African Journal of Agricultural Research Vol. 6(1), pp. 120-126, 4 January, 2011
Available online at http://www.academicjournals.org/AJAR
ISSN 1991-637X ©2011 Academic Journals

Full Length Research Paper

Nutritional efficiency of selected silkworm breeds of *Bombyx mori* L. reared on different varieties of mulberry under temperate climate of Kashmir

Awquib Sabhat, M. A. Malik*, Firdose Ahmad Malik, A. M. Sofi and M. R. Mir

Division of Sericulture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Mirgund- Post Box No. 674, G. P. O. Srinagar 190 001 (Jammu and Kashmir) India.

Accepted 22 September, 2010

Three silkworm breeds namely, SK1, SH6 and NB4D2 were reared on three different mulberry varieties such as Ichinose, Kokuso-20 and Goshoerami under temperate climates of Kashmir to find out the combined effect of the leaf quality and rearing season. The nutritional parameters such as leaf ingested, leaf digested, efficiency of conversion of ingested food (ECI) and efficiency of conversion of digested food (ECD) into body matter, approximate digestibility (AD), growth rate (GR), consumption index (CI) and coefficient of metabolism (COM) were studied. During spring, the dry matter ingestion and digestion was significantly higher in silkworm races fed with Goshoerami variety in addition to better efficiency of conversion of ingested and digested food into body substance. The bivoltine breeds of NB4D2 and SK1 were the better converters of ingested as well as digested food into body biomass. Seasons also significantly affected the efficiency of conversion of ingested and digested food irrespective of the varieties. Goshoerami was qualified as the best suited host plant for bivoltine silkworm breeds in all the seasons.

Key words: Silkworm, *Bombyx mori*, mulberry, nutritional efficiency, temperate climate.

INTRODUCTION

The silk production in India is mainly concentrated in the states of Karnataka, West Bengal, Andhra Pradesh and Jammu and Kashmir. It is well known that one of the country's rare and rich potential for sericulture abounds in mulberry silkworms. Jammu and Kashmir State presents an ideal and fertile land for the growth and development of bivoltine silkworm and mulberry cultivation. Sericulture has an important place in the economy of Jammu and Kashmir. Kashmir is suitable for univoltine rearing, producing only one crop in spring season with an annual turnover of cocoons worth 725 lac (Malik et al., 2010).

At present, the mulberry silkworm in India has several races falling into two voltine groups that are having distinct nutritional, developmental and cocoon characteristics. The races of the mulberry silkworm are known not only for their significant differences in the yield and the quality characters of the silk produced by them, but also for response of the silkworm to the physical environment and food quality. Miyashita (1986) observed that the productivity of the silkworm was controlled by mulberry leaf quality (38.20%), climate (37.00%), silkworm rearing techniques (9.30%), silkworm races (4.20%), silkworm eggs (3.10%) and other factors (8.20%). The two factors that affect most of the successful cocoon crop production are therefore, environment and leaf quality. The relationship between the environment and genes varies depending on the genetic background of an organism (Giacobino et al., 2003; Milner, 2004; Kang, 2008; Ogunbanwo and Okanlawon, 2009).

The mulberry silkworm, *Bombyx mori*, is a domesticated and monophagous insect, which feeds only on the leaves of mulberry for its nutrition. The mulberry leaves mainly constitute proteins, carbohydrates, vitamins, sterols, phagostimulants and minerals. Such nutritional requirement in food consumption have direct impact on the all genetic traits such as larval and cocoon weight,

*Corresponding author. E-mail: firdosahmed @gmail.com. Fax: +91-194-2482658.

quantity of silk production, pupation and reproductive traits (Ramesha et al., 2010). Silkworm nutrition refers to the substances required by silkworm for its growth and metabolic functions, which are obtained from ingested food of mulberry/artificial diet and the other remaining nutritional components are synthesized through various biochemical pathways (Takano and Arai, 1978; Hamano et al., 1986; Zhang et al., 2002).

