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Breeding of New Productive Bivoltine Hybrid, CSR12 × CSR6 of Silkworm *Bombyx mori* L.

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With an objective of evolving quantitatively and qualitatively superior bivoltine breeds/hybrids of silkworm *Bombyx mori* L. for tropical conditions, breeding work was initiated in Central Sericultural Research and Training Institute, Mysore during 1992 by utilizing two Japanese hybrids namely BN18 × BCS25 and Shunrei × Shogetsu along with Indian evolved breed, KA. The breed CSR12 which is characterized with sex-limited larval marking and white oval cocoons was evolved from the Japanese hybrid BN18 × BCS25 by crossing with KA, while the breed CSR6 which is characterized with normal marking (marked larvae) and white dumbbell cocoons was extracted from the Japanese commercial hybrid Shunrei × Shogetsu through continuous inbreeding coupled with selection. After fixation, these breeds along with other newly evolved breeds were subjected to hybrid study under optimum environmental conditions in the laboratory for expression of full potential of the genotypes. These hybrids were evaluated by Multiple Trait Evaluation Index (Mano *et al.,* 1993). The hybrid CSR12 × CSR6 was selected based multiple trait evaluation index value. The hybrid CSR12 × CSR6 recorded survival of 96.0%, shell weight of 50.0 cg, shell ratio of 24.3%, raw silk percentage of 19.6, filament length of 1,216 m, boil off loss of 22.4% and renditta of 5.1. On the other hand, the control hybrid (KA × NB4D2) has recorded survival of 90.6%, shell weight of 42. 1 cg, shell ratio of 20.4%, raw silk percentage of 15.9, filament length of 999 m, boil off loss of 24.8% and renditta of 6.3. The hybrid CSR12 × CSR6 was authorized during 1997 by Central Silk Board, Government of India for commercial exploitation during favourable months based on national level race authorization test.

Key words : *Bombyx mori* L., Breeding, Productive hybrid

Introduction

The breeding experiments conducted during 1970's yielded bivoltine hybrids with cocoon shell ratio of 18% at commercial level. These hybrids could not made much impact in the field. However, with growing emphasis to popularise bivoltine sericulture under Indian tropical/subtropical conditions, it has become imperative to develop productive and qualitatively superior bivoltine hybrids for commercial use. Keeping in view of this, reorientation in breeding approaches has been envisaged. Of late, adoption of bivoltine sericulture in India gathered momentum being armed with the evolution of good number of robust and productive bivoltine breeds/hybrids of silkworm, *Bombyx mori* L, for commercial exploitation under tropical conditions.

Systematic breeding approaches with appropriate selection procedures have contributed to amalgamate the major economic traits of choice from selected breeds and to synthesise genotypes of desirable constitution and expression in silkworm (Hirobe, 1968; Mano *et al.,* 1982; Sreerama Reddy *et al.,* 1992; Tanaka and Ohi, 1994). Chinese and Japanese breeders have already achieved remarkable progress in the improvement of several quantitative and qualitative traits of economic value in silkworm, *B. mori* (Mano *et al.,* 1991; Chen *et al.,* 1994).

By utilizing single and double hybrids of Japan, Harada during 1961 at Kalimpong (India) isolated the bivoltine Chinese type strain Kalimpong A (KA) which is used presently as one of the components for commercial hybrid

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production (Anonymous, 1955). Similarly, extraction of breeds was initiated during 1970s from commercial hybrids obtained from Japan. This has resulted in isolation of three bivoltine strains namely, NB4D2, NB7 and NB18 (Narasimhanna *et al.*, 1976; Krishnaswami, 1983). Similarly, CC1 and CA2 were bred at Central Sericultural Research and Training Institute, Mysore (Datta, 1984). Later on many bivoltine breeds were evolved by various breeders in India (Trag *et al.*, 1992; Raju and Krishnamurthy, 1993). However, for the last 15 years the cocoon shell ratio in bivoltine hybrids remained constant at 20% and the realization of cocoon shell ratio in commercial cocoon market is around 18%. This has made bivoltine crops unattractive to the farmers and reelers especially when they get similar silk content for multivoltine × bivoltine hybrids. Accordingly for improving the characters such as raw silk recovery and silk quality, breeding work was initiated and succeeded in evolving productive bivoltine hybrids viz., CSR2 × CSR4, CSR2 × CSR5 and CSR3 × CSR6 (Datta, *et al.*, 2000a, b).

