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Development of New Robust Bivoltine Silkworm Hybrid SR2 × SR5 for Rearing throughout the Year

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A Silkworm breeding programme was designed to develop a robust but productive bivoltine silkworm hybrid of *Bombyx mori* L. suitable for rearing throughout the year in tropical climate by utilizing indigenous polyvoltine and productive bivoltine breeds. The breeding was carried out under high temperature (36°C ± 1°C) and low humidity (50 ± 5%) conditions in the environmental chamber. By F_{12}, three oval and three dumbbell breeds were isolated with higher survival and productive merits. These breeds were utilized in the hybrid evaluation along with other popular breeds. Based on combining ability test results, the hybrid $SR_2 \times SR_5$ was selected for large scale testing and evaluated in different seasons. The evaluation studies indicated that the hybrid has higher viability and productive merits and it is suitable to rear throughout the year. The hybrid $SR_2 \times SR_5$ recorded a survival of 92.0%, cocoon shell weight of 0.417 g, cocoon shell percentage of 23.0 and a filament length of 1042 meters under hot and dry conditions of environmental chamber compared to the control thermo-tolerant hybrid CSR18 × CSR19.

Key words: *Bombyx mori* L., Higher survival, Hot and dry climates productivity traits

Introduction

Systematic hybridization coupled with appropriate selection procedures has contributed to amalgamate the major economic traits of choice from selected silkworm breeds and to synthesise genotypes of desirable genetic constitution. Evolution of robust, but productive silkworm breed is an important component in the development of sericulture. The requirement of summer hybrid is healthiness and adaptable to bad conditions of high temperature and low food quality, relatively higher economic traits or high temperature and dry climate but to have potential for increased cocoon production (Sudhakara Rao *et al.*, 2006). Considering the variable performance of productive bivoltine hybrids during summer season, emphasis was given to evolve robust bivoltine silkworm breeds/ hybrids suitable to tropical conditions. During last two decades, efforts made at Central Sericultural Research and Training Institute, Mysore resulted development of good number of highly productive bivoltine hybrids (shell ratio > 22%) by utilizing Japanese commercial hybrids (Datta *et al.*, 2000). The full potentiality of these hybrids can be realized only under optimum inputs to mulberry garden during favourable season.

In Silkworm most of the quantitative traits of economic importance are under the control of polygenes with modifiers and the influence of environmental conditions are significant during different stages of development and growth. Temperature is one of the a biotic factor which can influence the diversification of life with the interaction of other environmental components such as humidity and light. Earlier studies (Tazima and Ohnuma, 1995; Datta *et al.*, 1997; Suresh Kumar *et al.*, 2002) indicated that the tolerance to high temperature is a dominant and heritable character and could be exploited for the development of robust silkworm hybrids. Therefore, an attempt has been made to evolve robust silkworm hybrids suitable to varied climatic conditions prevailing in the tropics.

Materials and Methods

The present study was initiated by utilizing white poly-

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voltine and bivoltine breeds from the Germplasm collection of Central Sericultural Research and Training Institute, Mysore as breeding resource material. The initial hybridization was carried out based on larval markings and cocoon shape. The rearing was conducted as per the techniques outlined by Datta (1992). By the end of F_{12}, six lines *viz.*, SR_1, SR_2 and SR_3 characterized with plain larvae spinning white oval cocoons and SR_4, SR_5 and SR_6 characterized with marked larvae except SR_6 with plain larvae, spinning white dumb bell cocoons were fixed for the desired traits. Hybrid evaluation was carried out and based on the performance and combining ability test results, the hybrid $SR_2 \times SR_5$ was selected; hence $SR_2 \times SR_5$ development procedure only is discussed herewith.

Breeding procedure and selection methods adopted for SR_2

The line SR2 was evolved from BL_{36} and CSR_2 breeds. The females of BL_{36} were crossed with the males of CSR_2. Mass rearing was conducted from $F_1 \sim F_4$ and from F_5 onwards, cellular rearing was resorted and adopted directional selection for the targeted traits. The breeding lines were screened under high temperature (36°C ± 1°C) and relative humidity (50 ± 5%) conditions in the environmental chamber from second day of fifth in star for six hours daily from 10 a. m to 4 p. m (Shirota, 1992) till F_6 and there afterwards in alternate generations (HT line). The survived population were picked up and backcrossed with respective productive bivoltine parents to improve the productive traits and for fixing the cocoon traits. During the course of breeding, pupation rate and productive merits like shell weight and filament length were given priority. The respective control batches were also maintained simultaneously in optimum rearing conditions (RT line) to compare selection effect in every generation. By the end of F_{12}, the breed SR_2 with plain larvae spinning white oval cocoons were isolated.

