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INFLUENCE OF SEASONAL VARIATION ON COCOON, SILK FILAMENT AND ECONOMIC TRAITS OF *BOMBYX MORI* L.

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ABSTRACT
The present study was undertaken to evaluate ten popular bivoltine silkworm breeds viz., SK-6 (P), SK-24 (P), SK-34 (P), SK-30 (P), CSR-2(P), SK-1 (M), SK-13 (M), SK-28 (M), SK-31 (M) and Dun-22 (M) under temperate climatic conditions of Kashmir in a completely randomized design with three replications each. The results revealed that pooled analysis of variance showed significant differences among genotypes and their interaction with the environment for all the characters during both the seasons. In both spring and summer seasons significantly highest shell weight, shell ratio, raw silk and cocoon weight were recorded in SK-1 and SK-6. Significantly high filament length was recorded in SK-6 and SK-1, while filament size in spring was high in SK-31 and in summer season high filament size was found in SK-1. Silk gland somatic index was significantly higher in SK-34 in during both seasons, while significantly high silk conversion index recorded in SK-13 and CSR-2. Yield^{-10000} larvae were found significantly high in SK-1 and SK-6, whereas lowest yield^{-10000} larvae were recorded in CSR-2 during both the seasons as well as pooled data over environments. The study also revealed that irrespective of genotypes the values for these traits were marginally higher in spring than summer season.

KEY WORDS: Seasons, temperature, cocoon, silk filament and economic traits, genotypes, *Bombyx mori.*

INTRODUCTION
The mulberry silkworm, *Bombyx mori* L. is a very important economic insect that contributes substantially to the national economy of India and provides gainful occupation to lakhs of people. 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). Mulberry silkworm, *Bombyx mori* L. is very delicate, highly sensitive to environmental fluctuations, and unable to survive extreme natural fluctuation in temperature and humidity because of their long years of domestication since 5000 years. Thus, the adaptability to environmental conditions in the silkworm is quite different from those of wild silkworm and other insects. Temperature, humidity, air circulation, gases, light etc. shows a significant interaction in their effect on the physiology of silkworm depending upon the combination of factors and developmental stage affecting growth, development, productivity, and quality of silk (Hussain *et al*., 2011). The biological as well as cocoon related characters are influenced by ambient temperature, rearing seasons, and genetic constitution of silkworm strains. Different seasons affect the performance of *Bombyx mori* L. (Rajesh and Elangovan, 2010). The seasonal differences in the environmental components considerably affect the genotypic expression in the form of phenotypic output such as cocoon weight, shell weight, and cocoon shell ratio. Rearing conditions affects growth and development of larvae and cocoon production (Thapa and Ghimire, 2005).

Several researchers (Hussain *et al*., 2011 and Tazima and Ohnuma, 1995) reported that the silkworm larvae are sensitive to high temperature (above 25 ± 1◦C) during 4th and 5th instars and lower or higher levels of RH affect the growth and development of silkworm larvae. Some strains of silkworm due to consistent domestication have become highly sensitive to variations in environmental conditions, especially seasonal variations in temperature and humidity in tropical parts of the subcontinent (Lakshmi *et al*., 2010). Environmental stress during silkworm rearing adversely affects growth and development and impairs the production of good quality silk seed with resistance to diseases and ability to withstand high temperature and humidity (Srivastava *et al*., 2007). Hence, in the present investigation, 10 genotypes of silkworm were evaluated for economic traits against seasonal variation.

MATERIALS & METHODS
The present study was carried out at Temperate Sericulture Research Institute, SKUAST-K, Mirgund during the year 2010-2011. Two breed types viz., plain (SK-6, SK-24, SK-34, SK-30 and CSR-2) and marked each (SK-1, SK-13, SK-28, SK-31and Dun-22) each comprising of 250 silkworms were used as experimental material. The experiment was conducted during spring and summer season of 2011 in a Completely Randomized Design (CRD) with three replications. The data on the growth of silkworm and rearing performance as manifested single shell weight (g), shell ratio (%), filament length (m),

filament size (denier), raw silk percentage, silkgland somatic index (%), silk conversion index (%), single shell weight (g) and yield^{-10000} (kg) larvae were recorded separately for each replication. Ten randomly selected cocoons of each replicate were stifled and reeled individually to record the total filament length of each cocoon. Single shell weight and single cocoon weight were calculated in grams by making average of ten randomly selected cocoons.