Three silkworm breeds namely SK1, SH6 and NB4D2 were utilized in the present investigation to represent a temperate and two tropical bivoltine, respectively. Mulberry leaf is the sole food of silkworm, *B. mori*. The quality of leaf produced is different in different mulberry varieties as well as in the same variety in different seasons. The influence of mulberry varieties and seasons on the efficiency of converting ingested and digested food into body weight, cocoon and cocoon shell have been emphasized by Raman et al. (1995). Hence, three mulberry varieties namely, Ichinose (the most popular variety), Kokuso-20 and Goshoerami, which are known to be different in moisture content and nutritive composition (Khan et al., 2007), were utilized in the present study. The study on consumption and utilization of food is of great importance to identify promising silkworm breeds (Maribashetty et al., 1991) and optimize silk production in all seasons of the year. The raw materials required for silk synthesis, that is, amino acids and energy are derived from the leaf proteins consumed during 5th instar. Hence, in the present investigation, combined effect of leaf quality and rearing season on the rate of consumption and utilization of food by the selected silkworm races were examined.

MATERIALS AND METHODS

Silkworm rearing

Disease free layings (DFLs) of the three selected silkworm breeds such as SK1, SH6 and NB4D2 were brushed and reared separately as per the standard rearing techniques described by Dandin et al. (2003) on fresh leaves of the mulberry varieties of Ichinose, Kokuso-20 and Goshoerrami. The experiment was conducted from the beginning of the 5th instar up to the end of the 5th instar during three different seasons namely, spring, summer and autumn at the Division of Sericulture Mirgund, SKUAST-K. The silkworms fed with Ichinose variety were considered as the control and the remaining two varieties as the experimental. At the beginning of 5th instar, only 100 larvae were retained in each replication for further rearing. The experiment was laid down in a Completely Randomized Design with three replications for each treatment and each replication comprised 100 larvae.

Nutritional indices

As suggested by Delvi and Pandian (1972), the fresh leaves of the mulberry varieties of Ichinose, Kokuso-20 and Goshoerrami were cut through midrib into two symmetrical halves; one half was used to find out the moisture content of the leaf and the other half was weighed and fed to silkworm. In view of the consumption levels, equal and known quantity of leaf was offered to all silkworm batches on a daily basis of 5th instar larval development. The left over leaves and the excreta were dried in a hot air oven at 80˚C till constant weight and the values were recorded. The initial and final wet and dry weights of larvae were recorded daily. Food consumption, utilization and nutritional indices such as approximate digestibility (AD), efficiency of converting leaf ingested (ECI) and leaf digested (ECD) into larval body, consumption index (CI), growth rate (GR) and coefficient of metabolism (COM) were calculated as suggested by Waldbauer (1968).

Leaf ingested

Leaf ingested = Dry weight of the leaf offered – Dry weight of left over leaf

Leaf digested

Leaf digested = Dry weight of leaf ingested – Dry weight of excreta

Ingested food conversion efficiency (ECI)

$$ECI = \frac{\text{Dry weight gained by larva}}{\text{Dry weight of food ingested}} \times 100$$

Digested food conversion efficiency (ECD)

$$ECD = \frac{\text{Dry weight gained by larva}}{\text{Dry weight of food digested}} \times 100$$

Approximate digestibility (AD)

$$AD = \frac{\text{Weight of food digested}}{\text{Weight of food ingested}} \times 100$$

Consumption Index (CI)

$$CI = \frac{\text{Dry weight of food consumed}}{\text{Duration of feeding period} \times \text{Mean dry weight of larva during feeding period}}$$

Growth Rate (GR)

$$GR = \frac{\text{Dry weight gain of larva during feeding period}}{\text{Duration of feeding period} \times \text{Mean dry weight of larva during feeding period}}$$

Coefficient of Metabolism (COM)

$$COM = \frac{\text{Weight of food digested} - \text{Increase in weight of larva}}{\text{Weight of food digested}}$$

Statistical analyses

Analysis of variance was used to test the significance differences in

Table 1. Effect of mulberry varieties on leaf ingestion and digestion of selected races of the silkworm, *B. mori* L during different seasons.

