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COMPARATIVE PERFORMANCE OF PARENTS AND THEIR FOUNDATION CROSSES OF BIVOLTINE SILKWORM, *BOMBYX MORI* L. WITH REFERENCE TO EGG YIELD PARAMETERS

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In the present investigation, 10 bivoltine breeds maintained at Central Sericultural Research and Training Institute, Mysore, and their 12 foundation crosses were used to evaluate the reproductive parameters. Important productive traits viz., the number of eggs per laying, egg recovery percentage, egg yield per kilogram of seed cocoons, number of eggs per gram, percentages of pupal mortality, non diapausing eggs and unfertilized eggs were studied and the improvement in the Chinese and the Japanese type foundation crosses was estimated. Statistical analysis of the data, revealed significant differences ($p<0.05$) between the parents and their foundation crosses for all the parameters considered for the study. Heterosis expressed for eggs per laying, egg recovery and the egg yield in the foundation crosses was 16.8, 21.2 and 23.9 % respectively, over their parental breeds. There was significant reduction ($p<0.05$) in the percentages of dead pupae, non diapausing eggs and of unfertilized eggs. The overall results are imperative that the foundation crosses are superior in terms of quality of seed cocoons and increased egg yield, which would reflect in further combinations of these crosses to form the double hybrids. Utilization of foundation crosses hence, can be an effective means in reducing the cost of egg production, which gains importance from the point of view of the industry.

Key words : *Bombyx mori* L., bivoltine, parental breeds, foundation crosses, egg yield parameters.

INTRODUCTION

The present global sericultural scenario reveals that the silk production is focused on tropical countries and India occupies the second niche next to China. The bulk of raw silk production in India is from multivoltine x bivoltine hybrids, which qualitatively do not befit the international standards. This has necessitated the adoption of breeding strategies with due emphasis on evolution of productive bivoltine breeds/hybrids aimed at yielding increased output of quality silk (Datta, 1984). Accordingly, concerted efforts are made by silkworm breeders aiming at practical viability of bivoltine rearing for the tropical areas of the country. Consequentially, many productive and robust hybrids were identified for commercial exploitation. (Basavaraja *et al.*, 1995; Nirmal Kumar, 1995; Basavaraja, 1996; Datta *et al.*, 2000a; Suresh Kumar *et al.*, 2002; Mal Reddy *et al.*, 2005).

Although survival could be maintained in single hybrids, their parental breeds are poor in egg number. Unless the mother moth is a hybrid of closely related inbred lines, the fecundity cannot be increased. (Yokoyama, 1979). The increase in egg number is possible with foundation crosses and with their 'appropriate combinations' resulting in the 'double hybrid egg produce'. Production of quality silkworm seed is one among the important factors for successful cocoon crops. Health of pupae, percentage of pairs, fertileness of the eggs laid, contribute to the quality of the seed. Egg yield parameters, principally 'the number of eggs laid by individual moth, the egg yield per kilogram of cocoons and the number of eggs per gram', are vital for egg producers in terms of cost of production of quality seed. Egg productivity is revealed by the 'number of eggs laid and the percentage of moths ovipositing normal number of eggs' and these characters have a negative correlation with cocoon shell percentage and raw silk percentage (Gamo, 1976, Datta & Basavaraja, 1994). High raw silk• percentage, being one of the important breeding characters, selection of inbred lines for high egg productivity without reducing the cocoon shell percentage is obviously a difficult task. By hybridization of two closely valued inbred lines, the egg productivity in the F1 can be increased and the 'double hybrids' resulting from further crossing of these F1s, facilitate a gain in egg productivity without reducing the cocoon shell percentage (Gamo, 1976). Earlier, attempts were made to develop and identify double hybrids keeping in view of their advantages both in cocoon as well as egg production (Nirmal Kumar *et al.*, 1998). The present study reflects on the comparative performance of bivoltine parental breeds and their foundation crosses in respect of egg yield parameters.