Breeding procedure and selection methods adopted for SR_5

The line SR 5 was evolved from Daizo and CSR6 breeds. The females of Daizo were crossed with the males of CSR6. The larvae are marked spinning white dumb bell cocoons. The same methodology adopted for SR2 was repeated for evolution. After fixation of desired traits by F12, breed with marked larvae was isolated .These lines were involved in hybrid studies along with other productive breeds. Based on the performance and combining ability test results (Kempthorne, 1952), the hybrid SR2 × SR5 was adjudged as the best hybrid.

Characters of $SR_2 \times SR_5$ hybrid

The larvae are marked, spinning white intermediate shaped cocoons between oval and dumb bell. The performance of the hybrids along with their parents was evaluated in three different seasons comprising a year in the tropics. The hybrid was also subjected to rearing in hot (36°C ± 1°C) and dry (R.H. 50 ± 5%) climate in the environmental chamber and under optimum conditions (25°C ± 1°C, 70 ± 5%). The rearing results obtained were subjected to two-way classification (Kempthorne, 1952) and analysed by employing "t" test.

Results

Mean values of seven economic traits of importance *viz.*, pupation rate, cocoon yield, cocoon weight, cocoon shell weight, cocoon shell percentage, filament length and raw silk per cent of newly evolved HT lines SR_2 & SR_5 under hot and dry climatic (36°C ± 1°C) and low humidity (50 ± 5%) conditions of environmental chamber are presented in Table 1. SR_2 recorded a mean pupation rate of 88.5 with a shell percentage of 22.8 and SR_5 with 87.1 per cent pupation and a shell percentage of 22.2.

Table 1. Mean performance of SR_2 (HT) and of SR_5 (HT) under high temperature and low humidity

Breed	Pupation rate (%)	Yield (kg)	Cocoon weight (g)	Shell weight (cg)	Shell ratio (%)	Filment length (m)	Raw silk (%)
SR2							
Mean	88.5	13.531	1.543	36.4	22.8	854	12.4
C.D at 5%	4.26	1.003	0.071	0.23	1.40	49.14	1.413
C.V%	2.86	4.370	2.90	4.00	3.61	8.34	0.92
SR5							
Mean	87.1	13.816	1.577	35.0	22.2	811	13.81
C.D at 5%	4.65	1.176	0.053	0.016	1.03	21.38	1.118
C.V%	3.15	5.030	2.00	2.71	2.74	1.60	4.80

Table 2. Mean performance of newly developed hybrids in the laboratory under stress conditions

Hybrid	Season	Pupation rate (%)	Cocoon yield (Kg)	Cocoon weight (g)	Shell weight (cg)	Shell ratio (%)	Filament length (m)	Raw Silk (%)
$SR_2 \times SR_5$	Stress rearing	91.9	16.250	1.800	41.6	23.0	1042	15.49
$CSR_{18} \times CSR_{19}$*		88.1	12.400	1.808	36.8	20.3	953	12.27
C.D at 5%		4.6	1.08	-	-	0.74	31.2	0.66
(Season × Breed)								
C.D at 5%		-	0.58	0.061	-	-	36	-
C.V%		3.29	5.36	3.68	9.04	3.06	3.84	4.5

Table 3. Mean performance of newly evolved breeds during different seasons in the laboratory ("t" test values) (Mean of three seasons)

Breed	Pupation rate (%)	Cocoon yield (Kg)	Cocoon weight (g)	Shell weight (cg)	Shell ratio (%)	Filament length (m)	Raw Silk (%)
SR_2	91.2	16.010	1.747	39.8	22.8	969	15.55
CSR_{18}*	88.1	15.020	1.690	34.4	20.4	835	12.41
t-test value	0.01NS	0.036NS	0.147NS	5.24**	9.00**	7.58**	6.9**
SR_5	92.0	16.080	1.764	39.7	22.4	941	15.99
CSR_{19}*	89.7	14.090	1.573	31.8	20.1	811	11.77
t-test value	0.006NS	1.10NS	4.631**	3.877**	1.009**	4.31**	0.378NS

*Control breeds N.S: Non-significant

Table 4. Mean performance of new hybrid VS control hybrid in the laboratory ("t" test values over control hybrid) (Mean of three seasons)

Hybrid	Pupation rate (%)	Cocoon yield (Kg)	Cocoon weight (g)	Shell weight (cg)	Shell ratio (%)	Filament length (m)	Raw Silk (%)
$SR_2 \times SR_5$	93.4	18.230	1.937	44.8	23.0	1097	17.98
$CSR_{18} \times CSR_{19}$*	89.2	16.320	1.880	38.0	20.2	960	13.78
t-test value	8.807**	5.362**	0.041NS	8.224**	3.446**	3.00**	6.926**

*Control breeds N.S: Non-significant

Mean values of seven economic traits of importance *viz.*, pupation rate, cocoon yield, cocoon weight, cocoon shell weight, cocoon shell percentage, filament length and raw silk per cent of newly evolved hybrid $SR_2 \times SR_5$ under hot (36°C ± 1°C) and dry climatic (50 ± 5%) conditions of environmental chamber is presented in Table 2. A mean pupation rate of 91.9 with a shell percentage of 23.0 and a filament length of 1042 meters were recorded when compared to control hybrid (CSR18 × CSR19, pupation, 88.1 per cent with a shell percentage of 20.3 and a filament length of 956 meters.

