Int. J. Indust. Entomol. Vol. 4, No. 2, 2002, pp. 121~126

International Journal of *Industrial Entomology*

Evolution of a Productive Multivoltine x Bivoltine Hybrid, CAUVERY (BL67 x CSR101) of Silkworm, *Bombyx mori* L.

D. Raghavendra Rao*, V. Premalatha, Ravindra Singh, B. K. Kariappa, K. P. Jayaswal and S. B. Dandin

Central Sericultural Research and Training Institute, Mysore-570 008, Karnataka, India

(Received 12 March 2002; Accepted 21 April 2002)

Breeding programme was initiated during November, 1995 with the main objective to breed productive multivoltine breeds/ hybrids with suitable genetic constitution to suit the fluctuating tropical climate prevailed in India. Two multivoltine breeds viz., BL-24 and BL-27 selected were as breeding resource materials from the silkworm germplasm maintained at Central Sericultural Research and Training Institute, Mysore. By adopting hybridization, backcrossing, inbreeding and selection, a new multivoltine breed namely BL-67. This breed spins light greenish yellow cocoons and cocoon shape is oval with medium to coarse grains. The evolved breed was crossed with five tropical bivoltine breeds viz., NB4D2, CSR2, CSR5, CSR18 and CSR101 to study the combining ability, and identified a superior hybrid, BL67 x CSR101, named as CAUVERY. The hybrid is characterized by high pupation rate (> 95%), high shell weight (> 35 cg), high cocoon shell ratio (> 20%), longer filament length (> 900 m) and high neatness (93) with a renditta of 6.5 producing 2A - 3A grade silk. The hybrid is selected for Race Authorization test of Central Silk Board.

Key words : Hybridization, Inbreeding, Selection, *Bombyx mori.*

Introduction

Indian sericulture industry is fundamentally agro-based cottage industry. India ranks second in the world raw silk production and contributing around 19% of total silk produced in the world. The silk produced in India is mainly from multivoltine and multivoltine x bivoltine hybrids popularily called as "Sanna Misra" (PM x C.Nichi) and "Cross Breed" (PM x NB4D2). The silk produced from these hybrids is poor in quality (not gradable) and low in yield. During 1949, Ghosh made first attempt to improve indigenous multivoltine races by crossing Italian univoltine race and succeded in his attempt by evolving few breeds and were popular with the farmers during that period. Later, Tazima (1958) and Murakami (1989) emphasized the improvement of multivoltine breeds by hybridizing with exotic races. After the establishment of Central Sericultural Research and Training Institute, Mysore, systematic breeding programmes were initiated and resulted in evolution of improved multivoltine breeds viz., Kollegal Jawan, Kolar Gold, Mysore Princess, Hosa Mysore, PCN, RD1, MY1, P2D1, BL23 and BL24 (Siddu *et al.*, 1969; Sengupta, 1969; Datta *et al.*, 1981; Nagaraju *et al.*, 1987, 1989; Naomani *et al.*, 1990; Kalpana *et al.*, 1998; Kalpana and Sreerama Reddy, 1998). These breeds could not be popularized with the farmers due to crop instability, occurrence of diapause eggs in all seasons, irregular emergence of moths. In view of the above, an attempt has been made to evolve productive multivoltine breeds/hybrids with the genotypes having genetic constitution to suit the tropical climate prevailed in India.

Materials and Methods

The breeding programme initiated during November 1995 at Central Sericultural Research and Training Institute (CSR & TI), Mysore involving two multivoltine breeds as breeding resource materials. BL-24, which spins greenish yellow oval cocoons with coarse grains and BL-27, which spins creamy white oval cocoons with medium grains were crossed in order to amalgamate their genomes to derive desired genetic constitution suitable for changing

*To whom correspondence should be addressed.
Central Sericultural Research and Training Institute, Mysore-570-008, Karnataka, India. Tel: (0821) 362406; Fax: (0821) 362845; E-mail: raghavendra_1957@yahoo.com

Table 1. Characteristics of parental breeds utilized for evolution of productive multivoltine breed-BL67