MATERIALS AND METHODS

Ten promising bivoltine breeds *viz.* CSR2, CSR17, CSR21, CSR27 and CSR46, the oval and CSR4, CSR6, CSR26, CSR47 and GEN2, the dumbbell parental breeds were selected for the present study. Using these breeds, forty foundation crosses (FCs), comprising twenty oval type and twenty dumbbell type, were prepared and reared. Based on heterosis for 'pupation rate (which ranged from 6.6 to 14.0% and 2.7 to 12.0% in oval and dumbbell FCs respectively) and cocoon yield' (which ranged from 18.9 to 35.7% and 12.0 to 29.9% in oval and dumbbell FCs respectively), six each of oval and dumbbell type FCs were selected for the proposed work (Pallavi & Basavaraja, 2007). The selected FCs are (CSR2 x CSR21), (CSR17 x CSR21), (CSR17 x CSR46), (CSR27 x CSR46), (CSR46 x CSR2) and (CSR46 x CSR21) the oval type and (CSR4 x CSR26), (CSR6 x GEN2), (CSR26 x CSR47), (CSR26 x GEN2), (CSR47 x CSR26) and (GEN2 x CSR26), the dumbbell type.

The parental breeds and the selected foundation crosses were reared as per standard rearing technology (Krishnaswami, 1978) to raise the seed cocoons required. The cocoons were harvested on the seventh day and sorting of cocoons *viz* the good, double, uzi infested and cocoons with dead pupae was carried out. One kilogram of good cocoons from each breed / foundation cross was taken at random. Cocoons were cut at both the ends to facilitate moth emergence. The pupae of parental breeds/ FCs were preserved under optimum environment with a temperature of 25 ± 1°C and relative humidity of 75-80%. Preservation was effected in dark ambience. Coupling of moths of parental breeds and the FCs was carried out separately from the onset, to the end of emergence. After a duration of 4 hours of coupling, the mother moths were decoupled smoothly and placed on starch smeared egg sheets individually in the cellules. Oviposition was allowed for a period of 24 hours in a dark room. The method suggested by Samson *et al.* (1995) was followed to prepare loose eggs of the parental breeds / foundation crosses. Data were recorded for seven important parameters *viz.* the number of eggs per laying, egg recovery percentage, egg yield per kilogram of seed cocoons, the number of eggs per gram, percentages of dead pupae, non diapausing eggs and unfertilized eggs and were analyzed statistically. The phenomena of heterosis and overdominance were estimated using the mid parent and better parental value, respectively.

RESULTS

Fecundity **:** Significant variation ($P<0.05$) in fecundity was observed among the parents and FCs. The data revealed that the fecundity of oval parents varied from 523 (CSR46) to 553 (CSR2) and that of oval FCs ranged from 571 (CSR46 x CSR21) to 677 (CSR2 x CSR21). For dumbbell parents, it varied from 473 (GEN2) to 531 (CSR4) and for dumbbell FCs, the range was from 558 (GEN2 x CSR26) to 596 (CSR4 x CSR26).

Egg recovery **:** Egg recovery, calculated for the quantity of seed cocoons by number, showed significant difference ($p<0.05$) between parents and FCs. In oval parents, it ranged from 28.0 (CSR46) to 34.0% (CSR2) whereas in oval FCs, the percentage varied from 35.0 (CSR46 x CSR21) to 40.0% (CSR2 x CSR21) and the variation was significant. In dumbbell breeds, the trait ranged from 27.4 (GEN2) to 32.0% (CSR4) and in the dumbbell FCs, it showed a range from 34.5 (GEN2 x CSR26) to 38.4% (CSR4 x CSR26). In the dumbbell type, both among the parents as well as in the FCs, the variation was not significant.

Egg yield per kilogram of seed cocoon **:** Another parameter of importance is the egg yield, obtained for the quantity of seed cocoons by weight, kept for hybrid eggs preparation. The study revealed significant variation ($p<0.05$) for this trait between parents and the foundation crosses. Among the oval breeds, it varied from 50.2 (CSR46) to 62.0 g (CSR2) whereas in oval FCs, it was in the range of 63.0 (CSR46 x CSR21) to 72.8 g (CSR2 x CSR21). Among the dumbbell breeds, it showed a range from 50.0 (GEN2) to 59.0 g (CSR4) whereas among the dumbbell FCs, it varied from 62.0 (GEN2 x CSR26) to 70.8 g (CSR4 x CSR26). Both in the oval as well as the dumbbell type, significant difference ($p<0.05$) was recorded within the parental breeds and within the foundation crosses.