Shell ratio (%)

Ratio between shell weight and cocoon weight as calculated from a random sample of five cocoons from each laying represents the shell ratio:

$$\text{Shell ratio} = \frac{\text{Single cocoon shell weight (g)}}{\text{Single cocoon weight (g)}} \times 100$$

Filament size (denier)

Filament size was calculated by using following formula:

$$\text{Filament size} = \frac{\text{Conditional weight of raw silk (g)}}{\text{Total length of raw silk (m)}} \times 9000$$

Raw silk percentage (%)

Raw silk % was calculated as:

$$\text{Raw silk percentage} = \frac{\text{Silk weight (g)}}{\text{Cocoon weight (g)}} \times 100$$

Silk gland somatic index (%)

The silk gland index (SSI) represents the biomass of the silk gland in relation to total body weight and was calculated by the following formula:

$$\text{Silkgland somatic index} = \frac{\text{Silkgland weight (g)}}{\text{Mature larvae weight (g)}} \times 100$$

Silk conversion index (%)

The silk conversion index (SCI) is the ratio of shell weight to silk gland weight was calculated by:

$$\text{Silk conversion index} = \frac{\text{Shell weight (g)}}{\text{Silkgland weight (g)}} \times 100$$

Yield^{-10000} larvae (kg)

$$\text{Yield}^{-10000}\text{ larvae brushed by weight} = \frac{\text{Weight of cocoons harvested from each replicate}}{\text{No. of worms retained after 3}^{rd}\text{ moult}} \times 10000$$

The data generated was analyzed by using standard statistical procedure followed by Gomez and Gomez (1984).

RESULTS & DISCUSSION

The pooled analysis of variance revealed significant differences among genotypes for all the characters studied during both the seasons (Table 1-3) and thereby, indicating existence of a good amount of genetic variability. The interaction between season and race was also found to be significant ($p < 0.05$) for the traits studied. The magnitude in the phenotypic variability is dependent on the responsiveness of the different genotypes to different environmental conditions. Such studies are well documented in both plants and animals (Griffing and Zsiros, 1971; Orozco, 1976; Strickberger, 2002). It is understood that the performance of a race or a breed is mainly dependent on the combined action of hereditary potential of its population and the extent to which such potential is permitted to express in the environment to which it is exposed. The differential expression of different races in different seasons recorded in the present study is in conformity with the observations of several workers (Kumaresan *et al.,* 2000 & 2012; Mukherjee *et al*., 2000 and Pal and Moorthy 2011). This is largely due to the variable gene frequencies at different loci in different silkworm races which make them to respond differently to changing environmental conditions (Kalpana, 1992 and Nanjundaswamy, 1997). The present study revealed that shell weight was variable under different set of environmental conditions. The shell weight in the spring season was significantly high (0.47 g) in SK-6 followed by SK-1 (0.46 g) and SK-28 (0.41 g) and in summer season significantly high (0.45 g) shell weight was recorded in SK-34. The lowest shell weight during both the seasons was recorded in CSR-2. Similarly, shell ratio in spring season was significantly high in SK-6 (22.81 %) which was at par with SK-1 (21.80 %) and in summer season, a similar trend was observed with significantly high shell ratio of 21.50 % in SK-6 (Table 4, Fig 1a and 1b). The two correlated traits depend on presence and activity of genes related to silkgland development and silk protein biosynthesis. These results were in conformity with Singh and Kumar (1996) who also reported a highly significant positive correlation of 0.951** between silkgland weight and shell weight. The results indicate a clear difference in the way the biomass was utilized and the resources were channelized by these breeds during 5th instar towards cocoon production. Zhao *et al.* (2005) reported that transformation of larvae into pupae and adult depends heavily on shell weight which is greatly influenced by environmental conditions prevailing during different stages of larval development. In the present study, the highest mean filament length was observed in SK-1 (1252.67 and 1092.00 m) followed by SK-6 (1225.67 and 1010.67 m) in both spring and summer season and was relatively higher in spring than summer, respectively. The longer filament length in the race is associated with filament size (Table 5, Fig. 1c).