Keeping this in view, attempts have been made to evolve productive bivoltine breeds/hybrids with high silk recovery and quality and low boil off loss. The present paper delineates the breeding process of the productive hybrid, CSR12 × CSR6.

Materials and Methods

The present study was initiated during 1992 by utilising two Japanese bivoltine hybrids viz., BN18 × BCS25, Shunrei × Shogetsu and an Indian evolved breed KA as breeding resource materials. The former hybrid was crossed with KA and the latter one utilized for line separation breeding. The rearing was conducted 'enmasse'. The larvae were reared as per standard techniques recommended by Krishnaswami (1978) and Datta (1992).

Breeding method and selection procedure

CSR12 (Oval line)

The line CSR12 was evolved from Japanese hybrid BN18 × BCS25 crossing with KA. The larvae of this line was sex-limited for larval markings and spun white cocoons. On the basis of cocoon uniformity, selection of cocoons was carried out for continuation of further generations. The females were crossed with KA. Mass rearing was conducted from F1 to F4 and from F5 onwards cellular rearing was resorted to. During the course of breeding, survival, cocoon yield and high cocoon shell ratio with high quality silk were mainly considered and mating was performed between the females and males from the cocoons of above average cocoon weight, cocoon shell weight and cocoon shell ratio.

Characteristics of CSR12

The larvae are sex-limited for larval markings. Cocoons are white and oval with medium grains. Larval duration is around 23 days.

CSR6 (Dumbbell line)

The line CSR6 was evolved from Japanese commercial hybrid Shunrei × Shogetsu. At F2 (transgressive segregants) the segregants of marked larvae dumbbell cocoons were separated from the breeding line of plain larvae and dumbbell cocoon. The selected cocoons on their individual merit were pooled and mated enmasse. From F6 onwards cellular rearing was resorted to. The batch showing best performance for cocoon shape, survival, cocoon yield, cocoon characters and reeling characters related to breeding were selected. The individuals which were above the batch mean were selected for continuation of subsequent generations. During the course of breeding, robustness (high survival), cocoon yield and high cocoon shell ratio with high silk quality were mainly considered.

Characteristics of CSR6

The larvae are marked. Cocoons are white and dumbbell with medium grains. Larval duration is around 24 days. At F9 these lines (CSR12 and CSR6) were subjected to hybrid study and evaluated in the laboratory as per Multiple Trait Evaluation Index (Mano *et al.*, 1993) by providing optimum environmental conditions to silkworm to bring out the full potential of the genotypes. By utilising these two lines viz., CSR12 and CSR6 and breeds developed earlier 161 hybrids were tested. The hybrid CSR12 × CSR6 was selected based on index value for the major silk contributing traits viz., survival, cocoon yield, cocoon weight, shell weight, shell ration, raw silk, filament length, reelability and neatness.

Characteristics of CSR12 × CSR6

The larvae are marked (Fig. 1). Cocoons are white and inter-

Fig. 1. Larvae of CSR12 × CSR6.

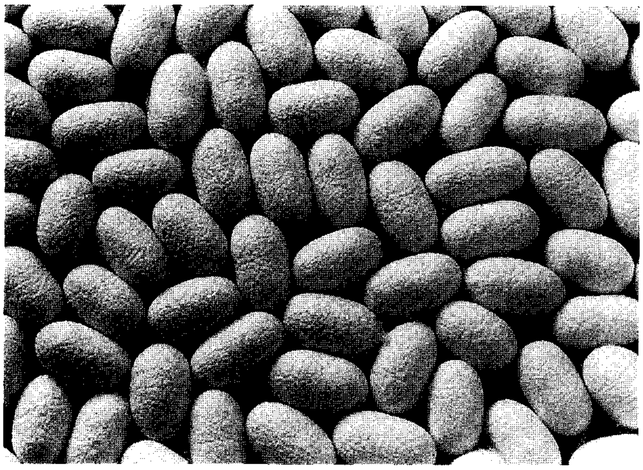

Fig. 2. Cocoons of CSR12 × CSR6.

mediate shape between oval and dumbbell (Fig. 2). Larval period is around 23 days. The most prominent characters of these hybrids are high survival, high cocoon shell ratio, longer filament length, high quality raw silk with low boil off-loss.

