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Breeding Resource Materials of Silkworm *Bombyx mori* L., Adaptive to Tropical Climates

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With the objective of selecting suitable breeding resource material, 10 polyvoltine and 10 bivoltine breeds were drawn from the germplasm collection of Central Sericultural Research and Training Institute, Mysore, and evaluated for 3 seasons comprising one year (6 trials). Data were collected on seven traits of economic importance such as fecundity, pupation rate, cocoon yield, cocoon weight, cocoon shell weight, cocoon shell ratio and filament length, and statistically analysed with two-way classification, Joint scoring method and evaluation index. Significant seasonal variations (P < 0.01) were observed in both polyvoltine and bivoltine breeds. Polyvoltines BL27, BL36 and BL54 and bivoltines CSR2, CSR4 and Daizo scored highest ranking values in all the three methods. Hybridization was initiated based on larval markings and cocoon shapes. Seasonal variations were discussed.

Key words : Silkworm breeding, Breeding resource material, Seasonal variations, *Bombyx mori* L.

Introduction

Breeding plays a pivotal role for improving the productivity in domestic animals. Breeding of superior silkworm breeds for commercial utilization has unequivocally contributed for the increased production of high quality raw silk and development of sericulture industry. Although India made a quantum jump and ranks second in the global silk market, there exists a wide gap in the overall qualitative and quantitative silk output. This is partly because the majority of the silk produced is from polyvoltine x bivoltine hybrids popularly known as cross breed in India (Datta, 1984). Bivoltines which adapt well to temperate climatic conditions and yield quality raw silk bred earlier are used as only male component in cross breeding program with locally available polyvoltine breeds (Jolly, 1983). The ultimate motive of the breeder in India is the adaptation of bivoltines to tropical climates to improve silk quality, and quite a good number of improved breeds like Central Sericultural Research (CSR) hybrids were developed (Datta *et al.*, 2000). The full potentiality of these breeds can be obtained under the optimum inputs (*i.e.*, assured irrigation and recommended dosages of farm yard manure and chemical fertilizers) to mulberry garden during favourable months (July - February) in the southern India.

The silkworm breeds developed for tropical conditions in India have to adapt to both seasonal and local conditions for stable cocoon production under the high temperature environment. The acquisition of desirable level in cocoon production depends on the successful selection of initial breeding resource. Thus, an attempt has been made to select suitable breeding resource material, which can be utilized as the breeding source suitable to high temperature (36°C ± 1) and low humidity (65% ± 5) conditions. This was performed by giving high temperature stress during the course of breeding. China was successful in breeding several breeds by introducing polyvoltine breeds and the resultant hybrids are strong, resistant to adverse climatic conditions and easy to rear in country side (Shao, 1989).

Materials and Methods

With an objective of selecting suitable parents for initiating new breeding program ten polyvoltine breeds *viz.*, Pure Mysore, Nistari, Cnichi, Guangnong plain (GNP),

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HS6, BL27, BL30, BL36, BL54 and TX; ten bivoltine breeds *viz.*, KA, NB_4D_2, CSR2, CSR4, CSR6, A, B, Daizo, J2 and 916B were drawn from the germplasm collection of CSR & TI, Mysore. These breeds were indoor-reared for six times comprising three seasons in a year (*i.e.*, Pre-monsoon, February - May; Monsoon, June - September and Post-monsoon, October - January with three replications each having 300 larvae as per standard rearing procedure; Krishnaswami, 1978). Data were collected on seven important economic traits *viz.*, fecundity, pupation rate, cocoon yield, cocoon weight, cocoon shell weight, cocoon shell ratio and filament length. The data were analysed by employing the statistical model of two way classification (Kempthorne, 1952) for seasonal variations, Joint scoring method (Arunachalam and Bandhopadhyay, 1984) and multiple trait evaluation index method (Mano *et al.*, 1993) to select parents.

Joint Scoring method

The data were calculated as the procedure outlined by Arunachalam and Bandhopadhyay (1984). Statistically significant components (C. D at 5%) were subjected to a method to make decisions jointly a number of dependant characters. The difference in the mean of races i and j was tested as follows. The means of the evaluated characters of each race were arranged in groups based on t test. A score was allotted to each race for each character. The group containing the highest mean for the character was given a score 1, the next score 2 and so on. The individual scores obtained were added across characters to get a final score for each race. Based on the descending order of final scores, the breeds were ranked and the best breed showing lowest value was selected.

