Available online at www.journalijmrr.com

INTERNATIONAL JOURNAL OF MODERN RESEARCH AND REVIEWS

Int. J. Modn. Res. Revs.

Volume 5, Issue 1, pp 1460-1467, January, 2017

ISSN: 2347-8314

ORIGINAL ARTICLE

STUDIES ON THE FEED EFFICACY, GROWTH RATE AND ECONOMIC TRAITS OF Silkworm *Bombyx mori* (L.) (LEPIDOPTERA : BOMBYCIDAE) FED WITH RIBOFLAVIN TREATED KANVA-2 MULBERRY LEAVES

[1]M. Meeramaideen, [1]P.Rajasekar, [1]M.Balamurugan and [2]P. Ganesh Prabu

[1]Department of Zoology, Jamal Mohamed College, Tiruchirappalli-620 020
[2]Department of Zoology, Annamalai University, Annamalai Nagar, Chidambaram -608 002

Article History: *Received 7th December,2016, Accepted 31st December,2016, Published 1st January,2017*

ABSTRACT

Silkworm *Bombyx mori* is an important economic insect and also a tool to convert leaf protein into silk protein. This study was carried out to determine the feed efficacy, growth and economic parameters of silkworm *Bombyx mori* (V instar larvae) fed by KANVA-2 mulberry (*Morus alba*) leaves and B-complex vitamins (Riboflavin (0.5%), Pantothenic acid (0.5%), Pyridoxal phosphate (0.5%) and Biotin (0.5%)) treated KANVA-2 mulberry leaves in relation to feed efficacy parameters like food consumption (FC), food utilization (FU), approximate digestibility (AD), consumption index (CI) and coefficient of food utilization (CFU). Morphometric parameters like length, width and weight of V instar larvae. Economic parameters like cocooning percentage (CP), shell weight (SW), shell ratio (SR), silk filament length (FL) and denier (D). The B-complex vitamins were treated to throughout the larval period. In the present study, it has been observed that the feed efficacy, growth and economic parameters of *B. mori* enhanced by 0.5% of B-complex vitamin (Riboflavin) treated group (T1) than control and other treated groups (Pantothenic acid (0.5%), Pyridoxal phosphate (0.5%) and Biotin (0.5%)). This study has been indicated that the B-complex vitamin (Riboflavin) exhibits the presence of more growth stimulant activity and can be used to increase the silk yield in commercial silkworm rearing with reference to sericulture.

Keywords: *Bombyx mori*, *Morus alba*, Riboflavin, KANVA-2 mulberry, Feed Efficacy, B-complex vitamins.

1.INTRODUCTION

The silkworm, *Bombyx mori*, is a monophagous lepidopteran insect which has been domesticated for more than five thousand years. Mulberry leaves suitable as food for silkworms must contain several chemical constituents such as water (80%), proteins (27%) and carbohydrates (11%), other extracts, mineral matters, vitamins etc. and at the same time, they must have the favourable physical features such as suitable tenderness, thickness and tightness, in order to be eaten by silkworms easily (Koul, 1989). Mulberry leaf is the sole food and source of nutrition for the silkworm, *Bombyx mori* due to the presence of morin (Tribhuwan and Mathur, 1989). Legay, (1958) has stated that silk production is dependent on the larval nutrition and nutritive value of mulberry leaves plays a very effective role in producing good quality cocoons. The physiology of this species has been studied extensively due to the economic importance of silk production over the centuries. Seki and Oshikane, 1959) have observed better growth and development of silkworm larvae as well as good quality cocoons when fed on nutritionally enriched leaves.

Corresponding author: **M. Meeramaideen, Department of Zoology, Jamal Mohamed College, Tiruchirappalli-620 020*

Recently, much research has been done on the diet supplementation of mulberry leaves fed to silkworms. These supplementations include vitamins such as ascorbic acid, thiamin, niacin, folic acid, multi-vitamins and vitamin C (Nirwani and Kaliwal, 1998; Saha and Khan, 1996; Etebari and Fazilati, 2003; Etebari *et al*., 2004). Etebari *et al*. (2004) have reported the yield decrease, when ascorbic acid concentration is enhanced in silkworm diet. Although some of the compounds have shown significant results, enrichment has not always caused the improvement of biological characteristics of the silkworm. Minerals and multi-vitamin compounds could enhance the intake of food, growth and feed efficiency conversion of silkworm (Muniandy *et al*., 1995). Akhtar and Asghar, (1972) have found that vitamins and mineral salts played an important role in the nutrition of silkworm.Food supplementation of potassium iodide, nickel chloride and copper sulphate enhance the physiological parameters of the silkworm (Magadum, 1987). Feeding behaviour have been observed in other lepidopteran insects like tobacco hornworm, *Manduca sexta* (Bowdan, 1988;

Timmins *et al*., 1988; Bernays and Woods, 2000), the woolly bear caterpillar, *Grammia geneura* (Bernays and Singer, 1998) and the corn earworm, *Helicoverpa armigera* (Barton Browne and Raubenheimer, 2003).

Nutrition is an important growth regulating factor in silkworm. It has been reported that the proteins, certain sugars, vitamins of B-complex, certain amino acids, certain minerals are responsible for the growth and development of the silkworm, *Bombyx mori* (Horie *et al*., 1966; Sengupta *et al*., 1972 and Faruki, 1998). The silkworm larvae have been attracted by three stimulants in mulberry leaves viz., the attractant, biting factor and swallowing factor (Hamamura and Naito, 1961). Sumioka *et al*. (1982) have observed that the leaf consumption influenced the body weight which in turn influences the silk output. Leaf consumption directly affects the silk producing capacity of the silkworm (Muthukrishnan *et al*., 1978). Cocoon characters, both quantitative and qualitative, depend largely on the quality and quantity of mulberry leaves (Koul, 1989). The feeding behaviour of *Manduca* larvae raised on artificial diet were found to be different from those of caterpillars fed plant leaves (Reynolds *et al*., 1986; Bernays and Woods, 2000).

