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Studies on differential adaptation of selected races of the silkworm (*Bombyx mori* L.) to temperate climates

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ABSTRACT

Seasonal effects of four bivoltine races of Pampore-1, Pampore-3, SKUAST-1 and NB4D2 to temperate conditions in Kashmir with reference to important economic traits were evaluated during different seasons of the year to understand genotype and environment interaction. Data were calculated on economic characters such as fecundity, hatching percentage, larval weight, larval duration, ERR, cocoon weight, shell weight, shell ratio, cocoon yield, filament length, filament size and rendita in three different seasons *i.e.*, spring, summer and autumn temperate climates. Among the selected silkworm races, Pampore-1 and Pampore-3 showed a significant improvement in economic traits during all seasons in temperate climates.

Key words : *Bombyx mori* L., Seasonal effect, Bivoltine races, Temperate environment, Silk worm

INTRODUCTION

Environment is the predominant factor in the development of sericulture. The success of a given animal or plant as much as the silkworm races depend on the degree of adaptation conferred by the range of reaction of the genotype in response to different environmental conditions. The overall response also depends on the environmental factors such as differences in temperature and other climatic conditions during different seasons of the year or places in time and space. A number of temperature tolerant races have been evolved for rearing in uncongenial Indian tropical climatic conditions. But, the rearing performance of such races is not consistent in all the seasons of the year. The desired level of success in silkworm breeding depends on the selection of initial breeding materials followed by their effective utilization in different combinations to create genetic variability for selection (Mano *et al*., 1992). The sericulturally advanced countries *viz.*, Japan and China have succeded in increasing the unit production of silk by evolving highly productive bivoltine silkworm races suitable to their local conditions and advanced agronomical practices with proper selection of initial breeding materials (Yokoyama, 1979).

The quantitative traits of economic importance are under the control of cumulative action of polygenes and their modifiers which are influenced by environmental conditions to which they are exposed. The genetic mechanism of phylogeny in relation to environmental factors makes it difficult for the breeder to understand the nature of genes that contribute to the expression of commercial traits. The improvement of quantitative traits needs a clear understanding of physiology of gene function under different environmental conditions. Genotype-environment interactions are of major importance to the breeder in developing new breeds. Though gross estimates of the performance of the different races in different seasons are available, the factors involved in gene-environment interaction are not known. Hence, the present study conducted during different seasons in temperate belt like Kashmir provide some understanding of genetic control of variability, genetic versatility in terms of racial adaptation to temperate environments. Therefore, it will help in bringing the confidence in bivoltine silkworm rearing among the farmers concerned, in addition to minimizing crop losses by the introduction of hardy genotypes of bivoltines in specified environmental conditions by the existing recommended rearing practices.

MATERIALS AND METHODS

For the present investigation four silkworm races namely Pampore-1, Pampore-3 and NB4D2 and SKUAST-1 have been procured from the germ plasm bank maintained in the CSR and TI, Pampore and Division of Sericulture Mirgund, Sher-e-Kashmir University of Agricultural Sciences and Technology, Srinagar, Kashmir. Kashmir valley has typically four seasons; spring (March to May), summer (June-August), autumn (September-November) and winter (December to February). The valley remains snow bound during winter and as such there is no growth of mulberry leaf and obviously no rearing of silkworms. The entire Kashmir valley is a moist temperate belt, July being the hottest month when temperature rises to 35^0C and December to January showing mercury level falling to subzero temperatures. The quantum of rainfall varies from 600 to 750 mm in a year. The experiment was laid down in a completely

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randomized block designs with three replications for each treatment and each replication comprised of 300 larvae. Rearing was conducted as per method suggested by Dandin *et al*. (2003). Observations were recorded for economic characters *viz.*, fecundity, hatching percentage, larval weight, larval duration, ERR, cocoon yield, cocoon weight, shell weight, shell percentage, filament length, denier, rendita, during different seasons *i.e.* spring, summer and autumn in climatically temperate region of Kashmir in order to understand the nature of relationship between the genetic and environmental interaction and variations which jointly give rise to variation in phenotype for qualitative and quantitative characters.

Stastical analysis :

Two–way analysis of variance was used to test the significance of differences in the mean of economic characters of the silkworm races reared during different seasons. Tukey's (1953) multiple comparison test was used to find significance of differences between the races and seasons. Differences were considered significant at $P< 0.05$.