$t = x_i - x_j$

$\sqrt{e}\ [(C1/n_i) + (1/n_j)]$, where

x_i = Mean of the i^{th} race

x_j = mean of the j^{th} race

n_i = Number of selected traits of i^{th} race

n_j = Number of selected traits of j^{th} race

e = Error m.s. in Anova.

Evaluation Index: Calculated as the procedure outlined by Mano *et.al.*, (1993).

$$\text{Evaluation Index} = \frac{A - B}{C} \times 10 + 50$$

Where,

A = Value obtained for a trait in a strain

B = Mean value of a trait of all the strains

C = Standard deviation of a trait of all strains

10 = Standard unit

50 = fixed value.

Results

The data on seven traits of economic importance from each ten polyvoltine and bivoltine reared in three replicates each in three seasons were compared and mean values were depicted in Table 1 and 2, respectively. The morphological features of polyvoltines and bivoltines were given in Table 3 and 4. The genotype environment interaction in polyvoltine breeds (Table 5) revealed highly

Table 1. Rearing performance of polyvoltine breeds during 1995 - 1996 (mean of 6 trials for 3 seasons)

Sl. No	Breed	Fecundity	Total larval duration	5^{th} age larval duration	Pupation rate (%)	Cocoon yield (kg)	Cocoon weight (g)	Shell weight (g)	Shell ratio (%)	Filament length (m)	Denier
	Oval Breeds										
1	BL36	533	512	120	89.97	11.230	1.234	0.198	15.9	591	2.20
2	BL27	555	504	115	93.26	12.035	1.279	0.223	17.0	543	2.27
3	BL30	538	539	121	90.25	10.857	1.225	0.195	15.9	548	2.20
4	GNP	433	542	100	86.47	8.673	1.057	0.153	14.5	512	2.19
5	Nistari	432	536	135	96.31	9.823	1.032	0.140	13.6	456	2.29
6	Pure Mysore	421	668	208	93.71	9.201	1.053	0.150	14.2	394	2.30
7	TX	137	512	137	93.94	9.439	1.047	0.03	13.4	458	2.28
	SD	65.1	52.3	32.4	3.04	1.13	0.10	0.03	1.26	61.9	0.04
	Dumbbells										
8	BL 54	475	500	116	92.74	11.033	1.239	0.179	15.0	554	2.31
9	HS 6	494	550	140	82.83	10.010	1.168	0.186	15.9	493	2.29
10	C.nichi	402	477	119	93.17	9.533	1.047	0.122	11.6	418	2.11
	SD	39.5	30.4	10.5	4.78	0.63	0.08	0.03	1.82	55.3	0.11

Table 2. Rearing performance of bivoltine breeds during 1995 - 1996 (Mean of 6 trials for 3 seasons)

Sl. No	Breed	Fecundity	Total larval duration	5^{th} age larval duration	Pupation rate (%)	Cocoon yield (kg)	Cocoon weight (g)	Shell weight (g)	Shell ratio (%)	Filament length (m)	Denier
	Oval Breeds										
1	A	491	517	141	83.58	12.877	1.501	0.337	22.4	1043	2.47
2	B	504	519	144	84.72	14.445	1.569	0.336	21.4	961	2.47
3	Diazo	466	527	131	96.17	10.885	1.262	0.200	15.8	454	2.34
4	KA	520	515	140	88.05	12.927	1.568	0.315	20.2	883	2.50
5	CSR2	536	526	149	87.73	15.294	1.550	0.338	21.8	1063	2.59
	SD	24.2	4.7	5.8	4.41	1.51	0.12	0.05	2.37	222.7	0.08
	Dumbbells										
6	CSR4	504	521	143	89.88	15.053	1.597	0.356	22.3	1012	2.58
7	CSR6	519	550	148	88.65	15.042	1.574	0.346	21.3	1011	2.52
8	J2	492	540	146	91.06	13.326	1.520	0.332	21.8	953	2.60
9	NB_4D_2	492	527	137	89.61	12.894	1.525	0.314	20.5	843	2.44
10	916 B	512	519	148	85.78	14.814	1.537	0.317	20.6	843	2.45
	SD	10.6	11.7	3.9	1.78	1.00	0.03	0.02	0.68	76.2	0.07

