding and reared under optimum temperature and humidity. Parameters like larval weight, silk gland weight, cocoon weight, shell weight and nutritional indices parameters like ingesta, digesta, approximate digestibility percentage and reference ratio were significantly higher in the control. Most of these parameters were significantly least in larvae reared under high temperature and low humidity. However, most of the feed conversion efficiency parameters and ingesta and digesta required to produce one gram of cocoon and shell were higher in treated batches. This may be due to physiological adaptation of the larvae under different stress conditions.

Keywords: Bivoltine silkworm, *Bombyx mori*, stress factors, silkworm growth, nutritional efficiency, nutritional indices

The silkworm, *Bombyx mori* is a poikilothermic insect and it is the main source for production of silk. Environmental factors such as temperature, humidity, light, air, feed quality as well as quantity have intimate influence on its growth and development. The consumption and utilization of food in insects facilitate the understanding of the adaptability of insects to the environment. Food consumption and utilization is influenced by various which influence the crop, the most important are the atmospheric temperature and humidity prevailing at the time of rearing (Benchamin & Jolly 1986). Humidity also plays a vital role and directly influences the physiological functions of the silkworm. With the increase of temperature (20° – 30°) leaf to silk conversion rate decreases (Ueda & Suzuki 1976), Junliang Xiaoffeng 1992). Studies on relation among food ingestion, digestion and body weight gain in silkworm under restricted feeding condition (Sumioka eta al. 1982, Ueda & Suzuki 1967, Singh & Ninagi 1995, Meenal & Ninagi 1995) showed that feed conversion efficiency parameters were higher under restricted feeding levels. It was established that the water content of the feed has a direct relation to the ingestion, approximate digestibility and efficiency of conversion of ingested and digested food (Paul et al. 1992). In the present study, an attempt was made to study the effect of various environmental and nutritional factors generally facing Indian farmers on growth and dietary efficiency of bivoltine mulberry silkworm.

*Corresponding author: claveriaf@dlsu.edu.ph

Materials and Methods

In the present study a new productive bivoltine hybrid silkworm (CRS2 x CRS4) suitable for rearing during favorable season (Aug-Feb) under Indian condition was used. Rearings were conducted as per the new standard package and recommendation (Rajan, 2001) by providing fresh leaves of VI mulberry variety.

The feed utilization study was confined to 5^{th} instar larvae as 80-85% of the total leaf is consumed in this instar. On rearing the 5^{th} instar, 50 larvae in three replicates were separated and kept in different temperature, humidity and feeding conditions (treatments) in a sericatron (environmental chamber with precise and automatic control facilities for uniform maintenance of temperature and humidity). The treatment were as follows; T1 – high temperature (36°C), low humidity (40%) and standard recommended feed quantum, T2 – low temperature ((20°C), high humidity (90%) and standard recommended feed quantum, T3 – optimum temperature ((25°C), optimum humidity (70%), and 30% less feed quantum were provided, T4 – optimum temperature ((25°C), optimum humidity (70%) and standard recommended quantum of over-mature mulberry leaves. T5 (control) – optimum temperature ((25°C), humidity (70%) and standard recommended feed quantum were provided. Known quantities of fresh mulberry leaves as per recommended (Rajan et al. 2001) were provided to the silkworm thrice a day taking utmost care to maintain the leaf moisture content to the maximum possible extent.

Sample of mulberry leaves used for each feeding was placed in separate tray as dummy for dry weight determination of ingesta. Additional larval batches of each treatment were maintained in parallel to determine the dry weight and for subsequent determination of daily increment in larval weight (Maynard & Loosli 1962). The healthy larvae were counted daily in each replication while the unhealthy and dad larvae were removed and replaced from additional batches. The litter was collected carefully on subsequent days of feeding. The excreta and leftover leaf in the litter were manually separated and dried in an oven. Observation on larval growth, larval duration and silk gland weight were recorded and for dietary efficiency calculation dry weight of left-over leaf, excreta, larval weight gain, cocoon weight and shell weight were recorded for all the replications of each treatment.