Mulberry variety	Races / Seasons	Leaf ingested (g)			Leaf digested (g)		
		SK1	SH6	NB4D2	SK1	SH6	NB4D2
Ichinose	Spring	1.40 ± 0.65	1.33 ± 0.64	1.41 ± 0.66	0.64 ± 0.33	0.62 ± 0.35	0.69 ± 0.37
	Summer	1.32 ± 0.65	1.30 ± 0.64	1.38 ± 0.66	0.60 ± 0.33	0.60 ± 0.35	0.67 ± 0.37
	Autumn	1.32 ± 0.65	1.24 ± 0.64	1.32 ± 0.66	0.58 ± 0.33	0.57 ± 0.35	0.65 ± 0.37
Kokuso-20	Spring	1.23 ±0.61	1.17 ± 0.61	1.39 ± 0.65	0.55 ± 0.31	0.54 ± 0.32	0.63 ± 0.34
	Summer	1.20 ± 0.61	1.12 ± 0.61	1.36 ± 0.65	0.54 ± 0.31	0.52 ± 0.32	0.61 ± 0.34
	Autumn	1.17 ± 0.61	1.09 ± 0.60	1.30 ± 0.65	0.50 ± 0.31	0.47± 0.32	0.59 ± 0.34
Goshoerami	Spring	1.40 ± 0.65	1.38 ± 0.65	1.44 ± 0.67	0.67 ± 0.35	0.65 ± 0.35	0.71 ± 0.38
	Summer	1.36 ± 0.65	1.30 ± 0.65	1.40 ± 0.66	0.65 ± 0.35	0.61 ± 0.35	0.68 ± 0.38
	Autumn	1.30 ± 0.65	1.28 ± 0.65	1.37 ± 0.65	0.62 ± 0.35	0.59 ± 0.35	0.66 ± 0.37

Each value is the mean ± SD of three separate observations.

the means of rates and efficiencies of food utilization of the silkworm fed with leaves of Ichinose, Kokuso-20 and Goshoerrami mulberry varieties. Multiple comparison Test (Tukeys, 1953) was used to find the significance of differences between the treatments. Differences were considered significant at $p < 0.05$.

RESULTS

The following nutritional parameters were calculated after feeding 5th instar larvae with Ichinose, Kokuso-20 and Goshoerrami mulberry varieties during three different seasons namely, spring, summer and autumn (Tables 1 to 4).

Leaf ingested

The tropical bivoltine NB4D2 showed significantly higher increase in leaf ingestion (1.37 g) followed by SK1 (1.30 g) and SH6 (1.24 g). Among the varieties, the leaf ingestion of all the races was relatively higher on Goshoerami (1.36 g) followed by Ichinose (1.33 g) and Kokuso-20 (1.23 g). The interaction effect due to seasons and breeds was significant. Spring season registered the highest leaf ingestion (1.35 g), while the lowest leaf ingestion (1.26 g) was recorded in autumn season.

Leaf digested

Among the varieties, NB4D2 showed significantly higher increase in leaf digestion (0.66 g) followed by SK1 (0.60 g) and SH6 (0.58 g). The leaf digestion of all the races was relatively higher on Goshoerami (0.65 g) followed by Ichinose (0.63 g) and Kokuso-20 (0.55 g). Significant higher values of leaf digestion (0.64 g) were recorded during spring season followed by summer (0.61 g) and autumn (0.58 g).

ECI and ECD

The values of ECI were lower than the corresponding ECD values. Both ECI and ECD of all the races increased significantly when larvae were reared on Goshoerami (8.24, 17.64%) followed by Ichinose (7.28, 15.74 %) and Kokuso-20 (6.11, 13.79%) (Table 4). NB4D2 showed a relatively higher ECI and ECD values (7.55, 16.54 %) than SK1 (7.27, 15.58%) and SH6 (6.80, 15.04%).

A significant increase in the ECI and ECD was observed during spring season in NB4D2 on Goshoerami (9.00, 18.79%), whereas, during autumn season, the least values were observed in SH6 on Kokuso-20 (6.44, 15.52%) (Table 2).

Approximate digestibility

Approximate digestibility was significantly higher in NB4D2 (44.98%) followed by SK1 (43.76%) and SH6 (43.58%). Among the varieties, a significant increase in approximate digestibility was observed in all the races on Kokuso-20 (45.33 %) followed by Ichinose (44.31%) and Goshoerami (42.68%). Autumn season recorded lowest digestibility (42.97%), while the highest approximate digestibility was recorded in spring season (45.03%).

Growth rate

The growth rate was significantly higher in NB4D2 (0.32) followed by SK1 (0.31) and SH6 (0.30). However, a

Table 2. Effect of mulberry varieties on ECI, ECD and AD of selected races of the silkworm, *B. mori* L. during different seasons.