Table 3. Morphological features of polyvoltine races*

No	Race	Origin	Commercial exploitation	Parentage	Larval markings	Cocoon shape	Cocoon colour
1	BL36	Mysore, India	-	Hua204 x Moria	Plain	Oval	Creamish white
2	BL27	"	-	Hua204 x GNP	Plain	Oval	White
3	BL30	"		-Do-	Plain	Oval	Creamish white
4	GNP	South China	Yes	NA	Plain	Oval	Creamish white
5	Nistari	W. Bengal, India	Yes	NA	Marked	Spindle	Golden yellow
6	Pure Mysore	Mysore, India	Yes	NA	Plain	Spindle	Greenish yellow
7	TX	Mysore, India	-	Nistari	Marked	Spindle	Golden yellow
8	Cnichi	Japan	Yes	JI x C4	Plain	Peanut	White
9	HS 6	Mysore, India	-	NA	Plain	Peanut	White
10	BL 54	Mysore, India	-	French plain x Cnichi	Plain	Peanut	White

NA, Not available.
*Collected from the germplasm bank of CSRTI, Mysore.

Table 4. Morphological features of bivoltine races*

No	Race	Origin	Commercial exploitation	Parentage	Larval markings	Cocoon shape	Cocoon colour
1	CSR2	Mysore, India	Yes	Shunrei x shogetsu	Plain	Oval	White
2	B	China	No	NA	Plain	Oval	White
3	KA	KalimpongIndia	Yes	(N122 x C.110) x (N124 x C124)	Plain	Oval	White
4	A	China	No	NA	Plain	Oval	White
5	Diazo	China	No	NA	Plain	Spindle	Yellow
6	CSR4	Mysore, India	Yes	NB_4D_2 x (BN18 x BCS25)	Plain	Dumbbell	White
7	CSR6	Mysore, India	Yes	Shunrei x shogetsu	Marked	Dumbbell	White
8	J2	China	No	NA	Marked	Dumbbell	White
9	916B	Mysore, India	No	Em x (Hua1 x Hua 2)	Marked	Dumbbell	White
10	NB_4D_2	Mysore, India	Yes	Kokuko. seihaku x (N124 x C124)	Plain	Dumbbell	White

NA, not available.
*Collected from the germplasm bank of CSRTI, Mysore.

Table 5. Analysis of variance (ANOVA) for polyvoltine races

Source of variation	Degree of freedom	Mean sum of squares						
		Fecundity	Pupation rate	Cocoon yield	Cocoon weight	Cocoon shell	Shell ratio	Filament length
Between seasons	2	2723.7000 NS	6.5182 NS	12.0860**	0.1075**	0.0081**	0.0081**	48.0487**
Between races	9	29763.2641**	51.0722**	6.1766**	0.0499**	0.024**	0.0024**	6.7092**
Races x Seasons	18	2345.8234**	33.5095**	2.3314**	0.0208**	0.0008**	0.008**	2.6627**
Error	60	949.1333	6.4321	0.3908	0.0030	0.0000	0.0000	0.0658
CD at 5%	Races	29.0460	2.3911	0.5894	0.0522	0.0082	0.0082	0.2420

NS, not significant; **significant at 1%; and *significant at 5%.

Table 6. Analysis of variance (ANOVA) for bivoltine races

Source of variation	Degree of freedom	Mean sum of squares						
		Fecundity	Pupation rate	Cocoon yield	Cocoon weight	Cocoon shell	Shell ratio	Filament length
Between seasons	2	9399.0333**	819.6386**	53.4465**	0.1171**	0.0081**	3.5490**	4153.8777NS
Between races	9	5196.2037**	120.7331**	21.6559**	0.1506**	0.0168**	26.3849**	253720.37**
Races x Seasons	18	4882.8111**	68.2551**	2.6502**	0.0176**	0.0006**	0.4744NS	8358.8037**
Error	60	1454.9333	13.2066	1.0209	0.0023	0.0001**	0.4115	2098.9111
CD at 5%	Races	35.9621	3.4626	0.9526	0.0457	0.0127	0.6077	43.1937

NS, not significant; **significant at 1%; and *significant at 5.