The *Bombyx mori* larval feeding behaviour through continuous observations of larvae throughout larval development. In addition to this analysis, the behaviour of starved larvae were also observed to determine how diet-deprivation affects feeding behaviour. Finally, the study examined defecation and physical stimulation in Bombyx larvae as possible triggers for feeding (Simpson, 1995). Shafique, (1993) has reported that dry matter consumed by silkworm was directly proportional to nitrogen contents of the leaves. Silkworm nutrition refers the substances required by silkworm for its growth and metabolic functions and obtained from ingested food of mulberry/artificial diet and remaining other nutritional components are being synthesized itself through various biochemical pathways including protenaceous silk fiber of commercial interest (Takano and Arai, 1978; Hamano *et al*., 1986; Zhang *et al*., 2002). Mahmood, (1989) has concluded that leaves dipped in 0.2% N solution produced the larvae with maximum weight as compared to the other doses. Rehman, (1997) has concluded that optimum doses of minerals in various combinations, when used enhanced silk production and silkworm growth to a greater extent than control. The relationship between the environment and genes has considered bidirectional with food consumption efficiency on gene expression varies depending on the genetic background of an organism and expressed physiological or nutritional unit in gene regulation studies (Giacobino *et al*., 2003; Milner, 2004; Kang, 2008; Ogunbanwo and Okanlawon, 2009).

The present study has been aimed to find out the feed efficacy of Riboflavin treated KANVA-2 mulberry leaves with regard to food utilization by larvae and ultimate impact on the cocoon parameters of silkworm so as to spot out the most nutritive one for bivoltine silkworm in Tamil Nadu climatic conditions. The work is related to the studies on the growth rate of *B. mori* fed with control and Riboflavin treated KANVA-2 mulberry leaves are fragmentary. Therefore, this study has been carried out to know the impact of riboflavin vitamins on feed efficcy of *B. mori*.

2.MATERIALS AND METHODS

Silkworm Rearing

The first day of V instar of popular Indian bivoltine hybrid (CSR2×CSR4) silkworm *Bombyx mori* (Local Bivoltine) race were collected from Silkworm Culture Centre at 2nd Agraharam, Salem in Tamil Nadu. The larvae were reared simultaneously both in control and experimental groups separately on mulberry leaves dipped in B-complex vitamins (Riboflavin (0.5%), Pantothenic acid (0.5%), Pyridoxal phosphate (0.5%) and Biotin (0.5%)) solution in the laboratory. Proper environmental conditions provided to the silkworms with photoperiod of 12:12 h light and darkness as recommended by Krishnaswamy *et al*. (1973). The first day of V instar larvae were placed at ambient temperature of 25 ± 27ºC and relative humidity of 70 to 80%. The larvae were reared in card board boxes measuring 22×15×5 cms covered with nylon net and placed in an iron stand with ant wells (Govindan, *et al*., 1981).

Feed Efficacy

The quantity of KANVA-2 mulberry leaf offered to the entire groups was similar and *Bombyx mori* larvae were fed five times a day. The left over mulberry leaves and litter were weighed daily and recorded. Similarly, initial and final weights of the V instar larvae were recorded in control group and B-complex vitamins treated groups. Fresh leaves were cut into two halves; one half was used to determine the initial water content. Three V instar larvae in control and B-complex vitamins treated groups were dried in a hot air oven to constant weight to determine the dry weights. Based on these weights, the physiological parameters like food consumption (FC), food utilization (FU), approximate digestibility (AD), consumption index (CI) and coefficient of food utilization (CFU) were calculated (Arsenev and Bromlei, 1957).

Food Consumption (FC) was calculated by following formula

$$\text{FC} = \text{Dry weight of leaves offered} - \text{Dry weight of residual leaves}$$

Food Utilization (FU) was calculated by following formula

$$\text{FU} = \text{Weight of food consumed} - \text{Weight of faecal matter}$$

Approximate Digestibility (AD) was calculated by following formula

$$\text{AD} = \frac{\text{Dry weight of food eaten} - \text{Dry weight of faecal produced}}{\text{Dry weight of food eaten}} \times 100$$

Food Consumption Index (FCI) was calculated by following formula

$$\text{FCI} = \frac{E}{T \times A}$$

Where, E = Dry weight of food eaten,
T = Duration of Experimental period
A = Mean dry weight of animal during experimental period.

Co-efficient of Food Utilization (CFU) was calculated by following formula

$$\text{CFU} = \frac{\text{Dry weight of food consumed} - \text{Dry weight of faeces}}{\text{Dry weight of food consumed}} \times 100$$

Economic Traits

The economic traits like cocoon parameters (length, width and weight), cocoon shell weight were measured by using scales and digital balance, the other economic traits like shell ratio, filament length and denier were calculated by following appropriate formulas. The economic traits were analyzed the control and B-complex vitamins treated groups only (group 1 and 2).

Cocooning Percentage (CP) was calculated by following formula (Evans, 1939)

$$CP = \frac{\text{Number of cocoons formed}}{\text{Total number of larvae kept for rearing}} \times 100$$

Shell weight (SW)

Average shell weight of 6 cocoons, selected randomly from control and B-complex vitamins treated groups (Pupae were removed from cocoons and only shell was weighed).

Shell Ratio (SR) was calculated by following formula (Evans, 1939)

$$SR = \frac{\text{Weight of cocoon shell}}{\text{Weight of whole cocoon}} \times 100$$

Filament Length (FL)

Six cocoons were taken randomly from control and B-complex vitamins treated groups. The cocoon was socked in boiled water (after 6th day of spinning) to soften the sericin content. Cocked cocoons were reeled on epprouvette. The total number of revolutions were recorded and converted into meters by using the following formula (Evans, 1939).

$$FL = R \times 1.125$$

Where,

FL = Total filament length (m/cocoon)

R = Number of revolutions

1.125 = Circumference of Epprouvette

The average filament length of 6 replications of control and B-complex vitamins treated group was recorded.

Denier (D)

Denier is defined as the strength of silk thread. The reeled silk thread is taken from the epprouvette. It was dried for 15 days and weight of reeled silk was recorded.