Mulberry variety	Races / Seasons	ECI (%)			ECD (%)			AD (%)		
		SK1	SH6	NB4D2	SK1	SH6	NB4D2	SK1	SH6	NB4D2
Ichinose	Spring	6.56 ± 3.07	8.35 ± 4.30	7.80 ± 3.92	14.32 ± 5.91	17.88 ± 7.72	16.04 ± 6.57	44.58 ± 3.72	44.41 ± 6.12	44.41 ± 6.12
	Summer	7.00 ± 3.02	8.54 ± 4.30	7.40 ± 3.59	15.49 ± 5.56	18.60 ± 7.51	15.47 ± 5.74	43.83 ± 4.61	43.50 ± 7.02	43.50 ± 7.02
	Autumn	6.42 ± 2.71	6.77 ± 3.44	6.66 ± 3.37	14.91 ± 4.57	15.15 ± 5.74	13.77 ± 5.38	41.41 ± 6.54	42.57 ± 8.46	42.57 ± 8.46
Kokuso-20	Spring	6.01 ± 2.71	6.56 ± 3.30	6.32 ± 3.37	13.39 ± 5.03	14.21 ± 5.83	13.95 ± 6.02	43.57 ± 4.30	44.58 ± 5.52	44.58 ± 5.52
	Summer	5.84 ± 2.61	6.60 ± 2.99	6.04 ± 2.92	12.90 ± 4.78	14.54 ± 4.70	13.63 ± 4.95	43.88 ± 4.28	43.61 ± 6.75	43.61 ± 6.75
	Autumn	5.62 ± 2.39	6.44 ± 2.72	5.56 ± 2.76	13.48 ± 3.93	15.52 ± 3.46	12.43 ±4.68	40.20 ± 6.83	39.82 ± 8.97	39.82 ± 8.97
Goshoerami	Spring	8.58 ± 3.59	8.66 ± 4.43	9.00 ± 2.80	18.26 ± 6.49	18.33 ± 8.11	18.79 ± 4.04	45.83 ± 4.24	45.56 ± 4.48	45.56 ± 4.48
	Summer	7.90 ± 3.22	8.38 ± 4.52	8.74 ± 2.42	16.89 ± 5.62	17.84 ± 8.16	18.92 ± 2.62	45.55 ± 4.58	44.86 ± 5.31	44.86 ± 5.31
	Autumn	7.27 ± 2.96	7.67 ± 4.27	7.95 ± 2.47	15.68 ± 4.82	16.78 ± 7.70	17.24 ± 3.19	44.99 ± 5.29	43.32 ± 6.64	43.32 ± 6.64

Each value is the mean ± SD of three separate observations; ECI- Efficiency of conversion of ingested food, ECD- Efficiency of conversion of digested food, AD- Approximate digestibility.

Table 3. Effect of mulberry varieties on GR, CI and COM of selected races of the silkworm, *B. mori* L. during different seasons.

Mulberry variety	Races / Seasons	GR			CI			COM		
		SK1	SH6	NB4D2	SK1	SH6	NB4D2	SK1	SH6	NB4D2
Ichinose	Spring	0.32 ± 0.15	0.35 ± 0.17	0.34 ± 0.16	5.04±1.62	4.43 ± 1.43	4.52 ± 1.50	0.88 ± 0.14	0.84 ± 0.15	0.86 ± 0.15
	Summer	0.32 ± 0.15	0.37 ± 0.20	0.31 ± 0.14	4.66±1.59	4.51 ± 1.54	4.39 ± 1.48	0.87 ± 0.14	0.84 ± 0.15	0.87 ± 0.14
	Autumn	0.30 ± 0.13	0.31 ± 0.18	0.26 ± 0.13	4.74±1.66	4.67 ± 1.91	4.13 ± 1.46	0.87 ± 0.14	0.87 ± 0.14	0.88 ± 0.14
Kokuso-20	Spring	0.29 ± 0.14	0.30 ± 0.16	0.32 ± 0.14	4.86±1.45	4.61 ±1.39	5.30 ± 1.69	0.89 ± 0.14	0.88 ± 0.14	0.88 ± 0.14
	Summer	0.27 ± 0.13	0.28 ± 0.14	0.30 ± 0.12	4.71±1.46	4.32 ± 1.36	5.15 ± 1.69	0.89 ± 0.14	0.88 ± 0.14	0.89 ± 0.14
	Autumn	0.27 ± 0.12	0.27 ± 0.12	0.26 ± 0.11	4.81±1.75	4.20 ± 1.33	4.86 ± 1.69	0.89 ± 0.14	0.87 ± 0.14	0.90 ± 0.14
Goshoerami	Spring	0.35 ± 0.14	0.35 ± 0.16	0.35 ± 0.12	4.13±1.26	4.23 ± 1.43	3.99 ± 1.17	0.84 ± 0.15	0.84 ± 0.15	0.84 ± 0.14
	Summer	0.32 ± 0.13	0.32 ± 0.17	0.33 ± 0.11	4.17 ± 1.38	4.02 ± 1.47	3.81 ± 1.05	0.86 ± 0.14	0.84 ± 0.16	0.84 ± 0.13
	Autumn	0.29 ± 0.11	0.29 ± 0.17	0.30 ± 0.09	4.04 ± 1.39	4.01 ± 1.53	3.88 ± 1.12	0.87 ± 0.14	0.86 ± 0.15	0.85 ± 0.14