From these data, the parameters, nutritional indices like ingesta, digesta, approximate digestibility % (AD%), reference ration (RR), efficiency of conversion of ingesta and digesta (ECI and ECD) to larval body, cocoon and shell and ingesta and digesta per gram (I/g and D/g) of cocoon and shell were worked out by gravimetric method as described by Waldbauer (1968). The experiment was repeated three times and the data were subjected to statistical analysis to find out the significance.

Result and Discussion

The parameters like larval growth, cocoon, nutritional indices and dietary efficiency are presented in Table 1 and Table 2.

Larval growth and cocoon parameters

Larval duration of 5^{th} instar larvae was recorded significantly shorter in T1 (136 hrs) and longer in T2 (170 hrs) and T4 (167 hrs). This is due to the higher humidity in the silkworm rearing bed. Humidity and temperature largely determine the growth of the silkworm and success of silkworm rearing (Kenten 1955). Similarly, larval weight of 10 fully mature larvae was recorded significantly less in T1 (32.25g). Height significant difference of larval weight was recorded between control (T5) and other treatments (Table 1). Significantly higher silk gland weight was in the control treatment (13.86 g) when compared with other treatments and least was recorded in T1 (11.40g) where larvae were reared under high temperature.

Significant differences of Single cocoon were observed between control and all the treatments except T2 (Table 1). Single cocoon weight of T2 (1.73g) was on par with control (1.72g) and least cocoon weight was recorded in T1 (1.29g). A higher or lower temperature than 25°C acts as a stress factor and increases the susceptibility of silkworm to viral infection and poor cocoon crop (Steinhaus 1958).

Shell weight of cocoon represents actual silk content and a significant difference of single shell weight was recorded between all the treatments and control (Table 1). Significantly higher shell weight was recorded in control (0.447g) and least in T1 (0.31g). Similarly shell ratio was also recorded significantly higher in control (25.98%) and least was recorded in T2 (23.29%) where larvae were reared under high humidity conditions. There is direct correlation between metabolic responses of the poikilothermic insect to temperature, the results are similar to that of earlier findings of Venugopala & Krishnaswamy (1987).

Nutritritional indices parameters

Takeuchi (1964) reported that there is an increase in the intake of mulberry leaves during late stage with decrease in rearing temperature. Significant

Table 1. Larval growth, cocoon and nutritional indices parameters of fifth instar larvae of bivoltine silkworm hybrid reared under various stress conditions.

Treatments	Larval Duration (Hrs)	Larval Weight (g) (10 nos)	Silk Gland Weight (g) (10 nos)	Single Cocoon Weight (g)	Single Shell Weight (g)	Shell Ratio (%)	Ingesta (g)	Digesta (g)	Approximate Digestibility (%)	Reference Ration
T1 (Temp. 36°C, Humidity – 40%)	136	32.25**	11.40**	1.29**	0.310**	24.03**	3.04**	0.850**	27.99**	1.392*
T2 (Temp. 20°C Humidity – 90%)	170	43.25	13.25*	1.73	0.403*	23.29**	4.45	1.320*	30.11**	1.370*
T3 (30% less quantity feeding)	165	29.35**	12.65**	1.47**	0.345**	23.46**	4.11**	1.141**	27.79**	1.380**
T4 (over matured leaf feeding)	167	34.15**	11.85**	1.35**	0.330**	24.44**	3.52*	0.987**	28.12**	1.378**
T5 (Temp. 24°C Humidity – 70%)	148	43.00	13.86	1.72	0.447	25.98	4.41	1.436	32.44	1.480
Control										
CD @ 5%	6.16	2.612	0.525	0.068	0.032	0.229	0.1067	0.110	1.798	0.064
CD @ 1%	6.76	2.917	0.695	0.094	0.051	0.285	0.1107	0.141	1.990	0.094
SE±	1.12	0.287	0.892	0.021	0.002	0.125	0.054	0.032	0.721	0.019

**Significant at 1% level **Significant at 1% level CD - Critical difference
Values of food intake are expressed in gm/larva/5th instar

Table 2. Dietary efficiency parameters of fifth instar larvae of bivoltine silkworm hybrid reared under various stress conditions.