The denier was calculated by following formula (Evans, 1939).

$$D = \frac{W}{L} \times 9000$$

Where,

W = Weight of single cocoon reeled silk in grams

L = Total length of single cocoon reeled filament in meters

9000 = Constant value

Selection of the Effective Concentration of B-complex vitamins

The B-complex vitamins riboflavin, pantothenic acid, pyridoxal phosphate and biotin was diluted to 0.5% concentration separately. Fresh KANVA-2 mulberry leaves were separately soaked with each vitamin for 15 minutes and then were dried in air for 10 minutes. The B-complex vitamins treated leaves were used for feeding the V instars larvae of silkworm *Bombyx mori* (Suleman, 1999). The *Bombyx mori* larvae were divided into two groups (Control and Treated). The treated group divided into four sub groups (T1, T2, T3 and T4) this sub groups were treated with B-complex vitamins. The feed efficacy of *B. mori* V instar larvae were compared to control and treated groups and also find out the morphometric and economic parameters. The control and B-complex vitamins treated KANVA-2 mulberry (*Morus alba*) leaves were fed by V instar of silkworm *Bombyx mori*, five feedings/per day.

Experimental Groups

The V instars of *Bombyx mori* larvae fed with the following KANVA-2 mulberry leaves. Control group (C) larvae fed with normal KANVA-2 mulberry leaves, group T1 larvae fed with 0.5% of riboflavin treated KANVA-2 mulberry leaves, group T2 larvae fed with 0.5% pantothenic acid treated KANVA-2 mulberry leaves, group T3 larvae fed with 0.5% pyridoxal phosphate treated KANVA-2 mulberry leaves and group T4 larvae fed with 0.5% biotin treated KANVA-2 mulberry leaves. (Rasool, 1995).

Observation of Feeding Behavior of Larvae

Only populations of larvae in synchronous growth were observed. During observations, each larva was placed in a plastic container facing a 3 cm3 block of artificial diet. Larvae were spaced within the container so as not to disrupt the feeding behaviour of other animals (Shinji Nagata and Hiromichi Nagasawa, 2006).

Statistical Analysis

All the data were analyzed by one way analysis of variance (ANOVA) followed by Duncan's multiple range test (DMRT) using a commercially available statistics software package (SPSS® for Windows, V. 16.0, Chicago, USA). Results were presented as mean ± standard deviation (SD).

3.RESULTS

Feed efficacy characters like Food Consumption (FC), Food Utilization (FU), Approximate Digestibility (AD), Food Consumption Index (FCI) and Co-efficient of Food Utilization (CFU) data of V instar larvae of *B. mori* fed with control KANVA-2 mulberry leaves and B-complex vitamins (Riboflavin (T_1), Pantothenic acid (T_2), Pyridoxal Phosphate (T_3) and Biotin (T_4)) treated KANVA-2 mulberry leaves were presented in Table 1.

Table 1 shows that the food consumption (FC) data of V instar larvae of *B. mori* fed with control and B-complex vitamins (Riboflavin (T_1), Pantothenic acid (T_2), Pyridoxal Phosphate (T_3) and Biotin (T_4)) treated KANVA-2 mulberry leaves. The food consumption (gm) of group 'C' larvae (45.1780±0.1662 gm), group T_1 larvae (54.7617±1.9709 gm), group T_2 (52.8633±0.9980 gm) larvae, group T_3 (53.8933±0.8817^a gm) and group T_4 (52.1500±0.7167 gm), respectively. In these five observations, the 0.5% (group T_1) B-complex vitamin (Riboflavin) treated larvae food consumption (gm) was significantly increased than the other four groups ('C', T_2, T_3 and T_4).

Table 1 shows that the food utilization (FU) data of V instar larvae of *B. mori* fed with control and B-complex vitamins (Riboflavin (T_1), Pantothenic acid (T_2), Pyridoxal Phosphate (T_3) and Biotin (T_4)) treated KANVA-2 mulberry leaves. The food utilization (gm) of group 'C' larvae (44.4076±0.2511 gm), group T_1 larvae (50.4733±1.6497 gm), group T_2 (48.9867±0.9018 gm) larvae, group T_3 (49.9033±0.8205 gm) and group T_4 (47.0740±0.7701 gm), respectively. In these five observations, the 0.5% (group T_1) B-complex vitamin (Riboflavin) treated larvae food utilization (gm) was significantly increased than the other four groups ('C', T_2, T_3 and T_4).

Table 1 shows that the food consumption index (FCI) data of V instar larvae of *B. mori* fed with control and B-complex vitamins (Riboflavin (T_1), Pantothenic acid (T_2), Pyridoxal Phosphate (T_3) and Biotin (T_4)) treated KANVA-2 mulberry leaves. The food consumption index (%) of group 'C' larvae (35.4560±1.0789 %), group T_1 larvae (45.5750±2.1505 %), group T_2 (41.9133±1.3264 %) larvae, group T_3 (40.7583±1.2203 %) and group T_4 (42.1950±1.4720 %), respectively. In these five observations, the 0.5% (group T_1) B-complex vitamin (Riboflavin) treated larvae food consumption (%) was significantly increased than the other four groups ('C', T_2, T_3 and T_4).

Table 1 shows that the approximate digestibility (AD) data of V instar larvae of *B. mori* fed with control and B-complex vitamins (Riboflavin (T_1), Pantothenic acid (T_2), Pyridoxal Phosphate (T_3) and Biotin (T_4)) treated KANVA-2 mulberry leaves. The approximate digestibility (%) of group 'C' larvae (84.7015±0.5684 %), group T_1 larvae (92.3173±1.2137 %), group T_2 (87.3981±0.7389 %) larvae, group T_3 (89.8357±0.9575 %) and group T_4 (85.9016±0.8190 %), respectively. In these five observations, the 0.5% (group T_1) B-complex vitamin (Riboflavin) treated larvae approximate digestibility (%) was significantly increased than the other four groups ('C', T_2, T_3 and T_4).

