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Identification of Potential Crossbreeds of Mulberry Silkworm, *Bombyx mori* L. and Their Performance Under Tropical Stress

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The performance of five newly evolved cross breeds were evaluated across seasons to understand the genotype and environment interactions and their stability under fluctuating tropical environmental conditions along with control hybrids PM × CSR2 and APM1 × APS8. The data was collected on eight economic traits namely fecundity, yield per 10,000 larvae by number, yield per 10,000 larvae by weight, survival rate, cocoon weight, cocoon shell weight, cocoon shell ratio and filament length. The data was subjected for Analysis of Variance (ANOVA) and relevant statistical methods. The performance data obtained was further subjected for multiple trait evaluation index method. The ranks were adjudicated based on the index values. The two hybrids *viz.*, MSO3 × APS45 and MSO1 × APS12 performed well under diversified environmental conditions indicating their overall stability and superiority. These hybrids revealed highly significant (p < 0.01) improvement for the majority of the traits over the control hybrids.

Key words: Silkworm, Hybrid, Seasonal effects, Environment, Performance, Consistency

Introduction

The silkworm is the important economic insect and most of the commercial characters in silkworm, *Bombyx mori* L. are polygenic in nature. The expressions of these traits are under the influence of complex interaction between the related genes and the dynamic environmental conditions to which they are exposed. Silkworm races evolved under similar conditions may tend to react differently to the ambient environmental conditions. The phenotypic expression is influenced by the environmental factors such as temperature, relative humidity, light as well nutrition. Therefore, the phenotypic expression of a race or species is determined by the interaction between genetic and environmental factors (Barlow, 1981). As such, seasonal performance of silkworm breeds is of vital importance in understanding combined action of environment and genetic potentiality under diversified environmental conditions (Thiagarajan *et al*., 1993). The consistency of a genotype or its population exhibiting less variation over a series of environments reflects its high buffering ability and stability. Since, a particular genotype has its own range of reaction and degree of penetrance depending on the genetic endowment, its stability is greatly influenced by genotype × environment interaction. As environment is dynamic, different seasons of the year bring about significant variations in the physical and biotic factors governing the expression of commercial characters in silkworm (Kobayashi *et al*., 1986). The choice of a breed / hybrid therefore depends not only on the genotype itself but also on its performance under diverse environmental conditions (Rahman and Ahmed, 1988).

The success of silkworm breeds depends largely on their adaptability to the environment to which they are exposed. The expression of phenotypic variation is attributed to three variables namely, genetic, environmental and genotype × environment. On the other hand, the sericultural practices are seen throughout the year in India, which is situated in tropical belt having wide range of geographic areas experiencing variable climatic conditions and the performance of hybrids may not be consistent during various seasons due to tropical stress. Hence, the sea-

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sonal evaluation is necessary for the final recommendation of suitable and flexible hybrid combinations for commercial use by the farmers.

Seasonal variations in the manifestation of phenotypic traits studied are also ascribed to the genetic differences among different silkworm strains and an interaction with changing environmental conditions. It is established that the unfavorable conditions prevailing in tropics during different seasons of the year affect the expression of majority of economic traits of silkworm (Reddy *et al.*, 2002). However, efforts to synthesize silkworm breeds suitable to different climatic conditions of the tropics have lead to the development of new hybrids and yet there is high potential to develop improved varieties. In view of the above, the present investigation was undertaken to understand the performance of crossbreed hybrids evolved in different seasons of the year.

Materials and Methods

Eight newly evolved polyvoltine breeds *viz*., MSO1, MSO2, MSO3, MSO4, MSO5, MSO6, MSO7 and MSO8 as lines and productively superior bivoltine breeds such as APS12, APS45 and APS8 as testers were utilized in the preparation of twenty four hybrid combinations by employing the Line × Tester method at Andhra Pradesh State Sericulture Research and Development Institute (APSSRDI), Hindupur. These newly evolved hybrids were reared in 3 replicates of each having 300 larvae and short listed to 5 hybrids. The newly evolved and short-listed hybrid combinations *viz.,* MSO1 × APS45, MSO1 × APS12, MSO2 × APS45, MSO3 × APS45 and MSO7 × APS8 along with the controls namely PM × CSR2 and APM1 × APS8 were reared in three different seasons such as pre-monsoon characterized by high temperature, low humidity and no rainfall, in the monsoon characterized by moderate temperature, high humidity and moderate to heavy rainfall and in the post-monsoon characterized by low temperature and low humidity. All the short listed hybrids along with the control hybrids were reared in each season in three replications with 300 larvae per replication and data was collected for eight traits namely fecundity, yield per 10,000 larvae by number, yield per 10,000 larvae by weight, survival rate, cocoon weight, cocoon shell weight, cocoon shell ratio and filament length. The data was analyzed using two way analysis of variance (Kempthorne, 1952) for three seasons to find out genotype - environment interaction. The merit of the individual hybrids and their relative superiority was evaluated by employing the Multiple Trait Evaluation Index Method (Mano *et al*., 1993).