Each value is the mean±SD of three separate observations; GR- Growth rate, CI- Consumption index, COM- Coefficient of metabolism

Table 4. Summary of ANOVA showing the interaction of mulberry varieties on nutritional parameters of selected silkworm races during different seasons.

Treatments	Nutritional parameter							
	Leaf ingested	Leaf digested	ECI	ECD	AD	GR	CI	COM
Races								
SK1	1.30 ± 0.63[b]	0.60 ± 0.33[b]	7.27 ± 3.24[b]	15.58 ± 5.32[b]	43.76 ± 5.22[a]	0.31 ± 0.13[b]	4.45±1.50[b]	0.87 ± 0.14[a]
SH6	1.24 ± 0.62[a]	0.58 ± 0.34[a]	6.80 ± 3.01[a]	15.04 ± 5.37[a]	43.58 ± 6.75[a]	0.30 ± 0.13[a]	4.33± 1.47[a]	0.86 ± 0.14[a]
NB4D2	1.37 ± 0.64[c]	0.66 ± 0.36[c]	7.55 ± 3.87[c]	16.54 ± 6.76[c]	44.98 ± 6.75[b]	0.32 ± 0.16[c]	4.57± 1.52[c]	0.87 ± 0.14[a]
F-test	**	**	*	*	*	**	**	NS
Variety								
Ichinose	1.33 ± 0.63[b]	0.63 ± 0.35[b]	7.28 ± 3.55[b]	15.74 ± 6.18[b]	44.31 ± 6.36[b]	0.32 ± 0.16[b]	4.56 ± 1.56[b]	0.87 ± 0.14[ab]
Kokuso	1.23 ± 0.61[a]	0.55 ± 0.32[a]	6.11 ± 2.83[a]	13.79 ± 4.84[a]	45.33 ± 5.69[c]	0.28 ± 0.13[a]	4.76 ± 1.54[c]	0.89 ± 0.14[b]
Goshoerami	1.36 ± 0.64[c]	0.65 ± 0.35[c]	8.24 ± 3.45[c]	17.64 ± 5.92[c]	42.68 ± 6.15[a]	0.32 ± 0.13[b]	4.03 ± 1.29[a]	0.85 ± 0.14[a]
F-test	**	**	**	**	**	*	**	NS
Seasons								
Spring	1.35 ± 0.63[c]	0.64 ± 0.34[c]	7.54 ± 3.63[c]	16.13 ± 6.49[c]	45.03 ± 5.06[c]	0.33 ± 0.15[c]	4.57 ± 1.47[b]	0.86 ± 0.14[a]
Summer	1.30 ± 0.63[b]	0.61 ± 0.34[b]	7.38 ± 3.43[b]	16.03 ± 5.94[b]	44.31 ± 5.87[b]	0.31 ± 0.14[b]	4.42 ± 1.47[a]	0.86 ± 0.14[a]
Autumn	1.26 ± 0.63[a]	0.58 ± 0.34[a]	6.71 ± 3.08[a]	15.00 ± 5.09[a]	42.97 ± 7.21[a]	0.28 ± 0.13[a]	4.37 ± 1.56[a]	0.87 ± 0.14[a]
F-test	**	**	*	*	**	**	*	NS

*Significant at 5% ($p < 0.05$); ** Significant at 1% ($p < 0.01$); NS- Non Significant; Means with different superscripts are significantly different from each other for various treatments (as indicated by Tukeys HSD). ECI- Efficiency of conversion of ingested food, ECD- Efficiency of conversion of digested food, AD- Approximate digestibility, GR- Growth rate, CI- Consumption index, COM- Coefficient of metabolism

relatively higher increase in growth rate was observed in all the races on Goshoerami and Ichinose (0.32) than Kokuso-20 (0.28). Spring season recorded the highest growth rate (0.33), whereas, the lowest growth rate (0.28) was recorded in autumn season.