Table 1 shows that the co-efficient of food utilization (CFU) data of V instar larvae of *B. mori* fed with control and B-complex vitamins (Riboflavin (T_1), Pantothenic acid (T_2), Pyridoxal Phosphate (T_3) and Biotin (T_4)) treated KANVA-2 mulberry leaves. The co-efficient of food utilization (%) of group 'C' larvae (83.0200±0.4906 %), group T_1 larvae (92.4 900±0.9715 %), group T_2 (88.6300±0.6762 %) larvae, group T_3 (89.2150±0.7474 %) and group T_4 (87.3633±0.5484 %), respectively. In these five observations, the 0.5% (group T_1) B-complex vitamin (Riboflavin) treated larvae co-efficient of food utilization (%) was significantly increased than the other four groups ('C', T_2, T_3 and T_4).

Table 2 shows the morphometric data of length, width and weight of larval, pupal and cocoon parameters of *Bombyx mori* larvae fed with control KANVA-2 mulberry leaves and B-complex vitamins (Riboflavin (T_1), Pantothenic acid (T_2), Pyridoxal Phosphate (T_3) and Biotin (T_4)) treated KANVA-2 mulberry leaves were presented in Tables 10, 11, 12, 13 and 14, respectively.

Table 2 shows that the morphometric data of length, width and weight of larval parameters of *B. mori* fed with control KANVA-2 leaves and B-complex vitamins (Riboflavin (T_1), Pantothenic acid (T_2), Pyridoxal Phosphate (T_3) and Biotin (T_4)) treated KANVA-2 leaves in Vinstar larvae of *B. mori*. The mean length, width and weight of V instar larvae of group 'C' were (7.0117±0.19831 cm, 10.6533±0.07111 cm and 3.4350±0.19550 gm), respectively. The mean length, width and weight of V instar larvae of group T_1 were (9.4560±0.29705 cm, 11.1233±0.18165 cm and 4.5283±0.32693 gm), respectively. The mean length, width and weight of V instar larvae of group T_2 were (8.8080±0.28887 cm, 0.9700±0.09142 cm and 3.9550±0.29302 gm), respectively. The mean length, width and weight of V instar larvae of group T_3 were (8.7863±0.25721 cm, 0.8600±0.08325 cm and 3.8150±0.25529 gm), respectively. The mean length, width and weight of V instar larvae of group T_4 were (8.5520±0.23340 cm, 0.7967±0.07663 cm and 3.7950±0.25609 gm), respectively. In these five observations, 0.5% (group T_1) B-complex vitamin (Riboflavin) treated V instar larvae length, width and weight was significantly increased than the other four groups ('C', T_2, T_3 and T_4).

Economic characters like Cocooning Percentage (CP), Shell Weight (SW), Shell Ratio (SR), Silk Filament Length (SFL) and Denier (D-Silk filament Strength) data of control KANVA-2 mulberry leaves and different concentrations of B-complex vitamins (Riboflavin (T_1), Pantothenic acid (T_2), Pyridoxal Phosphate (T_3) and Biotin (T_4)) treated KANVA-2 mulberry leaves fed *B. mori* larvae produced cocoon and silk filament were presented in Table 3.

Table 3 shows that the data of control and B-complex vitamins (Riboflavin (T_1), Pantothenic acid (T_2), Pyridoxal Phosphate (T_3) and Biotin (T_4)) treated KANVA-2 mulberry leaves fed V instar larvae produced cocoon's cocooning percentage (CP). The cocooning percentage (%) of group 'C' larvae (85.0750±0.45107 %), group T_1 larvae (90.1617±1.14792 %), group T_2 (88.7083±0.86253 %) larvae, group T_3 (86.6717±0.75811 %) and group T_4 (85.4083±0.56839 %), respectively. In these five observations, the 0.5% (group T_1) B-complex vitamin (Riboflavin) treated larvae cocooning percentage (%) was significantly increased than the other four groups ('C', T_2, T_3 and T_4).

Table 3 shows that the data of control and B-complex vitamins (Riboflavin (T_1), Pantothenic acid (T_2), Pyridoxal Phosphate (T_3) and Biotin (T_4)) treated KANVA-2 mulberry leaves fed V instar *B. mori* larvae produced cocoon's shell weight (SW). The shell weight (gm) of group 'C' larvae (0.7033±0.0318 gm), group T_1 larvae (1.0283±0.1557 gm), group T_2 (0.8967±0.0916 gm) larvae, group T_3 (0.8067±0.0880 gm) and group T_4 (0.7983±0.0756 gm), respectively. In these five observations, the 0.5% (group T_1) B-complex vitamin (Riboflavin) treated larvae shell weight (SW) was significantly increased than the other four groups ('C', T_2, T_3 and T_4)

Table 3 shows that the data of control and B-complex vitamins (Riboflavin (T_1), Pantothenic acid (T_2), Pyridoxal Phosphate (T_3) and Biotin (T_4)) treated KANVA-2 mulberry leaves fed V instar *B. mori* larvae produced cocoon shell ratio (SR). The shell ratio (%) of group 'C' larvae (18.9700±0.4958 %), group T_1 larvae (20.9200±1.2172 %), group T_2 (19.7583±0.8068 %) larvae, group T_3 (19.5583±0.7383 %) and group T_4 (19.3350±0.5198 %), respectively. In these five observations, the 0.5% (group T_1) B-complex vitamin (Riboflavin) treated larvae shell ratio (SR) was significantly increased than the other four groups ('C', T_2, T_3 and T_4).

Table 3 shows that the data of control and B-complex vitamins (Riboflavin (T_1), Pantothenic acid (T_2), Pyridoxal Phosphate (T_3) and Biotin (T_4)) treated KANVA-2 mulberry leaves fed V instar *B. mori* larvae produced cocoon's silk filament length (SFL). The silk filament length (meters) of group 'C' larvae (886.9733±12.8734 mts.), group T_1 larvae (974.3250±05.8491 mts.), group T_2 (942.7867±11.4419 mts.) larvae, group T_3 (932.5867±15.9575 mts.) and group T_4 (915.0333±40.6181 mts.), respectively. In these five observations, the 0.5% (group T_1) B-complex vitamin (Riboflavin) treated larvae silk filament length (meters) was significantly increased than the other four groups ('C', T_2, T_3 and T_4).