Results and Discussion

The data on seasonal performance pertaining to eight economic traits of the hybrids along with control hybrids are presented in Table 1. The perusal of the mean of three seasons revealed that the fecundity ranged from 465 (MSO2 × APS45) to 488 (MSO1 × APS45), yield per 10,000 larvae by number ranged from 9385 (MSO7 × APS8) to 9444 (MSO1 × APS45), yield per 10,000 larvae by weight varied between 17.058 kg (MSO2 × APS45) to 17.743 kg (MSO3 × APS45), survival rate from 92.56% (MSO7 × APS8) to 93.83% (MSO1 × APS45) for various traits among the hybrids. With regard to cocoon weight it ranged to the maximum of 1.892 g (MSO3 × APS45) and to a minimum 1.819 g (MSO2 × APS45) where as shell weight ranged between 0.329 g (MSO7 × APS8) to 0.355 g (MSO3 × APS45). The shell ratio % ranged between 17.90% (MSO7 × APS8) to 18.75% (MSO3 × APS45) and filament length recorded between 828 m (MSO7 × APS8) to 945 m (MSO3 × APS45). The newly developed hybrids performance was highly significant ($p < 0.01$) over the controls. The analysis of variance (ANOVA) results depicted in Table 2 revealed highly ($p < 0.01$) significant difference among the hybrids for all the eight economic traits evaluated. Highly significant ($p < 0.01$) seasonal variations were found among the hybrids for all the traits except for shell ratio. Since the silkworm, *Bombyx mori* L. is very sensitive to climatic fluctuations and as a consequence silk yield is greatly affected. It is established that the dynamic environmental conditions prevailing in different seasons of the year bring about profound changes in the physical and biotic factors influencing the growth, development and there by the expression of economic characters in silkworm races (Kobayashi *et al*., 1986; Muslim, 1986). Genotype × environmental effects were highly significant ($p < 0.01$) for six quantitative traits except for fecundity and shell weight. The relative merit as represented by average Evaluation index (EI) value recorded among the hybrids (Table 3) showed that highest index value for MSO3 × APS45 (60.68) followed by MSO1 × APS12 (56.41) and MSO2 × APS45 (54.56).

Seasonal studies made in both mulberry and non-mulberry silkworm breeds revealed differential expression to varied climatic conditions during different seasons (Dayananda and Rama Mohan Rao, 2009). Genotype and environmental interactions in the manifestation of phenotype is well documented in both plants and animals (Strickberger, 1976; Yokoyama, 1956). In silkworm, Harada (1961) has documented a high degree of phenotypic variability with regard to various traits during different seasons. In addition, several studies have been made to provide reliable estimates of phenotypic variability of dif-

Table 1. Mean values of short-listed hybrids during different seasons

Combination	Season	Fecundity (No.)	Yield / 10,000 larvae		Survival rate (%)	Cocoon weight (g)	Shell weight (g)	Shell ratio (%)	Filament length (m)
			No.	Wt. (kg)					
MSO1 × APS45	Monsoon	488	9533	17.483	94.70	1.836	0.336	18.28	899
	Post monsoon	494	9467	17.287	94.23	1.832	0.327	17.85	899
	Pre monsoon	482	9333	16.585	92.57	1.793	0.319	17.78	879
	Average	**488**	**9444**	**17.118**	**93.83**	**1.820**	**0.327**	**17.97**	**892**
MSO1 × APS12	Monsoon	499	9589	18.000	94.36	1.888	0.350	18.52	925
	Post monsoon	490	9455	17.848	93.94	1.903	0.353	18.55	938
	Pre monsoon	472	9256	16.934	91.51	1.843	0.332	17.99	895
	Average	**487**	**9433**	**17.594**	**93.27**	**1.878**	**0.345**	**18.35**	**919**
MSO2 × APS45	Monsoon	471	9522	17.462	94.45	1.848	0.341	18.46	925
	Post monsoon	475	9512	17.226	93.72	1.816	0.337	18.54	896
	Pre monsoon	450	9245	16.486	91.47	1.792	0.325	18.16	884
	Average	**465**	**9426**	**17.058**	**93.21**	**1.819**	**0.334**	**18.38**	**902**
MSO3 × APS45	Monsoon	495	9433	18.203	94.00	1.906	0.362	18.97	964
	Post monsoon	489	9467	18.023	94.23	1.923	0.359	18.65	953
	Pre monsoon	462	9300	17.004	92.33	1.847	0.344	18.63	920
	Average	**482**	**9400**	**17.743**	**93.52**	**1.892**	**0.355**	**18.75**	**945**
MSO7 × APS8	Monsoon	485	9500	17.717	94.13	1.871	0.334	17.83	833
	Post monsoon	488	9433	17.446	93.66	1.858	0.327	17.58	833
	Pre monsoon	463	9220	16.344	89.89	1.782	0.326	18.29	817
	Average	**479**	**9385**	**17.169**	**92.56**	**1.837**	**0.329**	**17.90**	**828**
APM1 × APS8	Monsoon	451	9156	14.960	90.97	1.652	0.280	16.93	727
	Post monsoon	456	9156	14.921	91.00	1.638	0.269	16.43	722
	Pre monsoon	426	9022	13.879	89.42	1.546	0.259	16.77	689
	Average	**444**	**9111**	**14.586**	**90.46**	**1.612**	**0.269**	**16.71**	**713**
PM × CSR2	Monsoon	448	9167	15.281	91.20	1.691	0.275	16.26	735
	Post monsoon	443	9178	15.463	91.36	1.693	0.278	16.40	727
	Pre monsoon	433	9017	14.104	91.20	1.572	0.261	16.60	695
	Average	**441**	**9120**	**14.949**	**91.25**	**1.652**	**0.271**	**16.42**	**719**