Consumption index

The consumption index was significantly higher in NB4D2 (4.57) followed by SK1 (4.45) and SH6 (4.33). Among the varieties, Kokuso-20 showed a relatively higher consumption index (4.76) followed by Ichinose (4.56) and Goshoerami (4.03) irrespective of seasons. The effect of seasons on consumption index of all the three races was found to be highly significant in all the varieties. Autumn season recorded the lowest consumption index (4.37), whereas, the highest consumption index was noticed in spring season (4.57).

Coefficient of metabolism

The coefficient of metabolism was relatively higher in Kokuso-20 (0.89) followed Ichinose (0.87) and Goshoerami (0.85). However, no significant difference in coefficient of metabolism was observed among the races and seasons (Table 4).

DISCUSSION

The feeding activity of silkworm is influenced by major ecological factors like temperature, relative humidity in addition to other physiological conditions. The silkworm growth is manifested by the accumulation of organic matter resulting from the balance between anabolic and catabolic reactions fuelled by the nutritive substances absorbed after digestion of food. The silkworms from the same genetic stock responded variedly when fed on the leaves of different nutritional quality, which is an indicator of efficient utilization and conversion of food into silk substance. Variation of the ingesta and digesta values among the different breeds and same breed in different seasons have been reported (Yomamoto and Fujimaki, 1982). The rate of food consumption and leaf quality influence significantly larval growth, weight and probability of survival (Murugan and George, 1992). Analysis of the nutritional indices like the rates of ingestion, digestion, assimilation and conversion in the growing larvae would be useful in understanding the racial differences in the digestive and assimilation abilities of the silkworm.

The present study revealed variation in the nutritional requirements of different races and in the same race during different seasons. The level of food ingestion and digestion was relatively highest in all the three races when fed with Goshoerami followed by Ichinose and

Kokuso-20 during all the seasons. Based on the level of food ingestion and digestion, the order can be represented as Goshoerami > Ichinose > Kokuso-20. Mulberry leaf as a food for the silkworm must contain several chemical constituents such as water, protein, carbohydrate, mineral and vitamins and also must have favourable physical features such as suitable tenderness, thickness and tightness etc., in order to be eaten by the silkworm. From the present study, it may be assumed that the high ingestion rates on Goshoerami and Ichinose are due to their palatability, nutritional superiority and water retention capacity of leaves for longer duration. Ingestion and related nutritional parameters varied from race to race in multivoltine breeds of silkworm (Remadevi et al., 1992). The present study revealed that the rate of food intake was more in NB4D2 than SK1 and SH6, particularly on Goshoerami and Ichinose.

The ECD measures the efficiency of conversion of assimilated food and the ECI measures the overall efficiency of conversion of ingested food into insect biomass. The mean ECI and ECD were relatively higher in the races fed with Goshoerami followed by Ichinose and Kokuso-20. Higher ECD values suggest higher food efficiency and lower cost of maintenance. Approximate digestibility depends on a number of factors like rate and quantity of food intake, retention time in the midgut, nature and efficiency of digestive enzymes and digestibility of the complex nutritive components in the diet. Higher AD was observed during spring followed by summer and autumn season in all the races irrespective of mulberry varieties. The higher AD in spring and summer seasons may be due to high water content of the feed and high content of nutrients in the mulberry leaves. The breeds exhibited better performance in terms of ECI and ECD during spring. NB4D2 and SK1 appeared to be better than SH6 as an efficient converter of ingested and digested food to body biomass. The consumption index and growth rate of all the races was high with Goshoerami and Ichinose and it was least with Kokuso-20. Spring rearing accounted for higher consumption index and growth rates irrespective of the races.