Table 3 shows that the data of control and B-complex vitamins (Riboflavin (T_1), Pantothenic acid (T_2), Pyridoxal Phosphate (T_3) and Biotin (T_4)) treated KANVA-2 mulberry leaves fed V instar *B. mori* larvae produced cocoon's silk filament denier (D). The silk filament denier of group 'C' larvae (2.1567±0.0906 %), group T_1 larvae (3.5450±0.1998 %), group T_2 (2.9150±0.1749 %) larvae, group T_3 (2.8833±0.1503 %) and group T_4 (2.6000±0.1397 %), respectively. In these five observations, the 0.5% (group T_1) B-complex vitamins treated larvae silk filament length (meters) was significantly increased than the other four groups ('C', T_2, T_3 and T_4).

Table. 1. Feed efficacy data of V instar larvae of *Bombyx mori* fed with control and B-complex vitamins treated KANVA-2 mulberry leaves

Experimental Groups / Concentration	Food Consumption (gm)	Food Utilization (gm)	Approximate Digestibility (%)	Food Consumption Index (%)	Co-efficient of Food Utilization (%)
Control (C)	45.1780±0.1662[b]	44.4076±0.2511[c]	84.7015±0.5684[b]	35.4560±1.0789[b]	83.0200±0.4906[b]
Riboflavin 0.5% (T_1)	54.7617±1.9709[c]	50.4733±1.6497[d]	92.3173±1.2137[c]	45.5750±2.1505[c]	92.4 900±0.9715[c]
Pantothenic acid 0.5% (T_1)	52.8633±0.9980[b]	48.9867±0.9018[a]	87.3981±0.7389[ab]	41.9133±1.3264[b]	88.6300±0.6762[b]
Pyridoxal phosphate 0.5% (T_3)	53.8933±0.8817[ab]	49.9033±0.8205[ab]	89.8357±0.9575[ab]	42.1950±1.4720[a]	89.2150±0.7474[a]
Biotin 0.5% (T_4)	52.1500±0.7167[a]	47.0740±0.7701[bc]	85.9016±0.8190 [a]	40.7583±1.2203[a]	87.3633±0.5484[a]

Values are Mean ± Standard Deviation of six observations. Values in the same column with different superscript letters (a, b & c) differs significantly at P<0.05 (DMRT).

Table. 2. Morphometric data of V instar larvae of *Bombyx mori* fed with control and B-complex vitamins treated KANVA-2 mulberry leaves

Experimental Groups / Concentrations	Larvae length (cm)	Larvae width (cm)	Larvae weight (gm)
Control (C)	7.0117±0.19831[a]	0.6533±0.07111[ab]	3.4350±0.19550[a]
Riboflavin 0.5% (T_1)	9.4560±0.29705[c]	1.1233±0.18165[b]	4.5283±0.32693[b]
Pantothenic acid 0.5% (T_1)	8.8080±0.28887[bc]	0.9700±0.09142[ab]	3.9550±0.29302[a]
Pyridoxal phosphate 0.5% (T_3)	8.7863±0.25721[bc]	0.8600±0.08325[ab]	3.8150±0.25529[ab]
Biotin 0.5% (T_4)	8.5520±0.23340[b]	0.7967±0.07663[a]	3.7950±0.25609[a]

Values are Mean ± Standard Deviation of six observations. Values in the same column with different superscript letters (a, b & c) differs significantly at P<0.05 (DMRT).

Table. 3. Economic traits of control and B-complex vitamins treated KANVA-2 mulberry leaves fed V instar larvae of *Bombyx mori* produced cocoon

Experimental Groups / Concentration	Cocooning Percentage (%)	Shell weight (gm)	Shell Ratio (%)	Silk filament Length (Meters)	Denier (%)
Control (C)	85.0750±0.45107[c]	0.7033±0.0318[ab]	18.9700±0.4958[b]	886.9733±12.8734[b]	2.1567±0.0906[b]
Riboflavin 0.5% (T_1)	90.1617±1.14792[d]	1.0283±0.1557[c]	20.9200±1.2172[c]	974.3250±05.8491[c]	3.5450±0.1998[c]
Pantothenic acid 0.5% (T_1)	88.7083±0.86253[bc]	0.8967±0.0916[a]	19.7583±0.8068[ab]	942.7867±11.4419[b]	2.9150±0.1749[b]
Pyridoxal phosphate 0.5% (T_3)	86.6717±0.75811[ab]	0.8067±0.0880[a]	19.5583±0.7383[ab]	932.5867±15.9575[a]	2.8833±0.1503[a]
Biotin 0.5% (T_4)	85.4083±0.56839[a]	0.7983±0.0756[b]	19.3350±0.5198[a]	915.0333±40.6181[a]	2.6000±0.1397[a]

4.DISCUSSION

In the present study, feed efficacy, growth and economic traits are significantly increased in some groups. Many researchers showed that the larval characters improve by different concentrations of supplementary compounds such as ascorbic acid, folic acid, thiamin (Sarker *et al*., 1993; Nirwani and Kaliwal, 1996, Etebari *et al*., 2004). According to Soo-Hoo and Frankel, (1966) the diminishing consumption rate of less preferred food was partially compensated by increased assimilation efficiency. Ashfaq *et al*. (2001) have mentioned that silkworm fed with M. nigra showed high food consumption, coefficient of nutrition utilization, larval size, larval weight and cocoon weight that may provide important factors for increasing silk tenacity and elongation. According to Mathavan and Krishnan, (1976) assimilation efficiency did not vary significantly as a function of reduced food consumption. The growth and development of silkworm is under the continuous influence of factors operating within and outside of the body (Murugan *et al*., 1998).