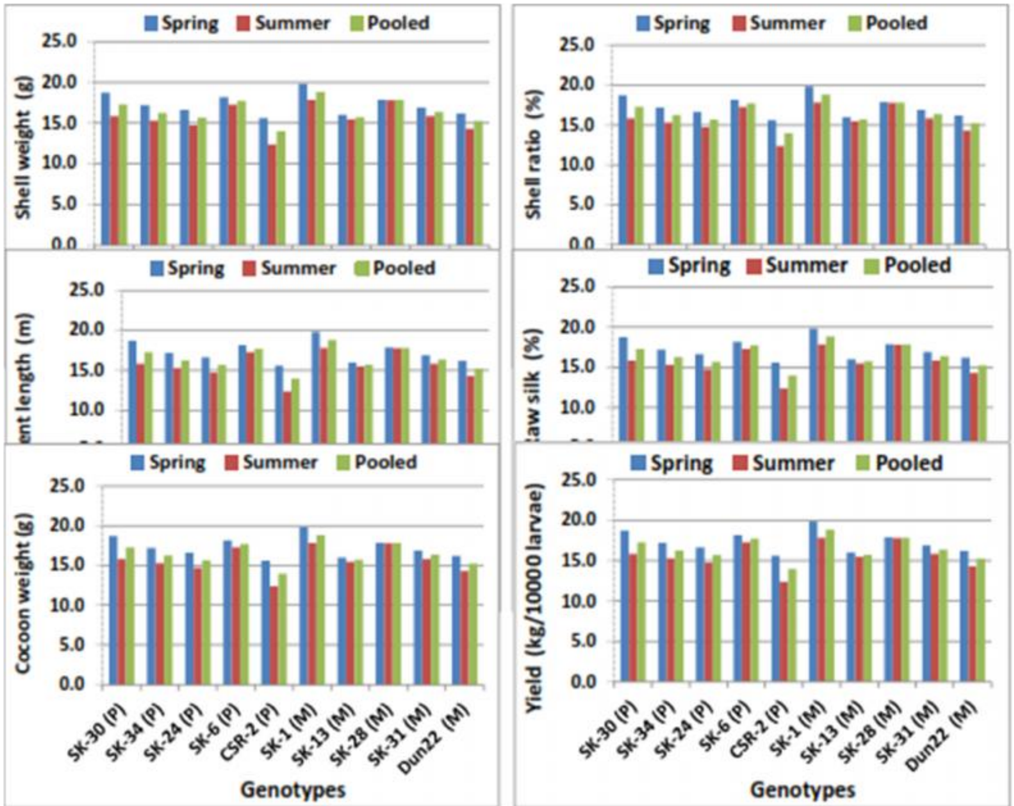

FIGURE 1: Figure showing various silk filament and economic traits of silk worm (*Bombyx mori* L.)

TABLE 1: Pooled analysis of variance (ANOVA) of cocoon and associated traits in *Bombyx mori* L.

Source of variation	df	Mean sum of squares		
		Single cocoon weight (g)	Single shell weight (g)	Shell ratio (%)
Environment	1	0.273**	0.1050**	171.400**
Genotype	9	0.166**	0.0430*	42.075*
Genotype x environment	9	0.002*	0.0004*	2.453*
Error	40	0.017	0.0029	1.240

TABLE 2: Pooled analysis of variance (ANOVA) of some silk filament traits in *Bombyx mori* L.

Source of variation	df	Mean sum of squares		
		Filament length (m)	Filament size (denier)	Raw silk (%)
Environment	1	357132.00**	0.454**	93.851**
Genotype	9	118928.90**	0.966*	48.589**
Genotype x environment	9	5731.55**	0.176*	3.747*
Error	40	211.70	0.108	3.663

TABLE 3: Pooled analysis of variance (ANOVA) of some economic traits of *Bombyx mori* L.

Source of variation	df	Mean sum of squares		
		Silkgland somatic index (%)	Silk conversion index (%)	Yield (kg^{-10000} larvae)
Environment	1	11.621**	20.324**	40.343**
Genotype	9	35.954*	43.146**	12.364*
Genotype x environment	9	3.271**	3.806*	1.505*
Error	40	1.167	3.500	2.047

** Significant at ($p<0.01$)
* Significant at ($p<0.05$)
NS – Non-significant

TABLE 4: Performance of cocoon and associated traits in silkworm (*Bombyx mori* L.)