Egg	Larvae	Cocoon
BL24		
Evolved at CSR & TI, Mysore, Egg colour yellow. Eggs number 480 -500.	Newly hatched larvae are dark brown in colour, matured larvae plain with bluish tinge. Larval period 22 - 24 days.	Dark greenish yellow, oval cocoons with coarse grains. Cocoon weight 1.2 - 1.4 g, cocoon shell weight, 20 - 24 cg and cocoon shell ratio 16 - 17%.
BL27		
Evolved at CSR & TI, Mysore, Egg colour white. Eggs number 500-520.	Newly hatched larvae are dark brown in colour, matured larvae plain with bluish tinge. Larval period 22 - 24 days.	Creamy white, oval cocoons with medium grains. Cocoon weight 1.2 - 1.4 g, shell weight 21 - 25 cg, shell ratio, 17 - 18%.

environmental conditoins. Characteristics of parental breeds are presented in Table 1.

Conventional breeding technique was adopted and base population was raised by crossing females of BL24 with BL27 males. At F_2 generation four sequegated types were clustered mainly based on cocoon colour. The line spinning light greenish yellow cocloured cocoons was back-crossed with BL24 at F_3 generation and the remaining three lines were discontinued. From F_4 generation onwards, selection pressure was imposed for target characters. Due importance was given for cocoon colour in each and every generation. At the end of F_{12} generation it was possible to isolate a line spinning light greenish yellow cocoons. The line was stabilized.

The isolated line was subjected for combining ability studies by crossing with five tropical bivoltine breeds viz., NB4D2, CSR2, CSR5, CSR18 and CSR101. Results of combining ability studies revealed that the hybrid, BL67 × CSR101 performed better than the other hybrids and superior to the control, PM × NB4D2. The hybrid was subjected to thermal exposure after second day of the fourth moult to assess its robustness by exposing the larvae six hours a day till spinning at 36°C in Sarikatron. Studies were also conducted to assess the resistance level of the hybrid against BmNPV by feeding the third instar larvae (immediately after second moult without feeding) with five concentrations of BmNPV (1×10^5, 1×10^6, 1×10^7, 1×10^8 and 5×10^8 polyhedral inclusion bodies PIB/ml/ 100 larvae) along with control hybrid and recorded mortality percentage up to ten days of post inoculation. In

Table 2. Average rearing p erformance of BL-67 in different generations during breeding

Season/ Year	Generation	No. of batches reared	Fecundity	Hatching (%)	Larval duration (h)	Yield/10,000 larvae		Cocoon weight (g)	Cocoon shell weight (g)	Cocoon shell ratio (%)
						By No.	By wt (kg)			
Nov.95	F_1	3	519	94.9	468	9523	15.410	1.650	0.291	17.65
Jan.96	F_2	3	570	89.3	558	9040	10.080	1.080	0.200	18.74
Mar.96	F_3	3	502	99.1	444	8250	12.065	1.195	0.210	17.60
May.96	F_4	10	449	98.3	508	9318	12.080	1.210	0.200	16.39
Jul.96	F_5	10	433	96.5	525	9076	14.517	1.598	0.246	15.41
Sep.96	F_6	10	537	97.9	504	9074	13.982	1.533	0.256	16.71
Nov.96	F_7	10	503	97.7	528	9655	14.115	1.463	0.247	16.86
Feb.97	F_8	10	488	92.5	500	9587	11.340	1.104	0.201	18.24
Apr.97	F_9	10	436	97.5	456	9550	11.600	1.166	0.198	16.98
Jun.97	F_{10}	10	475	96.6	508	9783	15.399	1.510	0.249	16.40
Aug.97	F_{11}	10	441	97.9	534	9541	12.270	1.330	0.230	17.50
Oct.97	F_{12}	10	542	96.3	448	9574	12.733	1.293	0.234	18.20
	Average		491	96.2	498	9330	12.965	1.344	0.230	17.22
	SD		43.7	2.68	3.5	402	1.623	0.190	0.028	0.90
	CV		8.89	2.78	7.1	4.32	12.320	14.20	12.15	5.24

Table 3. Performance of BL67 with control Pure Mysore in the laboratory (Mean of 3 years data, 1998 - 2000)