As dietary or nutrient factors and related metabolic interactions has direct and indirect influence on specific gene regulation and expression (Iftikhar and Hussain, 2002; Phillips *et al*., 2008). It has been reported that cocoon weight and pupal weight were directly proportional to the concentration of JH and the feeding period (Akai *et al*., 1985 and Chowdhary *et al*., 1990). Mulberry leaves with the combination of Nitrogen (0.2%) which enhances the growth and silk production (Javed and Gondal, 2002). According to Mathavan and Krishnan, (1976) assimilation efficiency did not vary significantly as a function of reduced food consumption. It was reported that cocoon weight and pupal weight were directly proportional to the concentration of JH and the feeding period (Akai *et al*., 1985 and Chowdhary *et al*., 1990). Such interactions and variations in the field of nutrigenetics could be applied to choose the silkworm breeds based on their nutritional efficiency parameter as biomarkers. The majority of silkworm germplasm breeds were evaluated based on the feeding habit and adaptability for the commercial rearing on artificial diet that can feed on low cost artificial diet lacking mulberry (Mano *et al*., 1991; Zhang *et al*., 2002).

In sericulture, nutritional requirement and its conversion efficiency contribute directly or indirectly on the cost benefit ratio of silkworm rearing. It was considered as an important physiological criterion for evaluating the superiority of silkworm breeds. In silkworm, 97% of the total food intake during the last two instars and the feed utilization study confined to V instar larvae as 80-85% of the total leaves consumed in this instar as silkworm very active metabolically at this stage (Rahmathulla *et al*., 2005). According to Soo-Hoo and Frankel, (1966) the diminishing consumption rate of less preferred food was partially compensated by increased assimilation efficiency. Javaid (1991) and Nadeem (1996) who have reported that silkworm larvae fed on mulberry leaves supplemented with mineral nutrients gave good food consumption and coefficient of utilization but low mortality. Verma and Atwal, (1963) have observed that feeding mulberry leaves supplemented with distilled water alone slightly increased the weights of larva, pupa and cocoon shell. Ascorbic acid had effect on the growth of silkworm (Javed and Gondal, 2002). Amway protein supplemented (0.5%) mulberry leaf significantly improved larval growth and economic characters of silkworm (Amala Rani *et al*., 2011).

Rehman (1997) has found similar impact of different doses nitrogen and concluded that higher doses resulted in decline food consumption and coefficient of utilization. Further, it was established that silkworm derives over 70% of the protein from the mulberry leaves and in V instar upto 96% of ingested protein is used for silk protein synthesis and variation in the quantity or quality of nutrition have profound effect on insect development (Fukuda and Higuchiy, 1963). Similar results have been reported by Magadum *et al*. (1996) and Gokulamma and Reddy, (2005). Javed and Gondal, (2002) have reported that the larvae which were offered mulberry leaves treated with 0.2% N + 0.150% ascorbic acid showed lower mean values of body weight, body length, food consumption, coefficient of utilization and cocoon shell ratio but higher mortality rate. Sarkar and Fujita (1994) have reported that the low intake of food results led to reduced larval period. This finding clearly indicates that the varieties with high conversion efficiencies may reduce the larval span and consequently less quantity of the food is needed to support optimal growth. The result obtained from the study revealed a highly significant variance on nutritional traits between the control KANVA-2 leaf and KANVA-2 treated with B-complex vitamins.

Feed conversion efficiency contributes directly and indirectly to the major chunk of the cost benefit ratio of silkworm rearing and considered as an important physiological criterion for evaluating the superiority of silkworm breeds. Efficiency of the nutrition almost nullified by the increase in consumption result in increased production of cocoon, shell and understood that dietary factors and related metabolic interactions has direct and indirect influence on specific gene expression. Previously Vyjayanthi and Subramanyam, (2002) have stated that multivoltine silkworms had significantly higher rates of feeding, assimilation and conversion with increased efficiency of conversion of ingested and digested food to body substance when compared with bivoltine silkworms. Vyjayanthi and Subramanyam, (2002) have stated in the silkworm, *Bombyx mori,* feeding behavior depends on the niche, amount of food offered, quality of food, age and health of the larva. Food utilization parameters have been studied in many insects (Rath *et al.,* 2003). The nutritive value of mulberry leaves depends on various agro-climatic factors and any deficiency of nutrients in leaves affect silk synthesis by the silkworm. Nutritional management directly influences the quality and quantity of silk production.

5.CONCLUSION

In the present study to be concluded that feed efficacy, growth rate and economic traits of *Bombyx mori* was comparatively more when the silkworm fed with 0.5% of riboflavin treated KANVA-2 mulberry leave than the control and other treated groups such as Pantothenic acid (T_2), Pyridoxal Phosphate (T_3) and Biotin (T_4).

6.REFERENCE

Akai, H., Kimura, K., Kiguchi, M and Shibukawa, K. 1985. An increase of silk production by repeated treatment with a juvenile hormone analogue. J. Seric. Sci. Jpn. 54: 297-299.

Akhtar, M and Asghar, A. 1972. Nutritional requirement of silkworm *Bombyx mori*. Pakistan J. Zool., 4: 101-107.

Amala Rani, G., Padmalatha, C., Sorna Raj, R and Ranjith Singh, A.J.A. 2011. Impact of Supplementation of Amway Protein on the Economic Characters and Energy Budget of Silkworm *Bombyx mori* L. Asian J. Animal Sci., 1-6.

Arsenev, A.F and Bromlei, N.V.1957.The effect of various food components on the yield and vitality of the mulberry and oak silkworm. Tr. Moskvet Akad. 21: 68-196.

Ashfaq, M., Nadeem, M.K and Nadeem, S. 2001. Impact of mulberry varieties and various alternate hosts on the development of *Bombyx mori* L. and silk yield. South Pacific Study 21(2): 61-64.

Barton Browne L., D. Raubenheimer, 2003.Ontogenetic changes in the rate of ingestion and estimates of food consumption in fourth and fifth instar Helicoverpa armigera caterpillars. Journal of Insect Physiology, 49 (1) 63–71.

Bernays E.A., H.A. Woods, 2000.Foraging in nature by larvae of Manduca sexta influenced by an endogenous oscillation. Journal of Insect Physiology, 46:825–836.