significant (P < 0.01) variation for fecundity, cocoon yield, cocoon weight, cocoon shell weight, cocoon shell ratio and cocoon filament length; whereas in case of bivoltines (Table 6) highly significant (P < 0.01) differences were found for all the characters except cocoon shell ratio. The results of evaluation index and Joint scoring method are presented in Figures 1 - 6 for polyvoltine and bivoltines. Perusal of results revealed that BL27 scored top ranking values followed by BL36 and BL54 (Fig. 1, 3 and 4) among polyvoltines and CSR4 (Fig. 2, 5 and 6) scored high ranking values followed by CSR2 and CSR6 in bivoltines for all the methods adopted. Since the objective of present study is to breed adaptable bivoltine breeds having higher survival and productive traits of economic importance to tropical climates, Daizo which scored highest (Fig. 5) rank value for pupation rate among bivoltine was also considered for selection.

Discussion

The selection of suitable breeding resource material helps the breeder to successfully amalgamate the material. An appropriate experimental design (*i.e.*, selection methods employed in fixing the majority of economic traits contributing to the improved cocoon yield) may lead to the success of any breeding program. Besides, understanding the genetic diversity of parental strains to be utilized in the breeding program by their systematic evaluation, critical assessment of their quantitative nature which is greatly

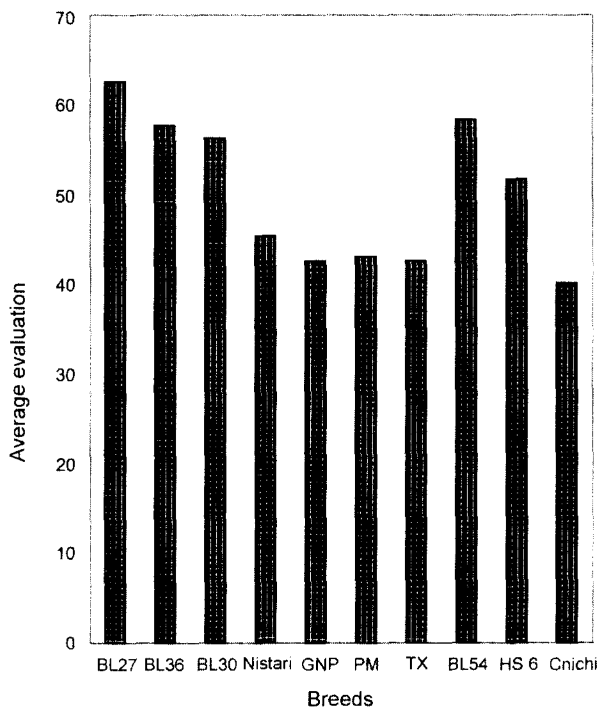

Fig. 1. Evaluation index values of breeds.

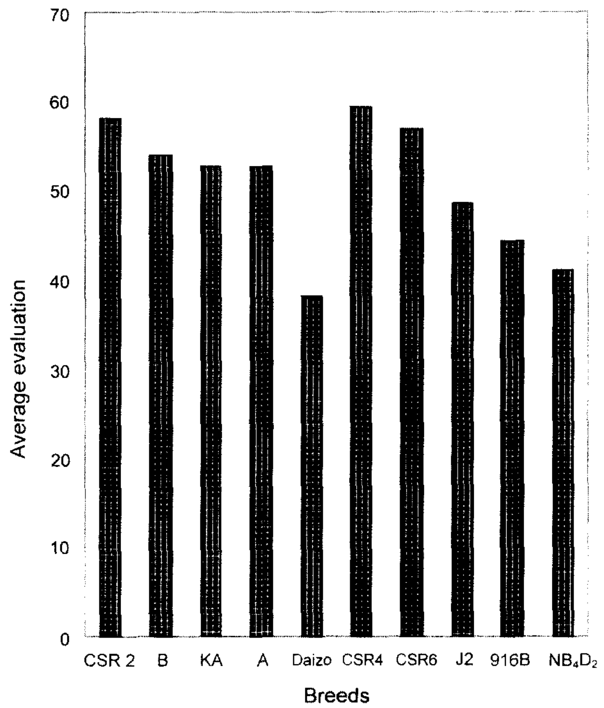

Fig. 2. Evaluation index values of bivoltine breeds.