Breed	Fecundity	Total larval period (hrs)	Yield/10000 larvae		Cocoon wt. (g)	Cocoon Shell wt. (g)	Cocoon shell ratio (%)	Average Filament length (m)	Denier (d)	Renditta	Reelability (%)	Neatness (p)
			By No.	By. Wt. (kg)								
BL67	481	477	9157	12.130	1.331	0.238	17.88	696	2.46	8.8	92.8	90
Pure Mysore	425	662	8883	10.211	1.113	0.151	14.3	352	2.04	17.0	74.5	75

Table 4. Performance of new multi x biv. hybrid with control in the laboratory (Mean of 10 trials, Jan. 2000 - Dec. 2001)

Hybrid	Fecundity	Total larval period (hrs)	Yield/10000 larvae		Cocoon wt. (g)	Cocoon Shell wt. (g)	Cocoon shell ratio (%)	Average Filament length (m)	Reelability (%)	Renditta	Neatness (p)	Over all Grade of silk
			By No.	By. Wt. (kg)								
CAUVERY	489	538	9567	17.300	1.932	0.389	20.1	920	85.5	6.5	93	2A-3A
PMxNB4D2 (control)	463	581	8729	15.274	1.724	0.306	17.8	701	81	9.0	83	A

order to evaluate post cocoon parameters, 3 kg of green cocoons were sent to Central Silk Technological Research Institute (CSTRI), Bangalore. Reeling and silk technological parameters were evaluated at CSTRI, Bangalore by reeling the cocoons on a multi end reeling machine. The hybrid has also been tested with the farmers of three south Indian states viz., Andhra Pradesh, Karnataka and Tamilnadu in a limited way through different Regional Sericultural Research Stations, to assess its performance with the sericulture farmers.

The rearings were conducted following standard schedule suggested by Krishnaswami (1983). Observations were conducted in each generation on fecundity, hatching percentage, total larval period, 5th instar larval period, pupation rate, cocoon yield by weight, cocoon weight, cocoon shell weight, cocoon shell ratio, filament length, and filament size. Due importance was given for egg and cocoon colour throghout the breeding programme.

Results

Mean rearing performance of isolated line, BL-67 from F_1 to F_{12} is presented in Table 2. The line is characterized by laying light yellow colour non-diapausing eggs, numbering 480 to 500. Newly hatched larvae were dark brown in colour and matured larvae were plain with bluish tinge. Larval period ranges from 20 to 22 days and fifth instar larval period was 5 to 6 days. Cocoons are light greenish yellow in colour with medium grains. Cocoon weight ranges from 1.20 to 1.40 g, cocoon shell weight 22 to 24 cg, cocoon shell ratio 16 to 18%, filament length 650 - 700 m, neatness 88 points and renditta of 8 to 9. The isolated line showed superiority over traditional tropical multivoltine breed, Pure Mysore. Comparative performance of these breeds in laboratory for three years is presented in Table 3.

Performance of evolved hybrid, CAUVERY at room and high temperature

Comparitive rearing performance of the new hybrid, Cauvery, with control hybrid, PM × NB4D2 both at room and high temperatures is presented in Table 4 and 5, respectively. The results indicated that the new hybrid exhibited its superiority over control hybrid for all the quantitative and qualitative characters. Further, it is found that the larvae reared at high temperature showed pupation rate of 90% and better than control hybrid, PM × NB4D2.

Studies on resistance to BmNPV

To know the susceptibility status of the new hybrid, the larvae of new hybrid and control hybrid was inoculated with five different concentrations of BmNPV. The results are presented in Table 6. Results indicated that the new hybrid was found resistant over control particularly at high dose of inoculation when compared with control hybrid.

Studies on reeling characteristics

Silk reeling technological characteristics (both qualitative and quantitative) of new hybrid along with control are presented in Table 7. It is clear from the data that the new hybrid has given a filament length of 920 m, filament size of 2.68, reelability of 85.5%, raw silk recovery of 15% and a renditta of 6.5 producing gradable silk with 2A - 3A grade.