RESULTS AND DISCUSSION

The results on economic traits of selected silkworm races under temperate climatic conditions are presented in Table 1 and 2.

Fecundity :

The fecundity in all races (expressed in number of eggs/laying) was high during spring season (560) followed by autumn (547) and summer (516). The average number of eggs laid by a moth was relatively high in Pampore-1 (572) followed by Pampore-3 (561), SKUAST-1 (538) and NB4D2 (493). However, a significant decrease in the fecundity was observed in NB4D2 (506) during autumn season whereas a significant increase was observed in Pampore-1 (593) during spring season.

Hatching :

The mean egg hatching percentage of all the races was found to be significantly higher during spring season (95.5 %) followed by autumn (91.1 %) and summer (87.3 %). Pampore-1 showed a relatively higher mean egg hatching percentage (93.7 %) followed by SKUAST-1 (92.0 %), NB4D2 (90.1 %) and Pampore-3 (89.6 %). A significant decrease in the egg hatching percentage was observed in NB4D2 and Pampore-3 (86.0 %) during summer season whereas a significant increase was observed in SKUAST-1 (97.4) during spring season.

Larval duration :

The selected silkworm races showed a significant decrease in larval duration during summer (637 hours) followed by autumn (666 hours) and spring season (686 hours). Among the races, NB4D2 showed a relatively shorter larval duration (647 hours) followed by Pampore-1 (654 hours), Pampore-3 (659 hours) and SKUAST-1 (692 hours). A significant decrease in the larval duration was observed in Pampore-1 during summer (616 hours) whereas SKUAST-1 showed a significant increase during spring season (717 hours).

Larval weight :

The mean larval weight of all the races was found to be significantly higher during spring season (5.10 g) followed by summer (4.57 g) and autumn (4.26 g). Among the races of silkworm, the maximum larval weight was observed in Pampore-3 (4.93 g) followed by Pampore-1 (4.77 g), SKUAST-1 (4.52 g) and NB4D2 (4.35 g). A significant decrease in the larval weight was observed in NB4D2 during autumn season (3.82 g) whereas a significant increase was observed in Pampore-3 during spring season (5.30 g).

Effective rate of rearing (ERR) :

The mean ERR of all the races was found to be significantly higher during autumn season (89.2 %) followed by spring (88.0 %) and summer (82.7 %). Among the races of silkworm, the mean ERR was higher in Pampore-1 (89.8 %) followed by Pampore-3 (88.5 %), NB4D2 (84.8 %) and SKUAST-1 (83.3 %). A significant decrease in the ERR was observed in SKUAST-1 (79.2 %) during summer season whereas a significant increase was observed in Pampore-3 during autumn season (92.8 %).

Yield :

The yield was expressed in terms of the quantum of viable cocoons as expressed in kilograms procured from a standard unit of 10,000 larvae. The highest mean yield by weight of all the races was observed during spring season (16.0 kg) followed by summer (14.1 kg) and autumn (13.3 kg). Pampore-1 showed a relatively higher mean yield (15.0 kg) followed by Pampore-3 (14.9 kg), SKUAST-1 and NB4D2 (13.4 kg). A significant decrease in the yield was observed in NB4D2 (13.4 kg) during summer season whereas SKUAST-1 showed a significant increase during autumn season (16.2 kg).

Cocoon weight :

The mean cocoon weight of all the races was found

Table 1: Influence of different seasons on economic characters of selected races of the silkworm, *Bombyx mori* L under temperate climatic conditions (Kashmir)