Number of eggs per gram **:** Fecundity of the breed / foundation cross and the number of eggs per gram, reflect the quality of seed cocoon in terms of richness and weight of the eggs. Data revealed significant difference ($p<0.05$) for this parameter, between both the parents and among both the FCs. The eggs per gram in oval parents ranged from 1745 (CSR2) to 1830 (CSR46), whereas in oval FCs, it varied from 1660 (CSR2 x CSR21) to 1708 (CSR46 x CSR21). For the dumbbell breeds, the range was from 1734 (CSR4) to 1865 (GEN2) whereas for dumbbell type FCs, it varied from 1625 (CSR4 x CSR26) to 1734 (CSR47 x CSR26).

Pupal mortality **:** Percentage of dead pupae, indicating the pupal mortality, is an important parameter reflecting the quality of the seed cocoon in terms of healthiness of the batch. Among the oval parents, it varied from 3.50 (CSR2) to 5.20 % (CSR46), and in oval type FCs, it ranged from 2.07 (CSR2 x CSR21) to 3.80 % (CSR46 x CSR2). In dumbbell parents, the range was from 3.20 (CSR6) to 5.90 % (GEN2) while in dumbbell FCs, it varied from 2.20 (CSR4 x CSR26) to 5.80 % (GEN2 x CSR26). In both the types of FCs, the oval and the dumbbell, the difference was non significant for this trait.

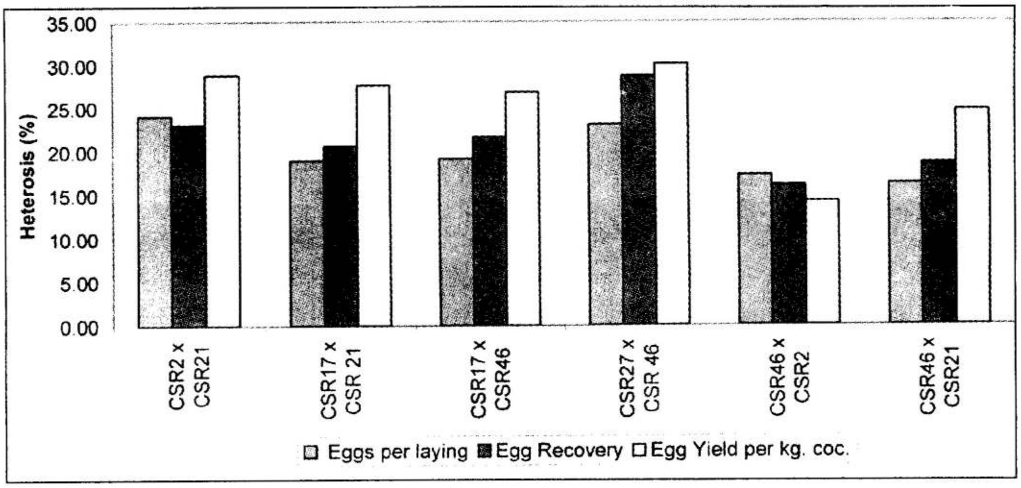

Fig. 1 : Heterosis (%) for eggs per laying, egg recovery and egg yield in oval foundation crosses.

