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Breeding of Productive Bivoltine Hybrid, CSR16 × CSR17 of Silkworm *Bombyx mori* L.

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The breeding work was initiated by utilizing two Japanese hybrids namely C135 × N134 and N137 × C146 along with two evolved Indian breeds, J14 and A24. The breed CSR16 which is characterized with marked larvae and white dumbbell cocoons was evolved from the Japanese hybrid C135 × N134 by crossing with J14, while the breed CSR17 which is characterized with plain larvae and white oval cocoons was evolved from the Japanese hybrid N137 × C146 by crossing with A24. The hybrid of these evolved breeds *i.e.*, CSR16 × CSR17 has shown superior over control hybrid KA × NB_4D_2 and on par with the ruling hybrid of CSR2 × CSR4. The hybrid CSR16 × CSR17 was authorized during 1999 by Central Silk Board, Bangalore, Government of India for commercial exploitation during favourable months based on national level race authorization test.

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

Introduction

Concerted efforts on silkworm breeding to improve the quantity and quality of raw silk have resulted in the development of many productive and qualitatively superior bivoltine hybrids. However, with growing emphasis to popularize 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 tropical conditions.

Hybrid vigour in silkworm has received a considerable attention because of marked effect of the yield components. It is well documented that F_1 hybrids are superior to their parents in many qualitative and quantitative characters (Toyama 1906). Chinese and Japanese breeders have already achieved a remarkable progress in the improvement of several quantitative and qualitative traits of economic value in silkworm, *Bombyx mori* (Harada, 1961; Gamo, 1976; Mano *et al.*, 1991; Chen *et al.*, 1994).

Earlier breeding experiments have yielded few bivoltine breeds *viz.*, KA, NB_4D_2, NB_{18}, CC1 and CA2 and their hybrids with cocoon shell ratio of 20% (Krishnaswami, 1983; Datta, 1984) and the realisation 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 recover similar silk content for multivoltine × bivoltine hybrids. Realizing the need for productive breeds/hybrids to the field, three productive hybrids *viz.*, CSR2 × CSR4, CSR2 × CSR5 and CSR3 × CSR6 were evolved and authorized for commercial exploitation (Datta *et al.*, 2000a, b).

Keeping this in view, attempts have been made to evolve productive bivoltine breeds/hybrids with more cocoon uniformity, high silk recovery, and quality. The present paper delineates the breeding process of the productive hybrid, CSR16 × CSR17 which was authorized during 1999 for commercial exploitation.

Materials and Methods

In the present study, two Japanese bivoltine hybrids *viz.*, C135 × N134 and N137 × C146 and an Indian evolved

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breeds J14 and A24 were utilized as breeding resource materials. The former hybrid (C135 × N134) was crossed with J14 and the latter one (N137 × C146) with A24 and evolved the breeds CSR16 (Japanese type) and CSR17 (Chinese type). The rearing was conducted in a environmentally controlled house by providing optimum conditions.

Breeding method and selection procedure

CSR16 (Dumb-bell line): The line CSR16 was evolved from Japanese hybrid C135 × N134 crossing with J14. The F_1 was reared in mass. The larvae of this line were marked and spun white cocoons. On the basis of cocoon uniformity, selection of cocoons was carried out for continuation of further generation. Mass rearing was conducted from F_1 to F_4 and F_5 onwards cellular rearing was resorted to. During the course of breeding, viability, 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 CSR16: The larvae are marked. Cocoons are white and dumbbell with medium grains. Larval duration is around 24 days.

CSR17 (Oval line): The line CSR17 was evolved from Japanese commercial hybrid N137 × C146 crossing with A24. The F_1 was reared in mass. The larvae of this line were plain and spun white cocoons. On the basis of size and compactness, selection of cocoons was carried out for continuation of further generation. Mass rearing was conducted from F_1 to F_5. During the course of breeding, viability, 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. The selected cocoons on their individual merit were pooled and mated enmasse. From F_6 onwards cellular rearing was resorted to. The batch showing best performance for cocoon shape, pupation, cocoon yield, cocoon characters and reeling characters related to breeding were selected.

Characteristics of CSR17: The larvae are plain. Cocoons are white and oval with medium grains. Larval duration is around 23 days.

Characteristics of CSR16 × CSR17: The larvae are marked. Cocoons are white and intermediate shape between oval and dumbbell. Larval period is around 23 days. The most prominent characters of these hybrids are uniform in shape and size, high survival, high cocoon shell ratio, longer filament length and high quality raw silk.

Observations were made on various silk governing parameters like pupation rate, cocoon yield/10,000 larvae, cocoon weight, cocoon shell weight, cocoon shell ratio, raw silk percentage, filament length, denier, neatness, reelability and renditta. Cocoon uniformity was calculated in terms of standard deviation (SD) of the ratio (%) of length and breadth of the 100 cocoons for each hybrid. The percent improvement of evolved breed/hybrid over control breeds (NB_4D_2 and CSR4 and KA and CSR2)/ hybrids (KA × NB_4D_2 and CSR2 × CSR4) for all the characters was calculated as indicated in our earlier paper (Datta *et al.*, 2000a).