The seasonal changes also have profound effect on the growth and quality of mulberry leaves, which in turn influence the silkworm health and cocoon crop production and, therefore, suggest the importance of leaf moisture both in palatability and assimilation of nutritive components of the leaf. The moisture content and moisture retention capacity being relatively higher in Goshoerami than in Ichinose and Kokuso-20 supports growth and development in all silkworm races in all seasons. Dwivedi (1992) also observed higher nutrient content in mulberry leaf in spring lower protein and water content in autumn and summer, in which the ash content increases, leading to hardness of the leaf. The quality of leaves is also influenced by the duration of sunlight, rainfall, wind and temperature. Under optimal conditions of rainfall and sunlight, the mulberry plants grow vigorously, rendering the leaves mature, soft, and rich in water and moisture contents, proteins and carbohydrates and other minerals that are essential for healthy growth and development of the silkworm (Firdose and Srinivasa, 2007). Continuous dry weather, which prevails in autumn and summer, retards the growth of mulberry trees, rendering the mulberry leaves hard and unsuitable for feeding the worms. Quality of leaves plays an important role in the nutritional ability and feeding activity of silkworms. Hence, based on the present study, it can be concluded that for higher leaf consumption, growth rate, digestibility and higher cocoon yield with superior quality of silk, Goshoerami is suggested as best suited host plant for autumn and summer rearing under temperate climatic conditions of Kashmir.

ACKNOWLEDGEMENTS

The authors express their gratitude to the authorities of Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir for providing laboratory facilities for the study.

REFERENCES

Dandin SB, Jayant J, Giridhar K (2003). Handbook of Sericulture Technologies. Central Silk Board, Bangalore.

Delvi MR, Pandian TJ (1972). Rates of feeding and assimilation in the grasshopper, *Poecilocerus pictus*. J. Insect Physiol., 18: 1829-1843.

Dwivedi NK (1992) Silkworm nutrition and mulberry. Indian Silk, May, 9-12.

Firdose AM, Srinivasa RY (2007). Role of mulberry nutrition on manifestation of post cocoon characters of selected races of the silkworm, *Bombyx mori* L. Sericologia, 47(1): 63-76.

Giacobino AP, Grimable R, Pichard C (2003). Review genetics and nutrition. Clin. Nutr., 22: 429-435.

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

Kang KJ (2008). A transgenic mouse model for genenutrient interactions. J. Nutrigenet. Nutrigenomics, 1: 172-177.

Khan IL, Malik GN, Dar HU, Baqual MF, Malik MA and Raja TA (2007) Evaluation of some mulberry (Morus Spp.) genotypes through chemo and bioassay under temperate conditions of Kashmir. Indian J. Seric., 46(2): 48-52.

Malik MA, Afifa Kamili S, Sofi AM, Malik GN, Awquib Sabhat, Shabir Ahmad and Firdose Ahmad Malik (2010) Second commercial silkworm rearing- A new hope for Sericulturists in Kashmir. Indian Silk, 48(9): 10-11.

Maribashetty VG, Chandrakala MV, Aftab AK, Rao R (1991). Food and water utilization patterns in new bivoltine races of silkworm, *Bombyx mori* L. Bull. Ind. Acad. Sericol., 3: 83-90.

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

Miyashita Y (1986). A report on mulberry cultivation and training methods suitable to bivoltine rearing in Karnataka. pp. 1-7.

Murugan K, George A (1992). Feeding and nutritional influence on growth and reproduction of Daphnis resi (Linn) (Lepidoptera: Sphingidae). J. Insect Physiol., 38(2): 961-967.

Ogunbanwo ST, Okanlawon BM (2009). Influence of nutrients utilization and cultivation conditions on the production of lactic acid by homolactic fermenters. Biotechnology, 8: 107-113.

Ramesha C, Anuradha CM, Lakshmi H, Sugnana Kumari S, Seshagiri SV, Goel AK and Suresh Kumar C (2010) Nutrigenetic Traits Analysis for the Identification of Nutritionally Efficient Silkworm Germplasm Breeds. Biotechnology, 9(2): 131-140.

Remadevi OK, Magadum SB, Shivashankar N and Benchamin KV (1992). Evaluation of the food utilization efficiency in some polyvoltine breeds of silkworm, *Bombyx mori.* Sericologia. 32(1): 61-65.
Takano K, 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.
Tukey JW (1953). *The problem of multiple comparison*. Mimeographed for limited circulation (Reference from Shedecor, G.W., Statistical Methods. Iowa state college press, Ames).
Waldbauer GP (1968). The consumption and utilization of food by insects. Advances Insect Physiology., 5, 229-288.
Yomamoto T, Fujimaki T (1982). Interstrain differences in food efficiency of the silkworm, *Bombyx mori* reare.d on artificial diet. J. Seric. Sci. Jpn., 51(4): 312-315.
Zhang YH, Xu AY, Wei YD, Li MW, Hou CX, Zhang GZ (2002) Studies on feeding habits of silkworm germplasm resources for artificial diet without mulberry. Acta Sericologia Sinica, 28: 333-336.