Observations were made on various silk governing parameters like survival, cocoon yield/10,000 larvae, cocoon weight, cocoon shell weight, cocoon shell ratio, raw silk percentage, filament length, denier, neatness, reelability boil-of ratio and renditta.

The percent improvement of evolved breeds/hybrid over control breeds (KA and NB4D2)/hybrid (KA × NB4D2) for all the characters was calculated as indicated in our earlier paper (Datta *et al.*, 2000a). The heterosis of the new hybrid CSR12 × CSR6 and control hybrid KA × NB4D2 was calculated based on mid parental value.

Results

The multiple trait evaluation index values for 34 hybrids which score mean value above 50 are given in Table 1. As could be seen from the results the hybrid CSR12 × CSR6 stood in second position (Mean Index value 60.5) among all 161 hybrids tested. The Generation wise mean values of ten economic traits of the breeding lines CSR12 and CSR6 are presented in Table 2 and 3, respectively. The

Table 1. Evaluation index for major silk contributing traits of bivoltine hybrids (Mean value>50; Season : April May 1994)

Sl No	Hybrid	Survi-val	Cocoon yield	Shell weight	Shell ratio	Raw silk	Fila-ment length	Reela-bility	Neat-ness	Mean Index value
1	CSR3 × CSR6	56.3	74.3	75.5	65.9	56.6	60.6	53.5	60.5	62.9
2	CSR12 × CSR6*	56.3	62.6	68.1	66.0	58.2	54.5	56.1	52.4	60.5
3	CSR2 × CSR5	56.9	62.4	66.4	67.0	63.8	54.6	53.5	50.8	59.4
4	CSR2 × CSR4	55.4	64.5	67.6	63.5	51.9	50.7	55.1	56.6	58.2
5	CSR2 × CSR6	51.4	48.0	61.2	69.7	66.0	55.1	52.9	58.5	57.9
6	CSR12 × CSR42	56.3	59.7	62.9	61.0	57.4	67.8	55.1	40.4	57.6
7	CSR45 × CSR36	50.7	71.4	68.6	58.9	51.9	52.1	44.4	58.5	57.1
8	CSR12 × CSR5	43.1	70.4	77.0	71.5	59.8	71.7	42.3	19.9	57.0
9	CSR13 × CSR6	50.4	49.0	59.0	65.2	66.9	49.2	55.1	56.6	56.4
10	CSR2 × CSR42	53.6	49.9	57.5	61.9	62.2	50.4	55.1	60.5	56.4
11	CSR13 × CSR5	43.7	55.8	65.9	69.1	65.3	63.1	39.1	47.0	56.1
12	CSR43 × CSR36	54.7	64.5	57.3	48.5	52.7	53.3	59.3	58.5	56.1
13	CSR3 × CSR5	51.4	46.0	60.2	70.1	63.8	54.8	43.3	54.7	55.5
14	CSR47 × CSR6	54.7	58.7	56.3	52.0	46.4	67.9	51.9	50.8	54.8
15	CSR23 × CSR28	55.8	49.9	52.6	54.3	54.3	54.9	56.1	60.5	54.8
16	CSR2 × CSR34	41.4	70.4	73.6	66.6	46.4	45.9	51.9	41.2	54.7
17	CSR13 × CSR40	42.5	64.5	65.4	60.2	52.7	51.8	46.5	50.8	54.3
18	CSR43 × CSR42	55.2	54.8	54.5	52.8	47.9	52.2	58.3	56.6	54.1
19	CSR41 × CSR40	54.1	59.7	57.3	52.6	41.6	45.8	57.2	56.6	53.1
20	CSR12 × CSR36	54.7	51.9	55.0	56.3	56.6	45.4	51.9	52.7	53.1
21	CSR2 × CSR40	54.1	49.9	55.5	58.9	52.7	40.8	50.8	58.5	52.7
22	CSR43 × CSR4	50.3	49.9	59.2	64.6	51.1	39.7	57.2	48.9	52.6
23	CSR1 × CSR45	54.1	63.6	60.0	53.2	41.6	46.3	43.3	58.5	52.6
24	CSR41 × CSR34	38.2	62.6	61.7	56.6	50.3	47.1	54.0	48.9	52.4
25	CSR3 × CSR44	54.1	50.9	63.4	70.2	55.1	71.8	13.7	39.2	52.3