Season	Races	Single cocoon weight (g)	Single shell weight (g)	Shell ratio (%)
Spring	SK-30 (P)	1.74	0.38	21.60
	SK-34 (P)	1.76	0..35	19.88
	SK-24 (P)	1.80	0.38	21.07
	SK-6 (P)	2.06	0..47	22.81
	CSR-2 (P)	1.57	0.26	16.98
	SK-1 (M)	2.11	0.46	21.80
	SK-13 (M)	1.81	0.38	20.95
	SK-28 (M)	1.82	0.41	22.31
	SK-31 (M)	1.91	0.39	20.41
	Dun22 (M)	1.54	0.30	20.40
CD (p<0.05)		0.097	0.238	2.034
Summer	SK-30 (P)	1.64	0.31	15.66
	SK-34 (P)	1.66	0.45	20.11
	SK-24 (P)	1.70	0.31	18.20
	SK-6 (P)	1.86	0.40	21.50
	CSR-2 (P)	1.47	0.19	15.74
	SK-1 (M)	1.87	0.39	20.85
	SK-13 (M)	1.63	0.28	17.84
	SK-28 (M)	1.67	0.31	17.55
	SK-31 (M)	1.70	0.32	20.63
	Dun22 (M)	1.39	0.20	16.81
CD (p<0.05)		0.087	0.218	1.749
Pooled mean	SK-30 (P)	1.69	0.34	18.63
	SK-34 (P)	1.71	0.48	22.02
	SK-24 (P)	1.75	0.35	19.63
	SK-6 (P)	1.91	0.47	24.60
	CSR-2 (P)	1.52	0.23	16.36
	SK-1 (M)	2.04	0.44	24.33
	SK-13 (M)	1.72	0.33	19.39
	SK-28 (M)	1.75	0.36	19.93
	SK-31 (M)	1.81	0.37	22.20
	Dun22 (M)	1.46	0.25	18.61
CD (p<0.05)		0.090	0.221	1.837

(P) – Plain race
(M) – Marked race

The filament size followed almost a similar trend as that of filament length with highest filament size of 2.94 denier in SK-1 followed by 2.93 denier in SK-6. The high temperature during summer increases various physiological functions and with a fall in temperature, the physiological activities are decreased. Increased temperature during silkworm rearing particularly in late instars accelerates larval growth and shortens the larval period. On the other hand, at low temperature, the growth is slow and larval period is prolonged which might have resulted in longer filament length. Naseema Begum *et al.* (2001) observed that size deviation is a racial character. The lesser size deviation increases the reliability percentage and raw silk recovery as long filament of fine denier will have less breaks in the reeling process.

High temperature during summers adversely affect nearly all biological processes including the rates of biochemical and physiological reactions (Willmer *et al*., 2004), and can eventually affect the quality or quantity of cocoon crops in the silkworm and subsequently silk produced. In the present study also it was found that relatively higher values of raw silk percentage of all races was observed in spring than summer. The raw silk percentage (Table 5, Fig. 1d) was highest in SK-1 (39.87 and 36.35 %) followed by SK-6 (39.76 and 36.12 %) duding both spring and summer season, respectively. Similar findings were also reported by Sabhat *et al*., (2011). It was also found that lowest raw silk percentage was observed in CSR-2 which could be attributed to the fact that CSR-2 spares more energy and nitrogen resources to egg production and pupal development by significantly reducing silk biosynthesis and hence raw silk recovery is very low in CSR-2. Silk biosynthesis and cocoon production was not constrained much in SK-1 and SK-6 which could be due to their better genetic potential over other races. Thus, it could be stated that temperate breeds SK-1 and SK-6 have the ability to utilize the available nitrogen and carbon (energy) resources even under nutrition stress condition towards biomass production and this tendency may be one of the reasons responsible for the temperature tolerance observed in the said races. A biovoltine breed having desired traits of cocoon production similar to SK-1 and SK-6 will be more suitable for rearing in temperate climatic conditions of Kashmir especially in summer season characterized by high ambient temperature and poor quality of mulberry leaf. These findings are analogous with the earlier observations of Krishnaswami