Performance of new hybrid with the farmers

Performance of new multi × bi hybrid with selected farmers of three South Indian stated is presented in Table 8. It is clear from the data that the new hybrid performed well with the farmers and obtained an average yield of 55 kg/ 100 dfls and rate of Rs 144 = 75p as against 45 kg/100 dfls and Rs119 = 32p with control hybrid, PM × NB4D2.

Table 5. Performance of new multi x bivoltine hybrid with control at room and high Temperatures (Mean of 5 trials, January to December 2000)

Performance of hybrids at high temperature (36±1°C and 80±5% RH)				At room temperature (25 ± 1°C and 65 ± 5% RH)	
Sl. No.	Hybrid	Yield/10000 Larvae		Yield/10000 Larvae	
		By No.	By Wt. (kg)	By No.	By Wt. (kg)
1	CAUVERY	9000	17.328	9209	20.38
2	PMxNB4D2(Control)	8950	14.907	9050	17.67

Table 6. Susceptibility status (Mortality, %) of New multi x bi hybrid with control against BmNPV inoculation

Hybrid/Dose (PIB/ml/100 larvae)	1×10^5	1×10^6	1×10^7	1×10^8	5×10^8
CAUVERY	5.00	5.00	11.00	42.00	61.00
PM × NB4D2	2.00	5.00	14.00	41.00	80.00

Table 7. Reeling and silk technological parameters of new hybrid with control

Sl. No.	Particulars		BL67 × CSR101 (Cauvery)		PM × NB4D2 (Control)	
I	Reeling Characteristics					
	a. Average filament length(mts)		920		610	
	b. Non-broken filament length(mts)		856		506	
	c. Filament size (d)		2.68		2.87	
	d. Reelability (%)		85.5		81.0	
	e. Renditta		6.5		9.2	
	f. Raw silk (%)		15.0		11.0	
II	Silk quality characteristics			**Grade**		**Grade**
	a. Average size		22.0	-	21.7	-
	b.Winding breaks/40 skeins/hour		8	**3A**	6	**3A**
	c. Standard size deviation		1.28	**3A**	1.59	**2A**
	d. Maximum size deviation		3.26	**3A**	3.48	**3A**
	e. Evenness variation	i	150	**4A**	130	**4A**
	(No. of stripes/100 panel)	ii	0	**4A**	0	**4A**
		iii	0	**4A**	0	**4A**
	f. Neatness (%)		93	**3A**	87	**A**
	g. Low Neatness (%)		90	**4A**	80	**A**
	h. Cleanness (%)		96	**3A**	92	**A**
	i. Tenacity Gms/denier		3.8	**4A**	3.95	**4A**
	j. Elongation (%)		18	**4A**	20.75	**4A**
	k. Cohesion (Strokes)		68	**4A**	65	**4A**
	Over all grade			**3A**		**A**

Table 8. Rearing performance of new multi x bi hybrid **'cauvery'** and control with the farmers of three South Indian States, Andhra Pradesh Karnataka and Tamilnadu

Station (RSRSs)	No. of farmers	No. of dfls	Act. yld. (kg)	Yld/100 dfls (kg)	Rate/kg (Rs. Ps.)
			Karnataka		
Kodathi	11	1050	617.000	58.760	138=85
Chamarajanagar	13	2825	1647.50	58.318	168=23
Tamil Nadu					
Salem	7	600	364.700	60.783	116=89
Andhra Pradesh					
Ananthapur	29	5180	2686.38	51.860	154=92
Total (Cauvery)	60	9655	5315.58	55.055 (17.35)*	144=75 (17.57)*
PM x NB4D2 (Control)	65	9653	4363.16	45.200	119=32

*Percentage improvement over control

Discussion

Fluctuating climatic conditions coupled with inferior leaf quality and poor rearing management prevailed in tropics emphasize the need to evolve robust silkworm breeds/ hybrids with more plasticity to adapt to the climate. The complex physiological, genetical and environmental associations of quantitative characters of silkworm can be successfully exploited by evolving the genotypes of desired constitution and expression. Breeding of silkworms are aimed towards evolving superior breeds either by selection alone or by cross breeding, backcrossing and/or outcrossing with selection in subsequent generations. The final goal of the breeder is primarily to evolve a breed which can give rise to stabilized crop and secondly to improve both qualitative and quantitative characters of the silk produced (Murakami, 1984). India has increased its silk production from 969 metric tonns during 1950s to 15,000 metric tonns in 2000. As sericulture industry in India is multivoltine oriented, the objective of evolving

productive multivoltine breeds in the present study ended with the evolution of productive multivoltine breed , BL67 and multivoltine x bivoltine hybrid, Cauvery.