Table 1. Continued

Sl No	Hybrid	Survi-val	Cocoon yield	Shell weight	Shell ratio	Raw silk	Fila-ment length	Reela-bility	Neat-ness	Mean Index value
26	CSR43 × CSR6	56.3	56.7	52.1	47.4	47.1	40.7	48.7	62.4	51.4
27	CSR47 × CSR46	50.8	71.4	62.0	49.5	41.6	47.3	46.5	41.2	51.3
28	CSR43 × CSR40	52.5	54.8	57.8	57.7	51.1	49.1	47.6	39.2	51.2
29	CSR1 × CSR40	55.2	53.8	57.0	57.5	50.3	49.3	48.7	37.3	51.1
30	CSR10 × CSR40	56.3	69.4	57.0	44.2	27.4	31.6	63.6	58.5	51.0
31	CSR1 × CSR34	56.3	53.8	50.8	48.1	44.8	39.0	59.3	54.7	50.9
32	CSR13 × CSR44	52.7	50.9	56.3	59.1	53.5	42.7	37.0	54.7	50.9
33	CSR43 × CSR34	56.3	55.8	55.0	52.7	47.1	41.4	52.9	45.0	50.8
34	CSR1 × CSR30	56.3	65.5	55.0	44.5	36.9	60.3	46.5	41.2	50.8

*Present paper deals this hybrid.

Table 2. Generation wise mean performance of CSR12

Genera-tion	Mode of brushing	Number of batches	Survival (%)	Cocoon yield (kg)	Cocoon weight (g)	Shell weight (cg)	Shell ratio (%)	Raw silk (%)	Filament length (m)	Denier (d)	Reela-bility (%)	Neat-ness (p)
F1	Mass	1	86.3	15.2	2.03	48.6	23.9	18.3	1260	2.71	72	93.0
F2	-do-	5	79.5	15.4	1.93	53.6	25.0	19.8	1198	2.86	78	89.0
F3	-do-	5	85.6	16.3	1.90	44.8	23.4	18.6	1236	3.06	81	92.0
F4	-do-	5	84.8	15.7	1.85	45.3	24.4	19.8	1236	2.74	80	92.0
F5	Cellular	6	93.4	16.5	1.84	44.1	24.0	18.6	1141	1.66	81	95.0
F6	-do-	4	75.6	12.8	1.66	37.6	22.7	17.9	1225	2.84	82	94.0
F7	-do-	6	83.7	14.7	1.77	41.2	23.3	18.2	1189	2.70	79	96.0
F8	-do-	5	85.1	16.6	1.90	43.6	23.0	19.2	1145	2.23	81	94.0
F9	-do-	5	61.3	10.8	1.76	42.9	24.4	18.2	1245	2.60	82	96.0
F10	-do-	5	87.2	15.5	1.77	44.2	25.0	19.2	1163	2.65	78	93.0
F11	-do-	5	89.6	15.5	1.73	42.2	24.6	18.2	1107	2.84	83	92.0
F12	-do-	5	87.2	16.5	1.87	45.3	24.2	19.2	1069	2.95	82	94.0
Mean			83.3	1510	1.83	44.5	24.0	18.8	1185	2.74	80	93.0
SD			7.9	1.6	0.1	3.7	0.7	0.6	57.6	0.2	2.8	2.4

mean values and the percentage of improvement over control breeds KA and NB4D2 are summarized in Table 4.