Bernays E.A., M.S. Singer.1998. A rhythm underlying feeding behavior in a highly polyphagous caterpillar. Physiological Entomology, 23 :295–302.

Bowdan E.1998. The effect of deprivation on the microstructure of feeding by the tobacco hornworm caterpillar. Journal of Insect Behavior 1:31–50.

Chowdhary, S.K., Raju, R.S and Ogra, R.K.(1990. Effect of JH analogues on silkworm, *Bombyx mori* L., growth and development of silk gland. Sericologia., 30: 155-165.

Etebari, K and Fazilati, M. 2003. Effect of feeding on mulberry's supplementary leaves with multi-mineral in some biological and biochemical characteristics of silkworm (*Bombyx mori*). J. Sci. Technol. Agric. Natur. Resour., 7: 233-244.

Etebari, K., Kaliwal, B and Matindoost, L. 2004. Supplementation of mulberry leaves in sericulture, theoretical and applied aspects. Int. J. Indust. Entomol., 9: 14-28.

Evans, A.C. 1939. The utilization of food by certain Lepidopterous larvae. Trans. Roy. Entomol. Soc., 89: 13-22

Faruki, S.I.1998. Nutritive effects of thianomin® enriched mulberry leaves on the silkworm, *Bombyx mori* L. Univ. J. Zool. Rajshahi Univ., 17: 39-44.

Fukuda, T and Higuchiy. 1963. Artificial food for oak silkworm rearing. Agric. Biochem., 27: 99-102.

Giacobino, A.P., Grimable, R and Pichard, C. 2003. Review genetics and nutrition. Clin. Nutr., 22: 429-435.

Gokulamma, K and Reddy, Y.S.2005. Role of nutrition and environment on the consumption, growth and utilization indices of selected silkworm races of *Bombyx mori* L. Indian J. Sericol., 44: 165-170.

Govindan, R., Devaina, M.C., Tippeswamy, C and Rangaswamy, H.R. 1981. Ovipositional behaviour of eri silk Samiacynth ricini under Dharwad conditions. Pro. Seri. Sym and Seminar TNAU. 35-38.

Hamamura, Y and Naito, K. 1961. Food selection by silkworm larvae, *Bombyx mori*. Nature, 190(3): 879-880.

Hamano, K., Miyazawa, K and Mukiyama, F. (1986). Racial difference in the feeding habit of the silkworm, *Bombyx mori*. J. Sericol. Sci. Jap., 55: 68-72.

Horie, Y., Watanabe, H and Ito, T. 1966. Nutrition of the silkworm, *Bombyx mori* – XIV. Further studies on the requirements for B vitamins. Bull. Seric. Exp. Sta., Tokyo, 20: 393-409.

Iftikhar, T and Hussain. A.2002. Effect of nutrients on the extracellular lipase production by mutant strain of *Rhizopus ologosporous*. Biotechnology, 1: 15-20.

Javaid M.A.,1991. Effect of feeding potassium and nitrogen treated mulberry leaves on the development of silkworm, *Bombyx mori* L. and silk yield. M.Sc (Hons) Thesis Deptt Agric Entomol Univ Agric Faisalabad Pakistan.

Javed, H and Gondal, M.H. 2002. Effect of food supplementation by N and Ascorbic acid on larval mortality of silkworm *Bombyx mori* L. Asian J. Plant Sci., 1: 556-557.

Kang, K.J. 2008. A transgenic mouse model for gene-nutrient interactions. J. Nutrigenet. Nutrigenomics, 1: 172-177.

Koul, A. (1989). Relationship among leaf consumption, body weight and silk production in *Bombyx mori* L. Agric. Sci. Digest., 9(4): 208-209.

Krishnaswami, S., Narasimahanna, M.N., Suryanarayan, S.K and Kumararaj, S. 1973. Sericulture Manual J. Silkworm Rearing, FAO, Rome, 131.

Legay, J.M. (1958). Recent advances in silkworm nutrition. Ann. Rev. Ent., 3: 75-86.

Magadum, S.B. 1987. Studies on the effect of some chemicals and hormones on the gonads and the life cycle of the silkworm, *Bombyx mori* L. Ph.D. Thesis, Karnataka Universtiy, Dharwad, India, 1-30.

Magadum, S.B., Ramadevi, O.K., Shivashankar, N and Datta, R.K. (1996). Nutritional indices in some bivoltine breed of silkworm, *Bombyx mori* L. Indian J. Sericol., 35: 95-98.

Mahmood, R. 1989. Effect of nitrogen on the larval development and silk yield of *Bombyx mori* L. M.Sc. (Hons.) thesis, Dept. Agric. Entomol., Univ. Agric, Faisalabad, Pakistan, 133.

Mano, Y., Asaoka, K., Ihara, O., Nakagawa, H., Hirabayashi, T., Murakami, M and Nagayashu, K. 1991. Breeding and evaluation of adaptability of silkworm, *Bombyx mori* to new low cost artificial diet, LPY lacking mulberry leaf powder. Bull. Nat. Inst. Seric. Entomol. Sci., 3: 31-56.

Mathavan, S and Krishnan, J.M. 1976. Effects of ration levels and restriction of feeding durations on food utilization in *Danaus chrysippus* (Lepidoptera: Daniadae). Entomol. Exp. Appl., 19: 155-162.

Milner, J.A. 2004. Nutrition and gene regulation: Molecular targets for bioactive food components. J. Nutr., 134: 2492-2498.

Muniandy, S., Sheela, M and Nirmala, S. 1995. Effect of vitamins and minerals (Filibon) on food intake, growth and conversion efficiency in *Bombyx mori*. Environ. Ecol., 13: 433-435.

Murugan, K., Jeyabalan, D., Senthil Kumar, N., Babu, R., Sivapirakasam, N and Nathan, S.S. 1998. Growth promoting effects of plant products on silkworm. A biotechnology approach. J. Sci. Indian Res., 57: 740-746.