Treatments	ECI Larva (%)	ECD Larva (%)	ECI Cocoon (%)	ECD Cocoon (%)	ECI Shell (%)	ECD Shell (%)	I/g Cocoon (g)	I/g Shell (g)	D/g Cocoon (g)	D/g Shell (g)
T1 (Temp. 36°C, Humidity – 40%)	15.48**	55.29**	18.27**	65.26**	8.94**	31.96**	5.47**	11.17**	1.53**	3.13**
T2 (Temp. 20°C Humidity – 90%)	21.86**	72.61**	16.91	56.16**	8.60**	28.57	5.91	11.62**	1.78*	3.50
T3 (30% less quantity feeding)	15.02**	54.76**	17.85**	62.27**	8.91**	31.48**	5.32**	10.95**	1.45**	3.16**
T4 (over matured leaf feeding)	16.65**	58.21**	17.98**	63.57**	8.85**	31.56**	5.42**	11.05**	1.47**	3.21**
T5 (Temp. 24°C Humidity – 70%)	20.90	64.43	16.86	51.98	9.17	28.28	5.92	10.89	1.92	3.53
Control										
CD @ 5%	1.551	5.538	0.521	4.352	0.113	2.25	0.1158	0.2313	0.121	0.1157
CD @ 1%	1.752	6.016	0.845	4.672	0.181	2.65	0.1570	0.4210	0.241	0.181
SE±	0.241	1.98	0.224	2.12	0.092	1.12	0.071	0.091	0.018	0.041

**Significant at 1% level **Significant at 1% level CD - Critical difference
ECI - Efficiency of conversion of ingesta; ECD - Efficiency conversion of digesta; I/g Cocoon - ingesta per gram cocoon; I/g Shell - Ingesta per gram shell; D/g Cocoon - Digesta per gram cocoon; D/g Shell - Digesta per gram shell

differences of ingesta were recorded between control (4.41g) and all other treatments except T2 (Table 1). Ingesta of T2 (4.45g) was on par with the control and least ingesta was recorded when larvae were reared under higher temperature (3.04 g). According to Hidashi et al. (1982) and Sumioka et al. (1982) the amount of ingestion and digestion decreases when the worms are fed with less feed during 5th instar.

However, there was a significant difference of digesta recorded between control and all the treatments. Significantly least digesta was recorded in T1 (0.850g). In T2 treatment ingesta were on par with the control, however there was significant difference of digesta observed between control and T2 (Table 1). This may be due to the availability of fresh leaves, continuous feeding as well as inadequate tome to digest the food. Higher food intake tends to mobilize the gut contents faster and provide less time for enzyme activity and food absorption making digestive efficiency poor (Walbauer 1994).

Similarly, significant differences of approximate digestibility (AD%) were observed between all the treatments and control. Significantly least AD% (Table 1) was recorded when larvae were reared with over matured leaf feeding condition (27.79%). Digestibility is affected by nutritional deficiency or imbalanced diet, high content of crude fiber or deficiency of water in food (Waldbauer 1964). The higher assimilation efficiency or approximate digestibility is certainly a racial character, as higher food intake does not necessarily result in higher digestibility (Magdum et al. 1996). Reference ration was recorded significantly higher in control (1.480) and least was in T2 (1.370). Reference ration (RR) is an indirect expression of absorption and assimilation of food. It also expressed the ingesta required per unit excreta production. Higher RR values mean high rate of digestion and absorption of food.