The perusal of data for the trait survival shows that the maximum survival was recorded at F5 in CSR12 (93.4%) and F10 in CSR6 (92.1%). The maximum cocoon yield/10,000 larvae was observed at F8 in CSR12 (16.6 kg) and at F10 in CSR6 (18.2 kg). The maximum cocoon weight was recorded at F1 in CSR12 (2.03 g) and F4 in CSR6 (1.99 g). The data indicate that the highest cocoon shell weight was recorded at F2 in CSR12 (53.6 cg) and F4 in CSR6 (48.2 cg).

The percent improvement of 26.5 was noticed for cocoon shell weight in CSR 12 over control breed KA whereas in CSR6 the percent improvement over NB4D2 was 14.0. The highest cocoon shell ratio of 25.0% at F2 and F10 in CSR12 and 24.9% at F2 in CSR6 was recorded. The percent improvement for the trait shell ratio was 25.0 in CSR12 and 14.2 in CSR6 over control breeds.

The highest raw silk percentage was recorded at F2 and F4 in CSR12 (19.8%) and F4 in CSR6 (21.1%). The percent improvement over control breeds was 25.3 in CSR12 and 22.3 in CSR6. The maximum filament length was found at F1 in CSR12 (1,260 m) and at F9 in CSR6 (1,308 m). The improvement was 27.1% in CSR3 and 18.3% in CSR6. The filament size (denier) varied from 2.23 to 3.06 d in CSR12 and 2.68 d to 3.11 d in CSR6. The new breeds CSR12 and CSR6 recorded less denier than KA and NB4D2, respectively. The percent improvement was 9.7 and 3.2 in CSR12 and CSR6, respectively. The reelability ranged from 72 to 83% and 74 to 85% in CSR12 and CSR6, respectively. Maximum neatness was recorded at F7 in CSR3 (96.0 points) and at F2 and F6 in CSR6 (95.0 points).

The laboratory performance of new hybrid is presented in Table 5. The hybrid CSR12 × CSR6 recorded survival of 96.0%, shell weight of 50.0 cg, shell ratio of 24.3%, raw silk percentage of 19.6, filament length of 1216 m,

Table 3. Generation wise mean performance of CSR6

Generation	Mode of brushing	Number of batches	Survival (%)	Cocoon yield (kg)	Cocoon weight (g)	Shell weight (cg)	Shell ratio (%)	Raw silk (%)	Filament length (m)	Denier (d)	Reelability (%)	Neatness (p)
F1	Mass	1	84.0	15.1	1.79	40.7	24.7	19.0	1007	2.95	84	92.0
F2	-do-	3	88.3	15.9	1.80	44.7	24.9	19.5	1047	2.87	76	95.0
F3	-do-	3	85.0	15.6	1.81	41.3	22.8	20.0	1105	3.11	74	92.0
F4	-do-	3	80.9	16.1	1.99	48.2	24.2	21.1	1116	3.07	84	90.0
F5	-do-	3	78.3	14.7	1.92	45.5	23.6	19.4	1058	2.98	79	94.0
F6	Cellular	4	80.6	14.9	1.81	43.9	24.3	20.4	1004	3.05	84	95.0
F7	-do-	7	90.3	14.2	1.67	40.1	24.1	19.6	1124	2.98	85	92.0
F8	-do-	13	81.1	14.7	1.80	43.8	24.3	20.0	1157	2.91	78	93.0
F9	-do-	3	77.0	15.9	1.94	44.4	23.9	20.5	1308	2.78	71	94.0
F10	-do-	4	92.1	18.2	1.98	47.6	24.0	19.5	1124	2.98	81	92.0
F11	-do-	6	86.8	16.1	1.85	44.8	24.2	19.7	1124	2.68	82	90.0
F12	-do-	4	80.3	14.8	1.82	43.5	23.9	18.9	1069	2.98	83	93.0
Mean			83.7	15.5	1.85	44.0	24.1	19.8	1112	2.95	80	93.0
SD			4.6	1.0	0.09	2.4	0.5	0.6	84	0.12	4.3	1.6