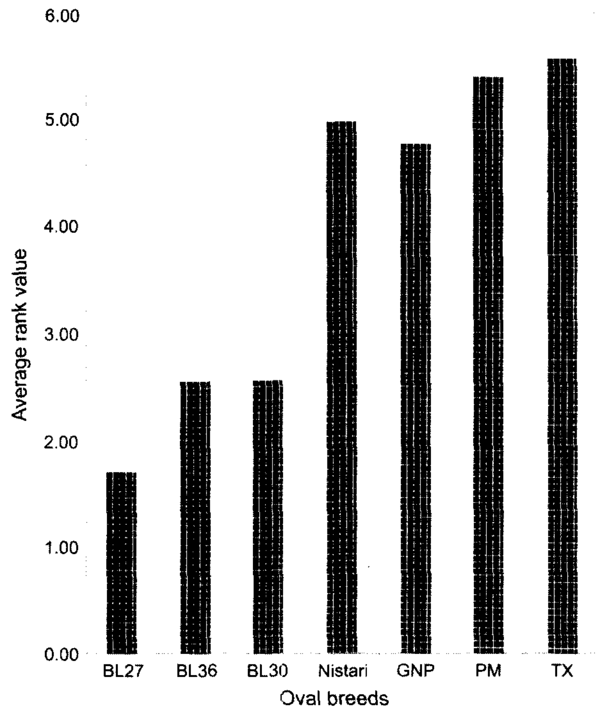

Fig. 3. Joint scoring values of polyvoltine breeds (Selected breeds showing lowest values).

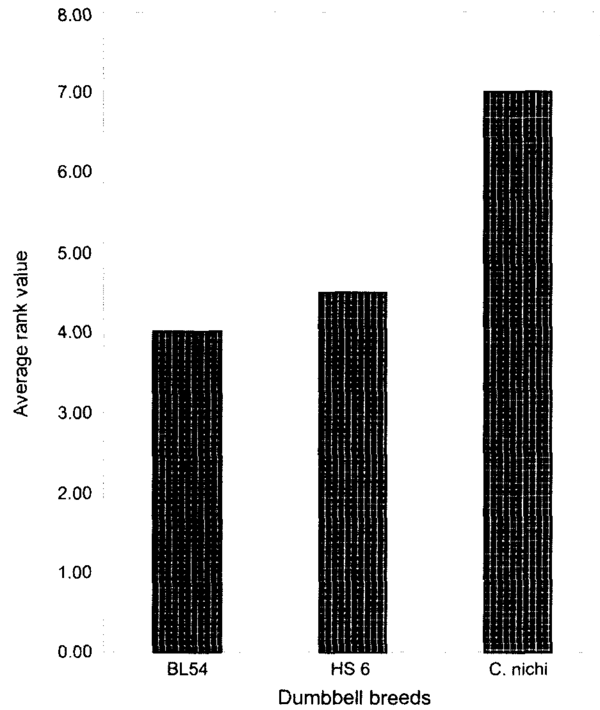

Fig. 4. Joint scoring values of dumbbell breeds (Selected breeds showing lowest values).

influenced by the environmental factors such as temperature, light, humidity, nutrition, and rearing techniques paves the way for breeder for their effective utilization (Kogure, 1933; Horie *et al.*, 1967; Nirmal Kumar and Reddy, 1998). The improvement obtained by selection under favourable conditions will not help in realising the