Muthukrishnan, J., Madhavan, S and Navarathna Jothi, V. 1978. Effect of restriction of feeding duration of food utilization, emergence and silk production in *Bombyx mori* L. (Lepidoptera: Bombycidae) Monitoire. Zool., 12: 87-94.

Nadeem S.1996. Collaborative effect of optimum dosages of N, K, Ca, P and Mg on larval development and silk yield of *Bombyx mori* (L). M.Sc (Hons) Thesis Dept. Agric. Entomol. Univ. Agric. Faisalabad, Paksitan, .

Nirwani, R.B and Kaliwal, B.B. 1996. Effect of Folic acid on economic traits and the change of some metabolic substances of bivoltine silkworm, *Bombyx mori* L. Korean J. Seric. Sci. 38: 118-123.

Ogunbanwo, S.T and Okanlawon, B.M. 2009. Influence of nutrients utilization and cultivation conditions on the production of lactic acid by homolactic fermenters. Biotechnology, 8: 107-113.

Phillips, C.N., Tierney, A.C and Roche, H.M.2008. Gene nutrient interactions in the metabolic syndrome. J. Nutrigenet. Nutrigenomics, 1: 136-151.

Rahmathulla, V.K., Haque Rufaie, H.Z., Himanthraj, M.T., Vindhya, G.S and Rajan. R.K. 2005. Food ingestion, assimilation and conversion efficiency of mulberry silkworm, *Bombyx mori* L. Int. J. Ind. Entmon., 11: 1-12.

Rasool, K.(1995. Effect of nutritional supplements on larval development and silk yield of silkworm (*Bombyx mori* L.) M.Sc. (Hons.) Thesis, Deptt. Agric. Entomol., Univ. Agric, Faisalabad, Pakistan.

Rath, S.S., Prasad, B.C and Sinha, B.R.R.P. 2003. Food utilization efficiency in fifth instar larvae of *Antheraea mylitta* (Lepidoptera: Saturniidae) infected with *Nosema* sp. and its effect on reproductive potential and silk production. J. Invert. Pathol., 83: 1-9.

Rehman, A. 1997. The impact of optimum dosages of minerals in various combinations on larval development and silk production of *Bombyx mori* L. M.Sc. (Hons.) Thesis, Dept. Agric. Entomol., Univ. Agric, Faisalabad, Pakistan.

Reynolds S.E., M.R. Yeomans, W.A. Timmins.1986. The feeding behaviour of caterpillars (*Manduca sexta*) on tobacco and on artificial diet. Physiological Entomology 11: 39–51.

Saha, B.N and Khan, A.R. 1996. The growth and development of the silkworm, *Bombyx mori* L. on feed supplemented with nicotinic acid. Bangladesh J. Life Sci., 1: 103-109.

Sarkar A., H. Fujita, Better technique for nutritive evaluation of mulberry leaves for silkworm *Bombyxmori* L. Indian J. Ser., 33(1994) 19-22.

Sarker, A. 1993. Effects of feeding different races of silkworm, *Bombyx mori* with leaves varying in ploidy level. Seriologia., 33(1): 25-34.

Seki, K and Oshikane, K.1959. Textile and Sericulture, Shinshu University, Res. Reports. Fac.

Sengupta K, Singh, B.D and Mustafi, J.C. 1972. Nutrition of silkworm, *Bombyx mori* L. I. Studies on the enrichment of mulberry leaf with various sugars, proteins, amino acids and vitamins for vigorous growth of the worm and increased cocoon crop protection. Indian J. Seric., 11: 1.1-27.

Shafique, M. 1993. Effect of feeding phosphorus and nitrogen treated mulberry leaves on the development of silkworm (*Bombyx mori* L.) and silk yield. M.Sc. (Hons.) Thesis, Deptt. Agric. Entomol., Univ. Agric, Faisalabad, Pakistan.

Shinji Nagata and Hiromichi Nagasawa, 2006. Effects of diet deprivation and physical stimulation on the feeding behaviour of the larvae of the silkworm, *Bombyx mori*. Journal of Insect Physiology, 52: 807–815.

Soo-Hoo, C.F and Frankel, G. 1966. The consumption, digestion and utilization of food plants by a polyphagous insect, *Prodenia eridania* (Cramer). J. Insect Physiol., 12: 711-730.

SPSS, 1999. SPSS Advance Statistics. Ver. 11.0, McGraw-Hill, SPSS, Inc., New York, USA., ISBN: 003055392X.

Sumioka, H.S., Kunda, S and Yoshitake, N. 1982. Relationship among food ingestion, food digestion and body weight gain in the silkworm larvae *Bombyx mori* under restricted feeding by indices. J. Seric. Science, 51: 52-57.

Takano, K and Arai, N. 1978. Studies on the food values on the basis of feeding and cocoon productivity in the silkworm, *Bombyx mori*. Seric. Sci. Jap., 47: 134-142.

Timmins W.A., K. Bellward, A.J. Stamp, S.E. Reynolds.1988. Food intake, conversion efficiency and feeding behaviour of tobacco hornworm caterpillar given artificial diet of varying nutrient and water content. Physiological Entomology, 13: 303–314.

Tribhuwan, S and Mathur, S.K. 1989. The Morin factor in mulberry that attracted the *Bombyx mori* L. Indian silk. 28(5): 39-40.

Verma, A.N and Atwal, A.S. 1963. Effect of chloromycetin and molasses on the growth and production of silk by *Bombyx mori* (Lepidoptera: Bombycidae). Indian J. Seric., 1: 1-14.

Vyjayanthi, N and Subramanyam, M.V.V. 2002. Effect of fenvalerate-20EC on sericigenous insects: I. food utilization in the late-age larva of the silkworm, *Bombyx mori* L. Ecotoxic. Environ. Saf., 53: 206-211.

Zhang, Y.H., Xu, A.Y., Wei, Y.D., Li, M.W., Hou, C.X and Zhang, G.Z. 2002. Studies on feeding habits of silkworm germplasm resources for artificial diet without mulberry. Acta Sericologia Sinica, 28: 333-336.

*****