Table 4. Performance of CSR12 and CSR6 in the laboratory (Mean of 5 Trails)

Breed	Survival (%)	Cocoon yield (kg)	Cocoon weight (g)	Shell weight (cg)	Shell ratio (%)	Raw silk (%)	Filament length (m)	Denier (d)	Reela-bil-ity (%)	Neat-ness (p)
CSR12	86.0	15.62	1.868	46.8	24.5	18.3	1125	2.71	78	93.0
KA (Control)	83.3	15.78	1.904	37.0	19.6	14.6	885	3.00	77	91.0
T test	NS	NS	NS	**	**	**	**	*	NS	NS
	(3.2)	(-1.0)	(-1.9)	(26.5)	(25.0)	(25.3)	(27.1)	(-9.7)	(1.3)	(2.2)
CSR6	86.3	15.50	1.832	44.1	24.0	18.1	1105	3.00	82	93.0
NB4D2 (Control)	90.3	16.48	1.827	38.7	21.2	14.8	934	3.10	79	91.0
T test	NS	NS	NS	**	**	**	**	NS	NS	NS
	(-4.4)	(-5.9)	(0.3)	(14.0)	(14.2)	(22.3)	(18.3)	(-3.2)	(3.8)	(3.1)

*Significant at 5%
**Significant at 1%
NS, Non-significant.
Values in the parenthesis indicate percent improvement over respective control breeds.

Table 5. Performance of CSR12 × CSR6 in the laboratory (Mean of 5 Trails)

Hybrid	Survival (%)	Cocoon yield (kg)	Cocoon weight (g)	Shell weight (cg)	Shell ratio (%)	Raw silk (%)	Filament length (m)	Denier (d)	Reelability (%)	Neatness (p)	Boil off-loss (%)	Renditta
CSR12 × CSR6	96.0	19.22	2.012	48.9	24.3	19.6	1216	2.99	84	94.0	22.4	5.1
KA × NB4D2 (Control)	90.6	18.86	2.064	42.1	20.4	15.9	999	3.09	83	93.0	24.8	6.3
T test	*	NS	NS	**	**	**	**	NS	NS	NS	*	**
Percent improvement	6.0	1.9	-2.5	16.2	17.2	23.3	21.7	-3.2	1.1	1.1	-10.7	-19.0

**Significant at 1% , *Significant at 5% , NS Non-significant

neatness of 94 points, boil off loss of 22.4 % and renditta of 5.1. On the other hand, the control hybrid (KA × NB4D2) recorded survival of 90.6%, shell weight of 42.1 cg, shell ratio of 20.4%, raw silk percentage of 15.9% , fil-

Table 6. Heterosis (%) over mid parental value

Hybrid	Survival	Cocoon yield	Cocoon weight	Shell weight	Shell ratio	Raw silk	Filament length	Denier	Reela-bility	Neat-ness
CSR12 × CSR6	11.4**	23.5**	11.2	9.9	0.2	7.7	9.1	4.7**	5.0	1.1
KA × NB4D2	4.4	16.9	10.6	11.1	0	8.2	9.8	1.3	5.1	1.1

**Significant at 1%

Table 7. Performance of CSR12 x CSR6 under race authorization test (Mean of spring and autumn seasons of eight test centres)

Sl No.	Character	Floor values	CSR12 × CSR6
1	Hatching (%)	>90	90.1
2	Larval period (Days:Hrs)	<25	23:17
3	Total missing larvae (%)	<9	5.3
4	Pupation (%)	<90	91.7
5	Cocoon yield/2,500 larvae (kg)	>3.7	4.46
6	Good cocoon	>90	91.1
7	Double cocoon	<4.0	3.04
8	Cocoon/litre	65-70(Spring)	71
		70-80(Autumn)	71
9	Cocoon weight(g)	>1.750	1.908
10	Shell weight (cg)	>35.0	45.0
11	Shell ratio(%)	>20	23.6
12	Filament length (m) (unbreakable)	>900	988
13	Filament weight(cg)	>30	30.8
14	Filament size (d)	<2.8	2.80
15	Reelability (%)	>70	83
16	Raw silk (%) (Based on wet weight)	>34.0	35.0
17	Boil-off-loss	<25(shell)	
		<21(yarn)	20.5
18	Neatness (%)	>89.0	91.1