The mean values for newly evolved pure lines (SR_2 and SR_5) compared to that of control breeds CSR_{18} and CSR_{19} ("t" test values) under normal laboratory conditions (25 °C ± 1°C, R.H. 70 ± 5%) during three major seasons are depicted in Table 3. Results of synthesized lines and control breeds indicated a pupation rate of 91.2% in SR_2 followed by 92.0% in SR_5 and showing non-significant values compared to control breeds (88.1 and 89.7 per cent in CSR18 and CSR19 respectively). Maximum cocoon yield of 16.0 kg/10,000 larvae was recorded in both SR_2 and SR_5 showing non-significant values when compared to control breeds. A maximum cocoon weight of 1.74 g was recorded in SR_2 and 1.76 g in SR_5. Cocoon shell weight values in SR_2 and in SR_5 indicated 0.398 and 0.397 g respectively. A cocoon shell percentage of 22.8 were observed in SR_2 and 22.4 in SR_5. However significant values ($P<0.01$) were recorded over control breeds in oval lines for cocoon shell weight, cocoon shell percentage, filament length and raw silk. In dumbbell lines, highest significant ($P<0.01$) "t" test values for cocoon weight, cocoon shell weight, shell percentage and filament length over control breeds CSR_{18} and CSR_{19} (Table 3).

Mean values of three seasons of newly evolved hybrid and to that of control hybrid under normal laboratory rearing conditions are given in Table 4. The results indicates maximum pupation rate of 93.4% with productive merits in newly evolved hybrid $SR_2 \times SR_5$. Significant ($P<0.01$)

"t" test values were recorded for pupation rate, cocoon yield, cocoon shell weight, cocoon shell percentage, filament length and raw silk per cent in $SR_2 \times SR_5$ over control hybrid $CSR_{18} \times CSR_{19}$ indicating overall superiority of the newly evolved hybrid.

Discussion

Among the environmental conditions, temperature, relative humidity and photoperiod are most important and plays significant role on individual organism (Alexandrov,1977) and more so on larval duration, survival rate, cocoon weight, pupation, fecundity and number of unfertilized eggs (Pillai and Krishnaswami, 1987). The results obtained in the present breeding experiment indicate that the fluctuations noticed in the pupation rate between seasons can be partially attributed to the influence of environmental factors and the interaction of alleles responsible for the expression of the trait. Pupation rate is taken as a measure to determine the viability of a breed particularly under high temperature environment (Kato *et al.*, 1989). The imposition of exposure to high temperature levels in 5^{th} in star led to low pupation rate could be attributed to the low feeding activity of the silkworm which results in the physiological de arrangement and poor health of the larvae and on increased number of non spinning worms on the mountages (Ueda and Lizuka, 1962). When lines are exposed to high temperature and low humidity continuously there is a drastic reduction in the pupation rate coupled with inferior cocoon traits. Due to high temperature and low humidity, leaf withering occurs in the rearing bed due to which silkworm larvae cannot feed more time on the leaf. Rearing initiated during cooler months like January - February in the tropics have shown better cocoon weight there by increasing the cocoon yield and rearing initiated and continued during hotter months recorded poor cocoon yields (Muniraju *et al.*, 2001). The phenomenon of cocoon yield is correlated to cocoon weight and because of high temperature stress, cocoon weight is drastically reduced thereby affecting the yield. However, the decrease in yield with increase in temperature suggests that higher temperature doesn't favour productivity which is found to be independent of leaf quality (Shiva Kumar *et al.*, 1997). The low larval weight recorded under stress condition is may be due to non-palatability of leaf in the rearing bed where silkworm larvae cannot feed for more time. During this situation, the silkworm ingests less food which leads to decline in the cocoon weight (Gangawar *et al.*, 1993). According to Ohi *et al.*, (1970) who worked out multiple correlation between the yield components, particularly cocoon shell weight which is positively correlated with cocoon filament length indicated that the increase or decrease in filament length is dependent on the increase or decrease of the thickness of the filament and cocoon shell weight. However, in the present investigation, the length of the filament was not always related to cocoon shell weight in high temperature treated batches might be due to more breakages while reeling. The profound effect of high temperature was observed on reel-ability in batches reared under high temperature without air current conditions by Naik *et al.*, (2003) and concluded that both have synergistic effect on reel-ability and other related traits. Thus, it is proved that the newly evolved hybrid has shown significant merits when compared to control hybrid in terms of survivability, productivity and suitable to rear through out the year in the tropics.

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