Results

The mean values and percent improvement over control breeds KA, NB_4D_2, CSR2 and CSR4 are tabulated in Table 1.

The perusal of data for the trait survival shows that the highest pupation rate was recorded in CSR16 (93.0%) in dumbbell breeds whereas CSR17 has recoded highest survival of (94.4%) than other control breeds. The percent improvement of 2.99 and 4.85 was noticed in CSR6 over control breeds NB_4D_2 and CSR4. respectively. Where as 13.33 and 3.28 percent improvement was recorded in CSR17 over control breeds KA and CSR2 respectively. The breed CSR17 has recorded highest cocoon yield of 19.0 kg and 20.09 and 7.06 percent improvement was recorded over control breeds. Highest cocoon shell ratio of 22.5% in CSR16 in dumbbell breeds whereas highest shell ratio of 24.8% was recorded in CSR17 over control breeds. The percentage improvement for the trait shell ratio was 6.13 and 1.80 in CSR16 over NB_4D_2 and CSR4 respectively and whereas in CSR17 the improvement was 26.53 and 4.05 over control breed KA and CSR2 respectively.

Highest raw silk percentage was recorded in CSR16 (18.2%) over control breeds whereas highest raw silk of 19.1% was recorded in CSR2 over control breeds. The percent improvement over control breeds was 22.97 and 4.60 in CSR16 over NB_4D_2 and CSR4 respectively and whereas in CSR17 the improvement was 35.00 over KA. The other characters such as filament length, filament size, reelability and neatness did not vary much.

The mean performance of CSR16 × CSR17 over control hybrids CSR2 × CSR4, and KA × NB_4D_2 are tabulated in Table 2. The hybrid CSR16 × CSR17 recorded pupation rate of 96.4%, shell weight of 50.7 cg, shell ratio of 23.9%, raw silk percentage of 19.7, filament length of 1,115 m, renditta of 5.1 and boil-off ratio of 23.2%. On the other hand, the control hybrid (KA × NB_4D_2) 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, renditta of 6.3 and boil-off ratio of

Table 1. Performance of CSR16 and CSR17 in the laboratory (Mean of 5 trails)

Breed	Pupation (%)	Cocoon yield/ 10,000 (kg)	Cocoon weight (g)	cocoon shell weight (cg)	Cocoon shell ratio (%)	Raw silk (%)	Filament length (m)	Filament size (d)	Reela-bility (%)	Neatness (p)
Japanese type										
CSR16	93.0	16.1	1.74	39.2	22.5	18.2	976	2.86	81	93
NB_4D_2 (c)	90.3	16.5	1.83	38.7	21.2	14.8	934	3.10	79	91
CSR4 (c)	88.7	16.1	1.86	41.0	22.1	17.4	938	3.18	75	92
Chinese type										
CSR17	94.4	19.0	1.96	48.5	24.8	18.9	1,022	2.76	82	93
KA (c)	83.3	15.8	1.90	37.0	19.6	14.0	885	3.00	77	91
CSR2 (c)	91.4	17.7	1.94	47.8	24.7	19.1	1,077	3.19	80	92
CD at 5%	7.9	1.6	0.2	3.8	0.08	2.5	86	0.04	-	-
Percent improvement										
CSR16 vs NB_4D_2	2.99	-2.12	-4.76	1.29	6.13	22.97	4.50	-7.74	2.53	2.31
CSR16 vs CSR4	4.85	0.19	-6.45	-4.39	1.80	4.60	4.05	-10.06	8.00	1.64
CSR17 vs KA	13.33	20.09	2.73	31.08	26.53	35.0	15.48	-8.0	6.49	2.64
CSR17 vs CSR2	3.28	7.06	0.52	1.46	4.05	-1.05	0.46	-13.48	2.50	0.20

(c) Control breeds.

Table 2. Performance of CSR16 x CSR17 in the laboratory (Mean of 5 trails)

Hybrid	Pupa-tion (%)	Cocoon yield/ 10000 larvae (kg)	Cocoon weight (g)	Cocoon shell weight (cg)	Cocoon Shell ratio (%)	Raw silk (%)	Fila-ment length (m)	Fila-ment size (d)	Reela-bility (%)	Neat ness (p)	Ren-ditta (kg)	Boil-off loss (%)	Cocoon unifor-mity (SD)
CSR16 x CSR17	96.4	20.4	2.12	50.7	23.9	19.7	1,215	3.08	85	94	5.1	23.2	6.5
CSR2 x CSR4	96.5	19.4	1.98	46.5	23.5	20.0	1,147	3.18	84	94	5.0	24.4	6.9
KA x NB_4D_2	90.6	18.9	2.06	42.1	20.4	15.9	999	3.09	81	93	6.3	24.8	8.8
CD at 5 %	5.5	1.4	-	3.5	1.6	1.6	92	-	-	-	0.13	-	0.84

Table 3. Performance CSR16 x CSR17 at Regional Sericultural Research Station (Mean of 8 trails)

Hybrid	Pupation (%)	Cocoon yield/ 10000 larvae (kg)	Cocoon weight (g)	Cocoon shell eight (cg)	Shell ratio (%)	Raw silk (%)	Filament length (m)	Filament size (d)	Reela-bility (%)	Neatness (p)	Renditta
CSR16 x CSR17	91.9	17.6	1.92	44.5	23.2	16.8	1,125	2.76	82	93	5.95
KA x NB_4D_2	87.2	15.8	1.81	36.5	20.1	13.8	927	2.65	79	92	7.25
T value	3.17**	2.48*	1.30	3.48**	4.40**	7.22**	49.8**	1.86	0.93	1.29	3.56**

*Significant at 5% and **Significant at 1%.