Dietary efficiency parameters

Nutritional efficiency in the larval stages significantly influences the resulting pupa, adult and production of silk particularly in an economically important insect like *Bombyx mori* (Takano & Aral 1978, Aftab Ahamed et al. 1998). The efficiency with which food substance is ingested and converted to larval body matter varied prominently among the hybrids. It was reported that silkworm hybrids were more efficient in converting the food to larval body matter (Trivedi & Nair 19). ECI to larvae body matter was recorded significant higher in T2 (21.86%) when compared with other treatments (Table 2) and least was recorded in T3 (15.02%). Similarly, ECD to larval body matter also recorded significantly higher in T2 (72.61%). This may be due to the higher larval weight of the treatment. However, dietary efficiency parameters concerned with cocoon like ECI and ECD recorded significantly higher in T1 (18.27 and 65.26% respectively). Conversion efficiency of ingested food into shell was recorded higher in control (9.17%) and least was recorded in T2 (8.60 %), the results shows that more efficient conversion of ingested food to cocoon shell take place when larvae were reared under optimum temperature and humidity condition (Table 2). Dietary water intake is directly related to the moisture content of mulberry leaf and the amount of feed intake. ECI and ECAD to cocoon and shell are the two efficiency parameters, which are of paramount importance in practical sericulture (Trivedi & Nair 1999). Paul et al. (1992) recorded poor ECI and ECD for low moisture leaf fed to silkworm.

Conversion of digested food into shell (ECD) was higher in T1 (31.96%) and least in control (28.28% (Table 2). Insects evolved a variety of strategies to acquire and accumulate energy from nutrient and water from food in a given environmental condition (Muthukrishnan & Pandian 1987). Singh & Ninagi (1995) reported that less food ingested silkworm batches have high ECI and ECD to cocoon and shell. This may be due to the fact that less choice of feed leads to some physiological adoptions to overcome nutritional stress conditions (Nath et al. 1990; Tzenov 1993).

Significantly lower value of ingesta required to produce one gram of cocoon was recorded when larvae were under stress condition (T1 and T3). This result indicated adaptability by the silkworms under adverse condition. However, ingesta required to produce one gram of shell (I/g shell) was recorded higher (Table 2) in T2 (11.62g) and this may be due to the less shell weight of the treatment. Significantly higher value of digesta required to produce one gram of cocoon was recorded (D/g cocoon) in control (1.92g) and least was recorded when larvae were reared under adverse (T1 and T3). Similarly D/g shell was recorded higher in control (3.53g) and T2 (3.50g) and significantly lower D/g shell was recorded in T1 (3.13g) and T3 (3.16 g.

Conclusion

For successful bivoltine silkworm crop, the larvae should be reared under optimum temperature and humidity conditions and fed with recommended quantity and quality mulberry leaf with sufficient leaf moisture. In the present study it was clear that larval growth, cocoon quality and nutritional indices parameters were recorded significantly higher when larvae were reared under optimum temperature and humidity with adequate feed quantum as per the recommendation. However, most of the feed conversion efficiency parameters were recorded higher when worms were reared under high temperature and 30% quantity of feed. Ingesta and digesta required to produce one gram of cocoon and shell were also recorded higher when larvae were reared under various stress conditions. Therefore, slightly lower temperature and humidity besides better aeration and sufficient quantum of quality leaf is recommended during later stages of development of silkworm larvae.

References

Aftab Ahamed CA, Chandrakala MV, Shivakumar C & Raghuraman R. 1998.

Food and water utilization patterns under restricted feeding duration in *Bombyx mori* of pure Mysore race. J. Exp. Zool. 1:29-34.

Benchamin KV. & Jolly MS. 1986 Studies on ingestion and conversion efficiency in polyvoltine and bivoltine silkworm breeds *(Bombyx mori L.).* Proc . III Oriental Entomology Symposium Feb 21-24, Trivandrum, India, pp 195-206.

Hidashi S, Shigeru K & Narmi T. 1982. Feed efficiency and expression of several characters of the silkworm, *Bombyx mori* L. under restricted feeding. J. Seric Sci. Jpn. 51, 415-419.

Junliang Xu. & Xiaoffeng Wu. 1992. Research on improvement of efficiency of transforming leaf ingested into silk of the silkworm *Bombyx mori*, International Congress of Entomology, Beijing, China, Ab. No. 169-003, 623 b

Kenten J. 1955. The effect of photoperiod and temperature on reproduction in Acyrthosiphon pisum (Harris) and the forms produced. Bull. Entomol. Res.46; 599-624.