Table 2. Analysis of variance of hybrid combinations for all three seasons

		Mean sum of squares							
Source of variation	df	Fecundity	Yield / 10,000 Larvae		Survival Rate	Cocoon Weight	Shell Weight	Shell Ratio	Filament Length
			No.	Wt.					
Race	6	4688.32804**	257899.59**	14.816459**	18.449**	0.10903**	0.010625**	7.01656**	85807.12698**
Season	2	2457.82539**	315364.11**	7.750768**	30.685**	0.03606**	0.00141**	0.196022	6597.4444**
Race* season	12	65.732804	5401.2778**	0.04951**	1.55146**	0.00113**	0.000045	0.205701**	217.722**
Error (B)	40	63.334921	3786.665873	0.027099	0.444621	0.000147	0.000032	0.070992	100.25873
Total	62	587.157195	39389.1371	1.714313	3.445999	0.012029	0.001104	0.773722	8657.564516
CD (R)		7.58228	58.62821	0.15684	0.63529	0.01154	0.00535	0.25385	9.5398
CD (S)		4.96377	38.38117	0.10268	0.4159	0.00755	0.0035	0.16619	6.24526
CD (R × S)		13.13289	101.54703	0.27166	1.10036	0.01999	0.00927	0.43969	16.52342

df = degree of freedom; * Significant ($p < 0.05$); ** Significant ($p < 0.01$)

Table 3. Evaluation index values of short listed hybrids

Hybrid Combination	Fecundity	Yield /10,000 Larvae		Survival Rate	Cocoon Weight	Shell Weight	Shell Ratio	Filament Length	Average E I value	Rank
		No.	Wt.							
MSO1 × APS45	55.63	55.42	54.02	57.71	53.01	52.48	52.11	54.62	54.37	4
MSO1 × APS12	55.34	54.76	57.73	53.76	58.24	57.60	56.46	57.37	56.41	2
MSO2 × APS45	55.43	54.35	53.55	53.37	52.86	54.57	56.78	55.59	54.56	3
MSO3 × APS45	60.26	61.55	58.89	62.50	59.52	60.52	60.94	61.30	60.68	1
MSO7 × APS8	51.68	51.92	54.42	48.82	54.55	52.95	51.32	48.01	51.71	5
APM1 × APS8 (C)	36.44	35.73	34.29	34.17	34.09	35.67	37.86	36.24	35.56	7
PM × CSR2 (C)	35.22	36.27	37.11	39.67	37.74	36.20	34.54	36.88	36.70	6

ferent genotypes under diverse environments (Perkins and Jinks, 1968). Variable gene frequencies at several loci in different silkworm races make them to respond differently to changing environmental conditions (Raju, 1990; Ueda *et al*., 1969). The differential expression of different hybrids across seasons recorded in the present study is in conformity with the observation of Ueda *et al*. (1975).

The field level success of silkworm breeds / hybrids depends largely on their adaptability to the environment in which it is intended to be reared. The analysis of the data on the performance of the short listed hybrids in various seasons of the year revealed maximum expression of economic traits during favourable post-monsoon season followed by monsoon and pre-monsoon season. These are in confirmation with the findings of earlier researchers (Lakshmi, 2008; Nagalakshmamma and Naga Jyothi, 2010; Sudhakara Rao *et al*., 2001). The observation based on the mean and stability parameters of the newly evolved hybrids performed well for most of the characters and found suitable to rear throughout the year confirming the findings of Dayananda (2009) and Sudhakara Rao *et al*. (2001). The average index values indicate that the hybrids MSO3 × APS45 and MSO1 × APS12 have scored higher average EI values establishing their superiority over multiple traits and such type of attempts for identification and evaluation of hybrids were made by many breeders (Gangopadhyay *et al*., 2006; Rao *et al*., 2004; Sashindran Nair *et al*., 2009). Based on the results obtained with regard to their merit in stability and superior traits, the hybrids *viz*., MSO3 × APS45 and MSO1 × APS12 are recommended for large scale field trials and for their further commercial exploitation.

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