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Hybrid Vigour in Polyvoltine × Bivoltine (Sex-Limited Cocoon Colour) Hybrids of Silkworm *Bombyx mori* L.

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Heterosis studies on rearing performance of 25 F1 Polyvoltine × bivoltine (sex-limited cocoon colour) hybrids revealed that manifestation of heterosis was highly significant for majority of the economic traits contributing to more silk yield. Five hybrids namely BL24 × CSR 19 (SL), BL24 × B72 (SL), BL67 × CSR19 (SL), BL67 × B72 (SL) and 96A × B72 (SL) were highly promising over the popular hybrid PM × NB4D2.These five hybrids exhibited significant heterosis and heterobeltiosis for most of the traits studied and can be commercially exploited by taking genetic advantage of sex-limited cocoon colour bivoltine breeds on economic lines.

Key words : Hybrid vigour, Heterosis, Heterobeltiosis, *Bombyx mori* L

Introduction

Utilization of hybrid vigour in the silkworm and introduction of F1 hybrids in sericulture for commercial exploitation has heralded a new era in most of the sericultural countries. The exploitation of hybrid vigour has made a remarkable progress in increasing the cocoon productivity. The superiority of hybrids over parental strains is undoubtedly due to the high magnitude of heterosis for most of the quantitative traits (Harada, 1961). Sex-determination has become indispensable in silkworm breeding because all present day silkworm rearers culture only hybrids to exploit heterosis for cocoon production to which accurate isolation of male and female is essential. In India, sex limited strains assume a special significance to use as male component since the bulk quantity of silk is produced from Polyvoltine × bivoltine hybrids (Nagaraju, 1996; Datta *et al.*, 2001). The separation of male and female to prevent the mating between individuals of the same parental variety is very important task for the preparation of correct hybrids and such separation by visual observation during pupal stage requires lots of labour. This method of sexing involves cutting open every cocoon and their unsuitability to silk reeling causes great loss to the industry (Nagaraju, 1996). As reciprocal crosses were not prepared between Polyvoltine and bivoltine breeds because of their inferiority and other related problems (Tazima, 1988; Murakami, 1989).

Kimura *et al.* (1971) for the first time developed silkworm strains with sex-limited cocoon colour by utilizing a female individual induced by translocation of yellow blood gene (y) to W chromosome by gamma irradiation. Later several Sex-limited yellow colour cocoon breeds were evolved both in bivoltine and Polyvoltines (Lee *et al.*, 1989; Liu *et al.*, 1996; Yamamoto, 1989; Ravindra singh *et al.*, 2000). However studies on the evaluation of sex-limited yellow cocoon colour breeds with Polyvoltine breeds are seems to be not available. Hence an attempt has been made to exploit hybrid vigour as sex-limited bivoltine cocoon colour breeds offers an easy and precise mechanism to produce F1 silkworm seed production efficiently (Yamamoto, 1989).

In this context a breeding programme was designed during 1996-97 to evolve viable sex-limited bivoltine cocoon colour breeds at this institute.

Material and Methods

Productive bivoltine breeds viz; CSR4, CSR5, CSR19, B71 and B72 (spinning Japanese type cocoons-Dumbbells) were selected as recipient parents. A sex-limited cocoon colour breed-NB4D2 (a dumb-bell breed) was utilised as donor

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parent and introduced sex-limited cocoon colour to all the above breeds. Breeding was carried out coupled with appropriate selection procedures. After fixing the breeds for target characters by F12, the male component of this newly evolved breeds were visually separated (yellow: female, white: male) and crossed to popular and productive polyvoltine breeds (female component) viz: Pure Mysore, Nistari, (Indigenous races) BL67, 96A and BL24 (newly evolved breeds) and prepared 25 F1 hybrids. Rearing was carried out during January-February 2001 as suggested by Krishnaswami (1978) having 3 replications each with 300 larvae. Data were collected on seven traits of economic importance viz., pupation rate, cocoon yield, cocoon weight, shell weight, shell ratio, filament length and raw silk recovery and subjected to Line×Tester analysis (Kempthorne, 1957). Heterosis and heterobeltiosis was calculated by using the following formulae.

Percent Heterosis =

$$\frac{\text{F1 value} - \text{Mid parent value (MPV)}}{\text{Mid parent value (MPV)}} \times 100$$

Percent Heterobeltiosis :

$$\frac{\text{F1 value} - \text{Better parent value (BPV)}}{\text{Better parent value (BPV)}} \times 100$$

The popular Poly × bi hybrid Pure Mysore × NB4D2 (Normal) was kept as "check hybrid". Fifty good cocoons from each bed was selected and reeled on Multi ends reeling machine to obtain reeling parameters.