Magdum SB, Ramadevi OK, Shiva Shankar & Datta RK 1996. Nutritional indices in some bivoltine breeds of silkworm, *Bombyx mori* L. India J. Seric., 35 : 95 – 98.

Maynard AL & KJ. 1962. Animal nutrition. 5th Edn., Mac Graw . Hill. Newyork, p 533.

Meenal A & Ninagi O. 1995. Comparative study of ingestion pattern in polyvoltine and bivoltine silkworm races at different feeding levels. Sericologia 35:747-752.

Muthukrishnan J & Pandian TJ. 1987. Relation between feeding and egg production in some insects, Pro. Indian acad. Of Sci. (Anim. Sci.) 96:171-179.

Muniraju E, Sekharappa BM & Raghuraman R. 1999. Effect of temperature on leaf silk conversion in silkworm *Bombyx mori* L. Sericologia 39:225-2331.

Nath T, Nath S, Shamsudin M & Rao G. 1990 Effect of food deprivation on dry matter utilization, shell and cocoon weight and fecundity of multivoltine silkworm, *Bombyx mori* Race Nistari. Indian J. Seric. 29:174 – 181.

Paul DC, Subba Rao G & Deb DC. 1992. Impact of dietary moisture on nutritional indices and growth of *Bombyx mori* and concomitant larval duration. J. Insect. Physiol. 38:229-235.

Rajan RK, Singh GB, Himantharaj MT, Nataraju B & Subbaiah MB. 2001. Illustrated working process of new bivoltine rearing technology. JICA publication, CSR&TI, Mysore, pp 1-92.

Reynolds SE & Nottingham SF. 1985. Effect of temperature on growth and efficiency of food utilization in fifth instar caterpillar of tobacco hornworm, Manduca sexta. J. Insect Physiol., 31:129-134.

Singh GB & Ninagi O. 1995. Comparative studies on food utilization efficiency in some silkworm strains under different feeding levels. Sericologia, 354:667-675.

Steinhaus EA. 1958. Stress as factor in insect diseases. Proc. Tenth. Int. Congr. Entomol. 4:725-730.

Sumoika H, Kuroda S & Yoshitake N. 1982. Relationships among food ingestion, food digestion and body weight gain in the silkworm larvae, *Bombyx mori* L. under restricted feeding by indices. J. Seric. Sci. Jpn. 51:52-57.

Takano K & Arai N. 1978. Studies on the food value on the basis of feeding and cocoon productivity in the silkworm, *Bombyx mori* L., Treatment of food intake and cocoon productivity. J. Seric. Sci. Jpn. 47:134-142.

Takeuchi Y, Kosaka T & Ueda S. 1964. The effect of rearing temperature upon the amount of food ingested and digested. Technical Bull. Sericult. Exp. Stn. 84:1-12.

Trivedi K & Nair KS. 1999. Feed conversion efficiency of improved multibivoltine hybrids of silkworm, Bombyx mori L. Indian J. Seric. 38:30-34.

Tzenov P. 1993. Study on the food utilization in generic sex limited breeds for egg and larval traits of the silkworm, *Bombyx mori* L., at moderate, reduced and excess feeding amounts. Sericologia 33:247-256.

Ueda S & Suzuki K. 1967. Studies on the growth of the silkworm *Bombyx mori* L. 1. Chronological changes of the amount of food ingested and digested, body weight and water content of the body and their mutual relationships. Bull. Seric. Exp. Stn. 22:65-67.

Venugopala Pillai S & Krishhnaswamy S. 1987. Adaptability of silkworm Bombyx mori (L) to tropical conditions III, Studies on the effect of high temperature during later development stages of silkworm, Ind. J. Seric., 26:63-71.

Waldbauer GP. 1964. The consumption, digestion and utilization of solanaceous and non-solanaceous plants by larvae of the tobacco horn-worm, Protoparea extra (Lepidoptera: Sphinigidae). Entomol. Exp. Appl., 7:252-259.

Waldbauer GP. 1968. The consumption and utilization of food by insects. Adv. Insect Physiol. 5:229-288.