(1994). The silkgland somatic index (SSI) represents the biomass of the silkgland in relation to total body weight. Silkgland somatic index in both spring and summer seasons was higher in SK-34 (32.80 and 33.49 %) and SK-1 (31.14 and 29.69 %), respectively (Table 6). The results of present study revealed that there was differential variation in silkgland somatic index of different breeds of silkworms evaluated in both the seasons and SK-1 was relatively higher in spring than summer. The differences in the mean values of silkgland somatic index could be traced to the high silkgland somatic index values. The temperate races have greater tendency to channelize the resources towards cocoon production even under nutrition stress conditions which mostly arise during spring season. Tazima (1973) reported that silkgland contributes 40 % of the body mass of the larvae. The high silk content of the cocoon protects the pupae from very low ambient temperatures prevailing in temperate climates. A less hardy cocoon facilitates exchange of gases across the cross sections of the shell making more oxygen available to support relatively high metabolic rate of pupae. Singh and Kumar (1996) reported 27.9 % of silkgland somatic index in NB18 race which is an evolved biovoltine suited to tropics.

TABLE 5: Performance of silk filament traits in silkworm (*Bombyx mori* L.)

Season	Races	Filament length (m)	Filament size (denier)	Raw silk (%)
Spring	SK-30 (P)	905.00	1.72	36.39
	SK-34 (P)	1119.67	2.78	32.24
	SK-24 (P)	1121.67	2.72	35.69
	SK-6 (P)	1225.67	2.99	39.76
	CSR-2 (P)	805.67	2.41	29.94
	SK-1 (M)	1252.67	2.84	39.87
	SK-13 (M)	814.00	2.60	38.95
	SK-28 (M)	1071.67	2.13	36.00
	SK-31 (M)	1153.33	3.06	37.54
	Dun22 (M)	1010.67	2.48	33.87
CD (p<0.05)		17.266	3.252	0.578
Summer	SK-30 (P)	806.00	1.61	33.32
	SK-34 (P)	963.00	2.53	30.07
	SK-24 (P)	942.33	2.79	34.52
	SK-6 (P)	1010.67	2.87	36.12
	CSR-2 (P)	710.33	2.23	29.08
	SK-1 (M)	1092.00	3.03	36.35
	SK-13 (M)	739.33	2.28	33.13
	SK-28 (M)	963.67	2.50	35.38
	SK-31 (M)	924.67	2.44	35.88
	Dun22 (M)	785.00	1.72	31.40
CD (p<0.05)		30.492	3.267	0.544
Pooled mean	SK-30 (P)	855.50	1.67	34.86
	SK-34 (P)	1041.33	2.66	31.16
	SK-24 (P)	1032.00	2.75	35.11
	SK-6 (P)	1131.67	2.93	37.94
	CSR-2 (P)	758.00	2.32	29.51
	SK-1 (M)	1158.83	2.94	38.11
	SK-13 (M)	776.67	2.44	36.04
	SK-28 (M)	1017.67	2.32	35.69
	SK-31 (M)	1039.00	2.75	36.71
	Dun22 (M)	897.83	2.10	32.64
CD (p<0.05)		23.996	3.157	0.544

(P) – Plain race
(M) – Marked race

Silk conversion index is a ratio of shell weight to silk gland weight. The silk conversion index value was highest in CSR-2 which was followed by SK-13 in both the seasons. A qualitative difference in the silk stored in the lumen of the silkgland of SK-1 and SK-6 is apparent. The silk protein biosynthesized and stored in the lumen of SK-1 and SK-6 could have dehydrated more during high temperatures thereby forcing expulsion of liquid silk through the spinneret. The present findings are in conformity with the reports of Firdous and Reddy (2009).