Results

The mean performance of Polyvoltines and newly evolved Bivoltine sex-limited cocoon colour breeds were given in Table 1. The heterosis and heterobeltiosis over check hybrid PM × NB4D2 for selected hybrids were presented in Table 2. The desired heterosis for silk productivity is positive. Out of 25 hybrids, 17 combinations exhibited positive heterosis for both mid parent heterosis values (MPV) and better parent heterosis value (BPV). The extent of heterosis ranged from 1.60 in the hybrid Nistari × CSR5 and maximum in BL24 × CSR4 (13.03) for pupation rate. Highly significant better parent heterosis value was recorded for the hybrid BL67 × B72 (9.63).

All the 25 hybrids were recorded positive MPV for cocoon yield and cocoon weight. The hybrid BL24 × CSR5 shown lowest (20.43) and highest (58.19) by the hybrid BL67 × CSR5 for cocoon yield. Except one hybrid (Nistari × CSR4), all hybrids expressed positive BPV (8.74 to 27.74). But highly significant positive heterosis and heterobeltiosis is expressed by the hybrid BL67 × CSR 5 (58.19 and 27.74) respectively. The hybrid PM × CSR4 expressed lowest (16.01) and BL67 × CSR5 expressed highest (36.96) MPV for cocoon weight; where as 11 hybrids recorded significant positive BPV (5.21 to 14.13). Highly significant heterosis and heterobeltiosis recorded (14.13) for the hybrid BL67 × CSR5.

Seventeen hybrids were expressed positive MPV and ranged from 7.94 to 35.98 for shell weight. The hybrid BL24 × CSR5 expressed lowest (7.94) and BL67 × CSR5 recorded highest MPV (35.98). Two hybrids namely 96A × CSR19 (10.59) and 96A × B71 (8.17) shown highest BPV. Only 4 hybrids expressed MPV for shell ratio. Two hybrids BL67 × CSR4 (12.29) and BL67 × B71 (11.48) expressed significant BPV for shell ratio.

Three hybrids namely PM × CSR4 (1.98), BL67 × B72 (13.78) and BL24 × CSR19 (13.68) expressed positive MPV

Table 1. Mean performance of polyvoltine and bivoltine breeds (January-February 2001)

Breed	Pupation rate (%)	Cocoon yield (kg)	Cocoon weight (g)	Shell weight (g)	Shell ratio (%)	Filament length (m)	Raw silk recovery (%)
POLYVOLTINES							
Pure Mysore	94.66	11.47	1.220	0.162	13.31	403	8.99
Nistari	97.09	9.96	1.030	0.132	12.81	369	8.39
96A	81.17	8.53	1.123	0.210	18.62	702	13.13
BL67	96.00	13.35	1.393	0.245	17.54	765	11.45
BL24	95.55	11.87	1.243	0.193	15.50	641	10.07
BIVOLTINES							
CSR4(SL)	88.53	13.93	1.670	0.356	21.35	934	14.56
CSR5(SL)	89.41	13.87	1.684	0.370	21.97	948	13.82
CSR19(SL)	90.72	13.82	1.650	0.359	21.74	903	14.27
B71(SL)	90.77	14.24	1.631	0.351	21.52	933	14.39
B72(SL)	92.14	13.89	1.660	0.367	21.64	953	14.15

Table 2. Heterosis and heterobeltiosis among selected hybrids over check hybrid PM × NB4D2

Hybrid	Pupation rate			Cocoon yield			Cocoon weight		
	MPV	BPV	CHECK	MPV	BPV	CHECK	MPV	BPV	CHECK
BL67 × CSR5 (SL)	6.11	6.10	-0.69	58.19**	27.74**	10.75**	36.96**	14.13**	10.14**
BL67 × CSR19 (SL)	9.22**	9.12**	2.14**	39.97**	13.20**	-2.25	24.60**	4.71	-1.03
BL67 × B72 (SL)	10.98**	9.63**	2.43**	51.31**	22.12**	6.06	29.64**	8.70**	3.32
96A × B72 (SL)	12.35**	7.23**	0.35	25.62**	23.16**	6.94*	21.96**	12.20**	6.65**
BL24 × CSR19	9.33**	8.70**	1.56	29.42**	20.27**	3.87	18.89**	4.22	-1.49
BL24 × B72	9.44**	8.70**	1.60	37.08**	27.08**	10.37**	25.37**	9.67**	4.24

Hybrid	Shell weight			Shell ratio			Filament length			Raw silk %		
	MPV	BPV	CHECK	MPV	BPV	CHECK	MPV	BPV	CHECK	MPV	BPV	CHECK
BL67 × CSR5 (SL)	35.98**	6.40	27.51**	0.96	-6.75**	17.02**	0.31	-13.24**	35.32**	0.38	-2.15	13.03**
BL67 × CSR19 (SL)	32.12**	4.55	-21.36**	7.61**	-0.12**	23.92**	-5.64	-16.13**	24.57**	-3.38	-7.26**	10.61**
BL67 × B72 (SL)	26.69**	0.47	15.86**	5.85**	-12.42**	8.22**	13.78**	-25.11**	17.34**	0.34	-3.30	14.37**
96A × B72 (SL)	-25.36**	2.99	18.77**	0.90	8.66**	-12.84**	-4.16	-13.58**	35.41**	28.01**	15.80*	36.92**
BL24 × CSR19 (SL)	14.87**	-11.71**	2.59	-1.11	-15.30**	5.14	13.68**	-2.83	44.31**	12.16**	-4.37	14.03**
BL24 × B72 (SL)	31.92**	1.59	17.15**	7.33**	-7.89**	13.82**	1.86	-14.82**	33.46**	16.07**	-0.68	17.46**