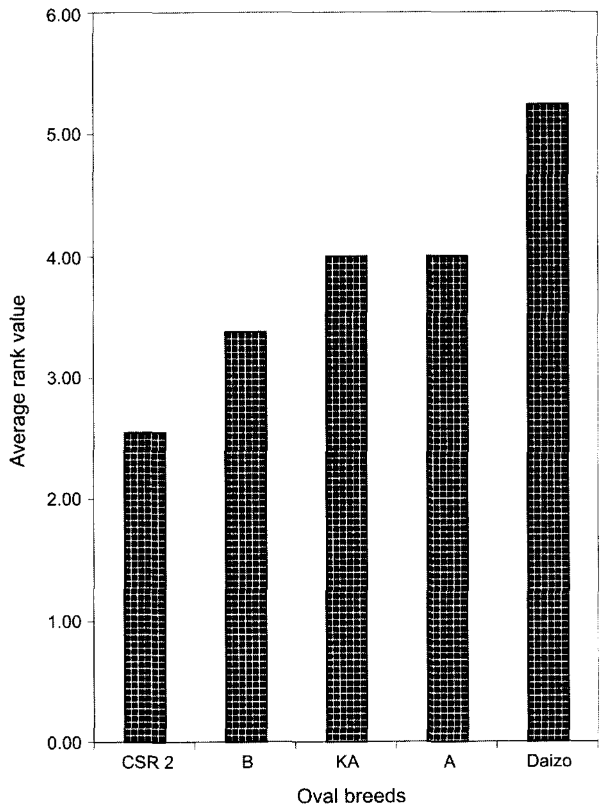

Fig. 5. Joint scoring values of bivoltine breeds (Lowest value for selected).

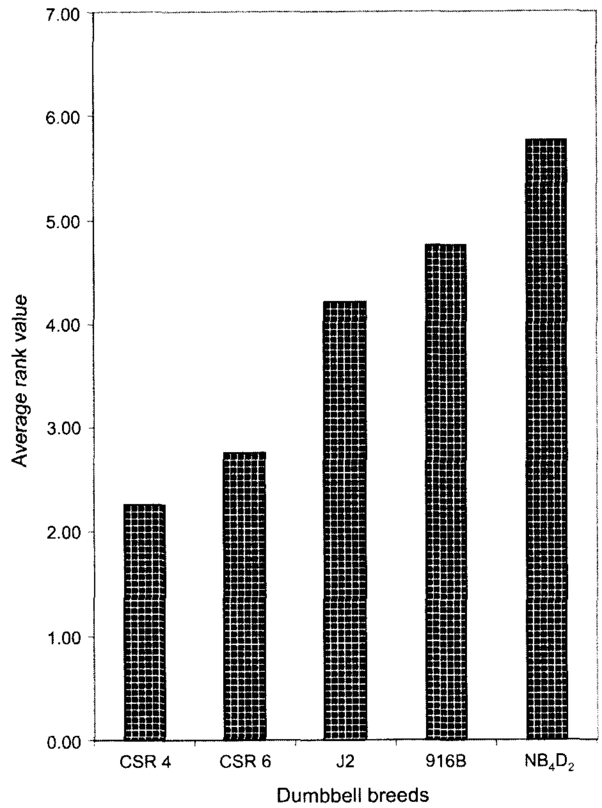

Fig. 6. Joint scoring values of bivoltine breeds (Lowest values for selected breed).

full potential when the selected strain is transferred to unfavourable conditions. Performance was best improved by selection under the conditions in which the performance was subsequently measured (Falconer, 1960).

The significant variations observed in the phenotypic manifestation for the traits analysed can be attributed to the genetic constitution of the strains and their degree of expression to which they are exposed during their rearing. Such seasonal variations in the traits studied can be ascribed to the influence of environment. Variable gene frequencies at different loci make them to respond differently. Similar results were obtained by Ueda *et al.* (1975), Kalpana (1992), Nirmal Kumar (1995) and Sudhakara Rao *et al.* (2001). It is interesting to note that the degree of responses of the characters in polyvoltine breeds indicate their responsiveness of genetic make up to changing environmental conditions. The findings are in line with Datta and Nagaraju (1987) which indicate that polyvoltines are well aclamotised to tropical conditions. On the other hand, the significant variations observed in bivoltine breeds with regards to the phenotypic manifestation for all characters except for cocoon shell ratio indicate that the genetic constitution of these races is amenable to changing environments prevailing in the tropics (Subramanya, 1985; Basavaraja, 1996). Usually, superiority of the breed is judged by more than twenty characters (Mano *et al.*, 1993). Therefore, selection based on the major traits were measured to know their co-related response systematically over the growth period during different seasons.

In all the three methods, BL27 stood first among polyvoltine breeds, and among bivoltine breeds CSR4 (dumbbell) stood first for all the important traits. However, Daizo (Spindle) which has shown highest viability and pupation rate also known for high temperature tolerance was considered for selection. After initial hibridization based on larval markings and cocoon shapes, foundation crosses are subjected to high temperature (36°C ± 1) and low humidity (65% ± 5) conditions in the environmental chambers for screening. The wide array of segregants will give scope for effective selection to amalgamate desirable characters into a single breed.

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