Source: Central Silk Board, Bangalore.

ament length of 999 m, neatness of 93 points, boil off loss of 24.8% and renditta of 6.3. The hybrid CSR12 × CSR6 exhibited lower denier (-3.2%) and boil-off loss (-10.7%) than the control hybrid (KA × NB4D2. Maximum percent improvement was noticed for raw silk percentage (23.3) followed by filament length (21.7), renditta (19.0) shell ratio (17.2) shell weight (16.2), boil off loss (-10.7) and survival (6.0) over control hybrid KA × NB4D2. The percent improvement for other characters like cocoon yield, reelability and neatness was marginal. The heterosis of CSR12 × CSR6 and control hybrid KA × NB4D2 is given in Table 6. The hybrid CSR12 × CSR6 recorded higher heterosis over control hybrid for the characters survival, cocoon yield and denier.

Race Authorization test at different test centres

Based on the performance at laboratory the hybrid CSR12 × CSR6 was subjected to race authorization test conceived and implemented by the Central Silk Board (CSB), Government of India during 1997. The hybrid was tested in 8 centres located at different regions in spring and autumn. The mean test results of this hybrid under race authorization test are given Table 7. The over all performance of this hybrid indicate superiority over floor values for almost all characters tested.

Discussion

Synthesis of new gene combination by conventional breeding technique is one of the important tools for exploiting the heterosis phenomena in the silkworm *B. mori* L. (Harada, 1961). The Chinese and Japanese silkworm breeders have already achieved remarkable progress in the improvement of several quantitative and qualitative traits of economic values (Harada, 1961; Gamo, 1976; Hirobe, 1968; Mano *et al.*, 1982; Chen *et al.*, 1994). But in India, the existing bivoltine hybrids are few in the field and silk recovery is less since the parents involved viz., KA, NB4D2, CC1 and CA2 are characterisied by the cocoon shell ratio of 20% (Narasimhanna *et al.*, 1976; Krishnaswami, 1983; Datta, 1984). More emphasis is required to develop productive hybrids with high raw silk recovery and quality silk for commercial exploitation. Accordingly, for improving the characters such as raw silk recovery and silk quality, breeding work was initiated in this Institute and resulted in evolving productive bivoltine hybrids viz., CSR2 × CSR4, CSR2 × CSR5 and CSR3 × CSR6 (Datta, *et al.*, 2000 a, b).

The data presented in Table 3 clearly indicate that the breeds CSR12 (Oval) and CSR6 (dumbbell) surpasses the control breeds KA (Oval) and NB4D2 (dumbbell) in characters like shell weight, shell ratio, raw silk percentage and filament length. Like parental breeds the new hybrid also surpass the control hybrid in many quantitative and qualitative characters which can be attributed to the involvement of Japanese hybrids known for high productivity and silk quality (Mano *et al.*, 1994) at the time of initiation of breeding process. Moreover, utmost care was taken to raise larger population size in earlier generations (F1 to F5) to ensure greater scope for expression of such desired lines and their selection over generations. Though the new hybrid CSR12 × CSR6 has shown marginal improvement in cocoon yield over control KA × NB4D2, significant improvement was noticed for majority of the characters viz., survival, shell weight, shell ratio, raw silk percentage, filament length, boil-off loss (low) and renditta (low).

In silkworm, the selection for one character is found to result in correlated changes in other quantitative characters of economic importance (Kobari and Fujimoto, 1966). For example, survival and productivity traits which are of high economic value, are negatively correlated with each other. As seen in the present breeding study keeping the cocoon yield on par with control hybrid, the productivity traits (shell weight, shell ratio, raw silk, filament length and low boil-off loss) and qualitative trait (neatness) were improved. Based on the performance at eight test centres for two seasons i.e., spring and autumn under national level race authorization test, the hybrid CSR12 × CSR6 was authorized by Central Silk Board in the year 1999 for commercial exploitation during favourable seasons.

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