Seasons /Races	Fecundity (No. of eggs/laying)	Hatching (%)	Larval weight (g)	Larval duration (hours)	ERR (%)	Yield/ 10,000 larvae by weight (kg)
Seasons						
Spring	560±29.0^{z}	95.5±1.43^{z}	5.10±0.17^{z}	686±14.6^{z}	88.0±2.38^{y}	16.0±0.31^{z}
Summer	516±40.6^{x}	87.3±2.48^{x}	4.57±0.24^{y}	637±14.6^{x}	82.7±3.62^{x}	14.1±0.79^{y}
Autumn	547±27.1^{y}	91.1±2.57^{y}	4.26±0.35^{x}	666±15.9^{y}	89.2±3.37^{z}	13.3±0.77^{x}
F-test	**	**	**	**	**	**
Races						
Pampore-1	572±19.9^{d}	93.7±2.13^{c}	4.77±0.27^{c}	654±9.10^{b}	89.8±2.03^{d}	15.0±0.90^{b}
Pampore-3	561±14.3^{c}	89.6±3.49^{a}	4.93±0.30^{d}	659±8.30^{c}	88.5±4.27^{c}	14.9±0.92^{b}
Skuast-1	538±16.0^{b}	92.0±4.90^{b}	4.52±0.46^{b}	692±8.30^{d}	83.3±3.32^{a}	13.9±1.71^{a}
NB4D2	493±31.6^{a}	90.1±4.17^{a}	4.35±0.48^{a}	647±6.60^{a}	84.8±3.51^{b}	13.9±1.22^{a}
F-test	**	*	*	**	**	**
Interaction						
Seasons × Races						
Spring × Pampore-1	593±5.51	95.5±0.83	5.10±0.10	676±3.51	89.7±0.62	16.1±0.03
Spring × Pampore-3	577±4.58	93.8±0.20	5.30±0.10	697±1.15	89.6±0.52	16.1±0.04
Spring × Skuast-1	551±7.00	97.4±0.53	5.09±0.08	717±2.08	84.3±0.62	16.2±0.17
Spring × NB4D2	520±5.51	95.3±0.61	4.91±0.10	654±0.58	88.3±1.14	15.5±0.16
Summer × Pampore-1	548±5.57	91.1±1.17	4.69±0.08	616±0.58	87.8±1.69	14.8±0.28
Summer × Pampore-3	545±5.29	86.0±0.95	4.87±0.06	639±0.19	83.3±1.40	14.7±0.26
Summer × Skuast-1	518±5.69	86.3±1.47	4.40±0.10	655±0.19	79.2±1.35	13.2±0.21
Summer × NB4D2	452±6.56	86.0±1.00	4.31±0.10	639±0.96	80.5±0.89	13.4±0.22
Autumn × Pampore-1	575±3.51	94.5±0.51	4.52±0.11	672±0.58	92.0±0.04	14.1±0.13
Autumn × Pampore-3	561±2.08	88.9±0.87	4.63±0.06	641±1.00	92.8±0.39	14.0±0.02
Autumn × Skuast-1	544±3.79	92.2±1.04	4.07±0.06	704±1.35	86.4±0.77	12.4±0.10
Autumn × NB4D2	506±5.51	88.9±0.26	3.82±0.13	647± 0.58	85.6±0.54	12.8±0.06
F-test	*	*	NS	**	*	*

* and ** indicate of significance of values at P = 0.05 and 0.01, respectively, NS- Non significant
Means with different superscripts are significantly different from each other (as indicated by Tukey's HSD);
(Each value is the mean ± SD of 3 separate observations)

to be significantly higher during spring season (1.94 g) followed by summer (1.68 g) and autumn (1.50 g). Among the races of silkworm, the mean cocoon weight was significantly higher in Pampore-1 (1.76 g) and Pampore-3 (1.73 g) followed by SKUAST-1 and NB4D2 (1.67 g). A significant decrease in the cocoon weight was observed in Pampore-3 during autumn season (1.44 g) whereas a significant increase was observed in Pampore-1 during spring season (2.03 g).

Shell weight :

The mean shell weight of all the races was found to be significantly higher during spring season (0.43 g) followed by summer (0.34 g) and autumn (0.30 g). Among the races of silkworm, the mean shell weight was significantly higher in Pampore-1 (0.38 g) and Pampore-3 (0.37 g) followed by NB4D2 (0.35 g) and SKUAST-1 (0.32 g). A significant decrease in the shell weight was observed in SKUAST-1 during autumn season (0.28 g) whereas a significant increase was observed in Pampore-1 during spring season (0.48 g).