24.8%. The hybrid CSR16 x CSR17 has shown superior over control hybrid KA x NB_4D_2 and on par with the ruling hybrid of CSR2 x CSR4.However, the hybrid CSR16 x CSR17 recorded more cocoon uniformity (SD 6.5) over CSR2 x CSR4 (SD 6.9) and KA x NB_4D_2 (SD 8.8).

Testing at Regional Sericultural Research Stations (RSRSs)

The mean performance CSR16 x CSR17 over control hybrids KA x NB_4D_2 at RSRSs was tabulated in Table 3. The hybrid CSR16 x CSR17 recorded significant

Table 4. Performance of CSR16 × CSR17 under race authorization test (Mean of spring and autumn seasons of eight test centres)

Sl no.	Character	Floor values	CSR16 × CSR17
1	Hatching (%)	> 90	93.5
2	Larval period (Days.Hrs)	< 25	23.67
3	Total missing larvae (%)	< 9	12.75
4	Pupation (%)	< 90	84.5
5	Cocoon yield/2500 larvae (kg)	> 3.7	4.1
6	Good cocoon	> 90	89.2
7	Double cocoon	< 4.0	0.98
8	Cocoon/litre	65-75(Spring)	78
		70-80(Autumn)	78
9	Cocoon weight (g)	> 1.750	1.819
10	Shell weight (cg)	> 35.0	41.3
11	Shell ratio (%)	> 20	22.7
12	Filament length (m)	> 900	972
	(Unbreakable)		
13	Filament weight (cg)	> 30	30.28
14	Filament size (d)	< 2.8	2.81
15	Reelability (%)	> 70	79.5
16	Raw silk (%)	> 34.0	37.7
	(Based on wet weight)	< 25(shell)	21.4
17	Boil-off-loss	< 21(yarn)	-
18	Neatness (%)	> 89.0	91.5

Source : Central Silk Board, Bangalore.

improvement in characters pupation rate, cocoon yield, shell weight, shell ratio, raw silk and filament length.

Race authorization test

Based on the performance of both at laboratory the hybrid CSR16 × CSR17 was subjected for race authorization test conceived and implemented by the Central Silk Board (CSB), Government of India during 1999. The hybrid CSR16 × CSR17 was tested in 8 centres located at different regions in spring and autumn. The mean test results under race authorization test was given in Table 4. The overall performance indicate the superiority over check values for fifteen characters out of eighteen tested.

Testing at farmers level under post authorization discipline (PAD)

A total quantity of disease free layings (6050 dfls) of CSR16 × CSR17 was distributed to farmers in Karnataka and Tamil Nadu (States) under PAD programme. This hybrid recorded an average cocoon yield of 66.14 kg/100 dfls and quality of 2A – 3A grade silk.

Discussion

Despite quantum jump in mulberry silk production since last three decades in India, the quality of silk remained short of international standards since the bulk of silk production comes from multivoltine × bivoltine hybrids. Therefore, it is essential that breeding strategies have to be directed towards the evolution of bivoltine strains/hybrids with high pupation, shell ratio and raw silk recovery with good quality silk for commercial exploitation. 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 and succeeded in evolving productive bivoltine breeds/hybrids namely CSR2, CSR3, CSR4, CSR5, CSR6 and their hybrids CSR2 × CSR4, CSR2 × CSR5 and CSR3 × CSR6 (Datta *et al.*, 2000a, b).

The data presented in Table 1 clearly indicate that the breeds CSR17 (oval) and CSR16 (dumbbell) surpasses the control breeds KA (oval) and NB_4D_2 (dumbbell) in characters like survival, shell weight, shell ratio, raw silk percentage and filament length and also marginal improvement over CSR2 and CSR4. Like parental breeds the new hybrid also surpass the control hybrid (KA × NB_4D_2) in many quantitative and qualitative characters which can be attributed for the involvement of Japanese hybrids known for high productivity and silk quality (Mano *et al.*, 1994) at the time of initiation of breeding process. Though the new hybrid CSR16 × CSR17 has shown marginal improvement over CSR2 × CSR4, sig-

nificant improvement was noticed in pupation, shell weight, shell ratio, raw silk recovery, filament length and renditta over control hybrid KA × NB_4D_2.

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, pupation and productivity traits which are 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 productive traits (shell weight, shell ratio, raw silk and filament length) and qualitative trait (neatness) were improved. The hybrid CSR16 × CSR17 was authorized during 1999 by Central Silk Board, Bangalore, Government of India for commercial exploitation during favorable months based on national level race authorization test. The hybrid is being tested at farmers level under post authorization discipline.

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