Table 3. Performance of short listed Multi × Bi (SL) hybrids (January-February 2001)

Hybrid	Pupation rate (%)	Cocoon yield (kg)	Cocoon weight (g)	Shell weight (g)	Shell ratio (%)	Filament length (m)	Raw silk recovery (%)
BL24 × CSR19 (SL)	96.77	16.600	1.719	0.317	18.41	913	13.65
BL24 × B72 (SL)	97.10	17.700	1.814	0.362	19.93	811	14.06
96A × B72 (SL)	94.22	17.000	1.803	0.367	18.95	713	13.72
BL67 × CSR5 (SL)	90.44	17.000	1.880	0.387	20.60	903	13.73
BL67 × B72 (SL)	91.99	17.100	1.861	0.363	19.76	848	16.39
PM × NB4D2 (cont)	91.77	16.000	1.745	0.309	17.51	608	11.97
CD at 5%	2.28**	NS	0.1*	0.03**	0.92**	82.13**	0.88**

for filament length. None of the hybrids expressed BPV. Six hybrids expressed MPV; where as two hybrids namely PM×B71 (21.47) and BL24×CSR4 (15.80) recorded significant BPV for raw silk recovery.

Discussion

Hybrid vigour effect is so prominent in the silkworm that it is utilized extensively in all commercial rearings for cocoon production at the farmers level (Lee *et al.,* 1989). Japan is the pioneer to synthesize and utilize the sex limited races commercially (Mano *et al.*, 1969). Efforts have been made earlier in India to evolve sex limited races (Sengupta, 1968; Nagaraju *et al.*, 1989, Rajendramundukur *et al.*, 1999; Ravindra singh *et al.*, 2001) and met with little success due to oblique reasons. By utilizing the newly evolved bivoltine cocoon colour breeds, maximum hybrid vigour can be exploited by taking advantage of sex limited character to use as male component with productive polyvoltine breeds. The present study indicated that newly evolved sex limited cocoon colour breeds when crossed to indigenous races Pure Mysore and Nistari there is no much significant differences in the performance of their F1 hybrids. This may be attributed to the genetic plateau reached by those races. Similar observations were made by Datta *et al.* (2001) in the hybrid PM × CSR8 (a bivoltine sex limited cocoon colour breed) and also when crossed with other productive breeds. But when crossed to newly evolved Polyvoltine breeds like BL24, BL67 and 96A there is significant positive heterotic effects with regards to the majority of the economic traits studied. Majority of new Poly × Bi hybrids exhibited significant mid parent heterotic values (>10) and better parent heterotic values (>6) for cocoon yield, cocoon weight, cocoon shell weight, shell ratio and raw silk recovery showing complete dominance which indicates the influence of additive genes. Similar observations were made by Bhargava *et al.* (1996) and Ramesh Babu *et al.* (2001) in different crosses of silkworm. Heterosis is the function of dominance effect and genetic distance between parents. When to completely genetically diverge homozygous parents are crossed, maximum heterozygosity can be achieved and this in turn leads to significant heterosis (Falconer, 1989). Mid parent heterosis was highly significant for cocoon yield for all the hybrids and better parent heterosis for majority of the traits. This can be attributed to significant heterosis for cocoon weight which is positively correlated with the number and weight of cocoons. Similar observations were made by Subba Rao *et al.* (1990) with respect to multi × bi hybrids. Out of 25 hybrids, the mean values of only those showing good heterobeltiosis over control hybrid PM XNB4D2 were given in Table 3. There appears good possibilities of increasing silk yield by exploitation of hybrid vigour through cocoon weight, shell weight and shell ratio.

The hybrids BL24×CSR19 (SL) and BL24×B72 (SL) were expressed highly significant positive heterotic effects for six traits (except shell ratio in former and filament length in later), out of seven traits evaluated. The hybrids BL 67×CSR19 (SL) expressed significant heterotic effects for five economic traits (pupation rate, cocoon yield, cocoon weight, shell weight, shell ratio) and BL67 × B72 (SL) for five traits (pupation rate, cocoon yield, cocoon weight, shell weight and filament length); where as 96A × B72 (SL) expressed significant better parent heterotic effects for four traits of economic importance (pupation rate, cocoon yield, cocoon weight and raw silk recovery). Thus the present study clearly indicated that the above hybrids can be conveniently exploited commercially by taking advantage of this economically viable genetic application to reduce the cost of production in Indian sericulture industry.

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