It is evident from the data presented in Table 3 that the evolved breed, BL67 performed well and superior to the control, Pure Mysore excelling in almost all quantitative and qualitative characters. The evolved hybrid, CAUVERY can withstand the fluctuating environmental conditions as the hybrid expressed resistance to BmNPV and tolerance to high temperature producing gradable silk (Table 4, 5, 6 and 7). The most striking features of the new hybrid is characterized by high pupation rate (> 90%), high shell weight (> 35 cg), cocoon shell ratio (> 20%), longer filament length (> 900 m), good reelability (> 85%), high raw silk recovery (> 15%), high neatness (93) with 2A - 3A grade silk.

To judge the performance of the new hybrid with the farmers, the hybrids has been tested in three south Indian states through Regional Sericultural Research Stations in a limited way. The rearing results of about 10,000 dfls revealed that the hybrid performed well with the farmers and obtained an average yield of 55 kg/ 100 dfls (Table 8). Based on the results, the hybrid has been recommended by the Central Silk Board for Race Authorization test during 2002 with twenty centers located all over India. After completion of the test, the new multi × bi hybrid, CAUVERY will be released for commercial exploitation with the farmers which in turn increases the production of quality silk in India.

References

Datta, R. K., D. C. Pal, S .K. Das and K. Sengupta (1981) Evolution of superior multivoltine breeds through mutation breeding technique. Proc. Seric. Symp. Tamilnadu, India.

Ghosh, C. G. (1949) Silk production and weaving in India. CSIR, New Delhi.

Kalpana, G. V., P. J. Raju, G. Subramanya and G. Sreerama Reddy (1998) Synthesis of promising multivoltine races of silkworm, *Bombyx mori* with productivity merits. Proc. Nat. Workshop on Silkworm Breeding.

Kalpana, G. V. and G. Sreerama Reddy (1998) Studies on combining ability of the new multivoltine race, MU953 with tropical bivoltine races. *Sericologia* **38**, 309-316.

Krishnaswami, S. (1983) New Technology of silkworm rearing. *Bull. Central Silk Board* **2**, 1-23.

Murakami, A. (1984) Genitical studies on tropical races of silkworm (*Bombyx mori*) with a special reference to cross breeding strategy between tropical and temperate races. multivoltine silkworm strains in Japan and their origin. *JARQ* **23**, 127-133.

Nagaraju, J., M. K. R. Noamani, M. S. Jolly, R. K. Datta, K. Vijayaraghavan, V. Premalatha, and R. Singh (1987) MY1 - A new multivoltine strain which holds promise. *Indian Silk*, 6-9.

Nagaraju, J., V. Premalatha, R. Singh , M. K .R. Noamani, and M. S. Jolly (1989) Isolation of a polyvoltine strain with sex-limited larval markings in silkworm, *Bombyx mori* L. (Lepidoptera: Bombycidae). *Sericologia* **29**, 495-502.

Noamani, M. K. R., K. Sengupta, J. Nagaraju, K. Vijayaraghavan, V. Premalatha, R. Singh and P. R. M. Rao (1990) Breeding of multivoltine breeds of the silkworm, *Bombyx mori* L. for high cocoon and shell weight. *Indian J. Seric.* **29**, 227-232.

Sengupta, K. (1969) An analysis of genotype environment interaction in some races of silkworm, *Bombyx mori* L. *Ind. J. Seric.* **8**, 4-6.

Siddu, N. S., K. Singh, S. Venugopal Pillai and R. Sreenivasan (1969) Performance of some of the breeds of silkworm, *Bombyx mori* L. *Silkworm Infor. Bull.* **1**, 41-53.

Tazima, Y. (1958) Report on sericulture industry in India, Published by Central Silk Board, India.