In the present study, the mean cocoon weight during the spring season was found significantly higher in SK-1 (2.11 g) which was at par with SK-6 (2.06 g) than other genotypes. The lowest cocoon weight was recorded in Dun22 (1.54 g). However, during summer season a significant decrease in the cocoon weight was observed in Dun22 (1.39 g) as compared to SK-1 (1.87 g), SK-6 (1.86 g) and SK-24 and SK-31 that recorded cocoon weight of 1.70 g (Table 4, Fig. 1e). Further, the cocoon weight of all the races evaluated was relatively lower in summer season than spring which could be attributed to higher room temperature prevailing in summer season thereby adversely affecting the cocoon weight. The higher cocoon weight recorded in SK-1 and SK-6 indicates a clear difference in the way the biomass is utilized by SK-1 and SK-6 during 5th instar larvae towards cocoon production. The performance of silkworm breeds clearly indicates the role of their origin and genetic diversity on cocoon output for seed purposes. Higher cocoon weight of SK-6 and SK-31 prove commercial superiority of these lines. Singh *et al.* (2010) concluded that temperature and humidity are key environmental factors that influence the physiology of insects. Kumar *et al.* (2003) noticed the deleterious effect of higher temperature and humidity on economic traits.

TABLE 6: Performance of some economic traits of silkworm (*Bombyx mori* L.)

Season	Races	Silkgland somatic index (%)	Silk conversion index (%)	Yield (kg^{-10000} larvae)
Spring	SK-30 (P)	31.00	25.91	18.73
	SK-34 (P)	32.80	28.95	17.20
	SK-24 (P)	30.32	28.65	16.63
	SK-6 (P)	28.59	29.01	18.17
	CSR-2 (P)	25.31	32.14	15.60
	SK-1 (M)	31.14	28.95	19.83
	SK-13 (M)	25.57	32.67	16.00
	SK-28 (M)	28.65	26.86	17.87
	SK-31 (M)	27.36	30.88	16.90
	Dun22 (M)	27.17	29.15	16.20
CD (p<0.05)		1.826	3.013	2.247
Summer	SK-30 (P)	27.90	22.45	15.83
	SK-34 (P)	33.49	28.35	15.30
	SK-24 (P)	28.93	25.90	14.73
	SK-6 (P)	29.69	26.86	17.27
	CSR-2 (P)	23.56	34.15	12.37
	SK-1 (M)	28.30	27.78	17.83
	SK-13 (M)	25.72	32.31	15.47
	SK-28 (M)	27.07	25.66	17.80
	SK-31 (M)	27.83	28.68	15.83
	Dun22 (M)	26.60	29.41	14.30
CD (p<0.05)		1.854	3.351	2.613
Pooled mean	SK-30 (P)	29.45	24.18	17.28
	SK-34 (P)	33.15	28.65	16.25
	SK-24 (P)	29.62	27.28	15.68
	SK-6 (P)	29.14	27.93	17.72
	CSR-2 (P)	24.43	33.15	13.98
	SK-1 (M)	29.72	28.36	18.83
	SK-13 (M)	25.65	32.49	15.73
	SK-28 (M)	27.86	26.26	17.83
	SK-31 (M)	27.59	29.78	16.37
	Dun22 (M)	26.89	29.28	15.25
CD (p<0.05)		1.782	3.086	2.360

(P) – Plain race
(M) – Marked race

The data (Table 6, Fig. 1f) revealed that irrespective of genotypes the yield kg^{-10000} larvae was higher in spring season compared to summer season. In spring season SK-1 recorded significantly highest yield of 19.83 kg which was at par with SK-30 (18.73kg), SK-6 (18.17kg) and SK-28 (17.87kg) and the lowest yield (15.60 kg) was recorded in CSR-2 while during summer season the yield was significantly higher in SK-1 (17.83 kg) followed by SK-28 (17.80 kg) and SK-6 (17.27 kg) and the lowest yield 12.37 kg was noticed in CSR-2. Higher cocoon yield observed in SK-1, SK-30, SK-6 and SK-28 could be attributed to better effective rate of rearing. The higher cocoon yield in spring season than summer could be attributed to higher survivability of races under congenial room temperature. In commercial crop seasons (spring and summer) the quantitative traits are stressed due to congenial weather and quality of feed. These findings are in conformity with Legay (1958), Rao *et al.* (2004), Ramesh-Babu *et al.* (2009) and Hussain *et al.* (2010) who reported that cocoon production is chiefly dependent on larval nutrition and nutritive value of mulberry leaves and conversion efficiency of larvae which is affected by weather conditions.

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