Shell ratio :

The mean shell ratio of all the races was significantly higher during spring season (22.1 %) followed by summer (20.1 %) and autumn (19.9 %). Pampore-1 and Pampore-3 showed a relatively higher mean shell ratio (21.5 and 21.2 %, respectively). followed by NB4D2 (20.8 %) and SKUAST-1 (19.2 %). A significant increase in the shell ratio was observed in Pampore-1 during spring season (23.6 %) whereas a significant decrease was observed in SKUAST-1 during autumn season (19.2 %).

Filament length :

The mean filament length of all the races was relatively more during spring season (1018 m) followed by summer (910 m) and autumn (837 m). Pampore-1 showed a relatively higher mean filament length during all the seasons (980 m) followed by NB4D2 (917 m), Pampore-3 (911m) and SKUAST-1 (878 m). A significant decrease in the filament length was observed in SKUAST-1 (772 m) during autumn season whereas Pampore-1 showed a significant increase during spring season (1085m).

Filament size :

The average filament size of all the races was relatively more during spring season (2.91) followed by summer (2.22) and autumn (2.16). A significant decrease in the filament length was observed in Pampore-3 (2.13) during autumn season whereas a significant increase was observed in Pampore-1 during spring season (3.95).

Rendita :

The mean rendita of all the races was found to be significantly higher during summer (7.78 kg) followed by autumn (7.48 kg) and spring season (6.55 kg). Among the races of the silkworm, SKUAST-1 showed a relatively higher mean rendita during all the seasons (7.73 kg) followed by Pampore-1 (7.21 kg), NB4D2 (7.17 kg) and SKUAST-1 (6.97 kg). A significant decrease in the rendita was observed in Pampore-3 (6.45 kg) during spring season whereas a significant increase was observed in SKUAST-1 during summer season (8.49 kg).

Genetic stability and plasticity are two aspects of

Table 2 : Influence of different seasons on cocoon and post-cocoon characters of selected races of the silkworm, *Bombyx mori* L under temperate climatic conditions (Kashmir)

Seasons /Races	Cocoon weight (g)	Shell weight (g)	Shell ratio	Filament length (m)	Filament size (denier)	Rendita (kg)
Seasons						
Spring	1.94±0.09^{z}	0.43±0.05^{z}	22.1±1.87^{y}	1018±48.4^{z}	2.91±1.18^{y}	6.55±0.12^{x}
Summer	1.68±0.04^{y}	0.34±0.02^{y}	20.1±0.89^{x}	910±60.4^{y}	2.22±0.09^{x}	7.78±0.45^{z}
Autumn	1.50±0.06^{x}	0.30±0.02^{x}	19.9±0.83^{x}	837±39.9^{x}	2.16±0.03^{x}	7.48±0.43^{y}
F-test	**	**	*	**	*	**
Races						
Pampore-1	1.76±0.22^{b}	0.38±0.08^{d}	21.5±1.70^{c}	980±98.0^{c}	2.73±1.47^{a}	7.21±0.57^{c}
Pampore-3	1.73±0.25^{b}	0.37±0.08^{c}	21.2±1.81^{bc}	911±77.3^{b}	2.41±0.31^{a}	6.97±0.42^{a}
Skuast-1	1.67±0.19^{a}	0.32±0.04^{a}	19.2±0.49^{a}	878±109.2^{a}	2.31±0.17^{a}	7.73±0.90^{d}
NB4D2	1.67±0.12^{a}	0.35±0.04^{b}	20.8±1.19^{b}	917±40.3^{b}	2.27±0.07^{a}	7.17±0.35^{b}
F-test	*	**	**	**	NS	**
Interaction						
Seasons × Races						
Spring × Pampore-1	2.03±0.02	0.48±0.01	23.6±0.58	1085±9.64	3.95±2.30	6.47±0.02
Spring × Pampore-3	2.02±0.02	0.47±0.02	23.4±0.62	1013±6.19	2.81±0.02	6.45±0.03
Spring × Skuast-1	1.89±0.02	0.37±0.01	19.4±0.66	1016±14.0	2.53±0.03	6.55±0.02
Spring × NB4D2	1.82±0.01	0.40±0.02	22.0±0.96	956±11.5	2.36±0.01	6.73±0.03
Summer × Pampore-1	1.69±0.01	0.36±0.01	21.1±0.24	994±5.51	2.08±0.01	7.71±0.01
Summer × Pampore-3	1.73±0.02	0.34±0.01	19.5±0.18	871±3.51	2.29±0.01	7.41±0.04
Summer × Skuast-1	1.65±0.01	0.32±0.01	19.2±0.45	846±19.8	2.26±0.01	8.49±0.03
Summer × NB4D2	1.63±0.01	0.33±0.01	20.5±0.72	927±9.29	2.27±0.02	7.51±0.06
Autumn × Pampore-1	1.55±0.02	0.31±0.01	19.8±0.20	860±2.08	2.16±0.01	7.45±0.03
Autumn × Pampore-3	1.44±0.02	0.30±0.01	20.7±0.69	848±2.65	2.13±0.01	7.04±0.02
Autumn × Skuast-1	1.46±0.01	0.28±0.01	19.2±0.55	772±3.51	2.14±0.02	8.15±0.03
Autumn × NB4D2	1.56±0.01	0.31±0.02	20.1±1.11	867±4.67	2.20±0.02	7.28±0.06
F-test	*	*	*	*	NS	**

* and ** indicate of significance of values at P = 0.05 and 0.01, respectively, NS- Non significant
Means with different superscripts are significantly different from each other (as indicated by Tukey's HSD);
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the same phenomenon called adaptation. Wide and sudden fluctuations in the environment coupled with poor quality mulberry leaf and management practices by the farmers under tropical conditions require more flexible genotypes. Selection of potential parents to serve as resource material is one of the pre-requisites contributing to the success of breeding potential of breeds/ hybrids for the given environment (Ramesh Babu *et al*., 2005). As balancing and fixing the desirable traits for local environments being a challenge for the breeder, proper understanding on the range of reaction of the selected genotypes under variable environmental conditions for appropriate use in breeding program is very essential (Naseema Begum *et al*., 2001). Obviously the present investigation on the variable performance of the four bivoltine races of Pampore-1, Pampore-3, SKUAST-1 and NB4D2 to temperate conditions in Kashmir with reference to important economic traits has yielded rich information, to identify promising breeds which can be recommended for commercial exploitation in the interest of the industry.

Comparison of the performance of selected silkworm races for some fitness parameters is a means by which we can qualify the said genotypes in regard to their relative status in a given environment. The adaptedness of a population to certain environments is a measure of its ability to survive and reproduce in a given situation (Dobzhansky, 1968). Fecundity and hatching percentage are two important components indicate the fitness of an organism and hence the reduced fecundity and hatching percentage are not favoured by natural selection. In this context, perusal of the data on fecundity and hatching percentage (Table 2) under temperate conditions, it is clear that Pampore-1 and SKUAST-1 has exhibited best performance among pure races during spring and autumn than summer seasons. Bonnier (1960) reported that rate of development depends on both genetic and environmental factors. The larval duration varies depending on the prevailing temperature. High ambient temperature during summer tends to reduce the larval duration by several hours to one or two days, where as lower temperature during spring and autumn season extends the larval duration.

Larval weight among selected races was best manifested by Pampore-3 and Pampore-1 during spring, summer and autumn season. The decrease in larval weight during autumn season may be related due to differences in nutritive value of mulberry leaf. The effective rate of rearing (ERR) is a measure of the survival rate of larvae that spin good cocoons and the degree of manifestation of this trait was largely influenced by environmental factors. As can be seen from the present findings Pampore-1 showed highest ERR during spring and autumn seasons under temperate conditions (Table 1). Seasons also had a significant influence on the ERR which was less in summer particularly in the optimal environmental and nutritional conditions for manifestation of its genetic potential.

Highest cocoon and post-cocoon characters were obtained during spring and summer than autumn season (Table 2). Decrease in the cocoon and shell weights in NB4D2 was relatively more compared to other races during summer compared to autumn and spring reared batches. The significant values for cocoon weight which is positively related to cocoon yield in Pampore-1 over other races indicating more productivity under diversified environmental conditions showed their over all productivity and better post cocoon parameters. The filament length during all seasons was best manifested in Pampore-1 and NB4D2. The increase or decrease in filament length is dependent on the increase or decrease of the thickness of the filament and cocoon shell weight (Nagaraju, 1990). Thus, it could be concluded that Pampore-1 is best suited to rear during all season while NB4D2 for autumn season under temperate climates of Kashmir.

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