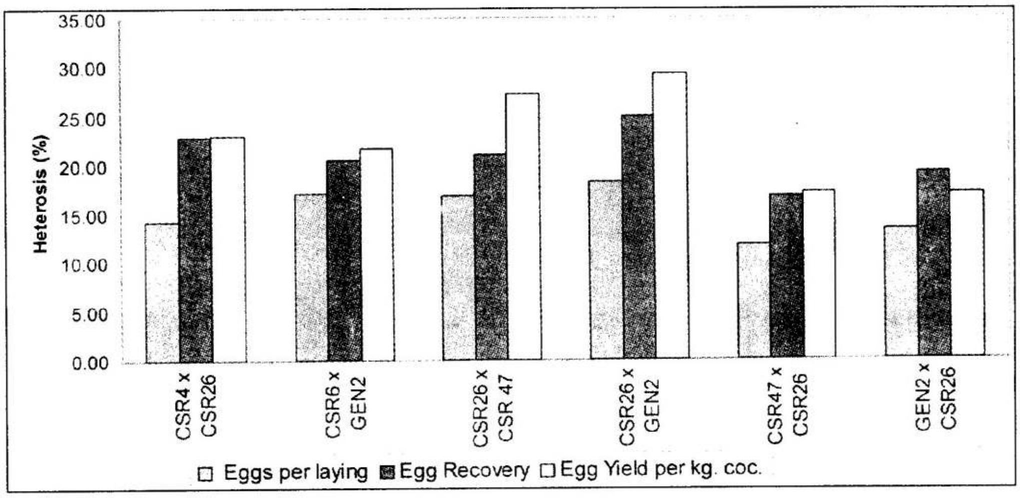

Fig. 2 : Heterosis (%) for eggs per laying, egg recovery and egg yield in dumbbell foundation crosses.

Non diapausing eggs : The extent of occurrence of non-diapausing eggs in the oval parents was from 1.00 (CSR2) to 2.67% (CSR46) and in oval FCs, it varied from 1.40 (CSR2 x CSR21) to 2.00% {(CSR17 x CSR21) and (CSR46 x CSR21)}. Among the dumbbell parents, it varied from 1.90 (CSR26) to 6.80% (GEN2) whereas among the dumbbell FCs, the range was from 1.00 (CSR4 x CSR26) to 7.60% (GEN2 x CSR26). Among oval parents and among the oval FCs there was no significant difference for this parameter, whereas in dumbbell parents and among the dumbbell FCs, it revealed significant difference ($p<0.05$).

Unfertilized eggs Incidence of unfertilized eggs revealed non-significant difference among the oval parents and among the oval FCs. It varied from 2.17 (CSR2) to 4.57% (CSR46) in oval parents, whereas the range was from 2.00 (CSR2 x CSR21) to 4.60% (CSR46 x CSR2) for oval FCs. The dumbbell parents showed significant difference ($p<0.05$) for the trait, ranging from 3.60 (CSR4) to 6.70% (GEN2) whereas in dumbbell FCs, there was no significant difference for this parameter, which ranged from 3.20 (CSR4 x CSR26) to 5.80 % (GEN2 x CSR26) (Tables I & II).

Heterosis and overdominance : The foundation crosses revealed distinct heterotic and overdominant effect for the parameters, fecundity, egg recovery, egg yield and eggs per gram (Table III, Figs. 1 & 2).

In the oval FCs, the heterosis for eggs per laying, ranged from 6.33 (CSR46 x CSR21) to 24.11% (CSR2 x CSR21) and overdominance from 6.13 (CSR46 x CSR21) to 22.42% (CSR2 x CSR21). In dumbbell FCs, heterosis for this parameter ranged from 11.81 (CSR47 x CSR26) to 18.29% (CSR26 x GEN2) and overdominance ranged from 9.20 (GEN2 x CSR26) to 16.2% (CSR26 x CSR47).

Similarly the heterosis for egg recovery in oval FCs, ranged from 16.13 (CSR46 x CSR2) to 28.71% (CSR27 x CSR46) and overdominance from 5.88 (CSR46 x CSR2) to 28.71% (CSR27 x CSR46); in dumbbell FCs, the heterosis for this parameter ranged from 16.70 (CSR47 x CSR26) to 25.00% (CSR26 x GEN2) and overdominance from 12.70 (CSR6 x GEN2) to 20.00% {(CSR4 x CSR26) and (CSR26 x CSR47)}.

Table I : Egg yield parameters of Parental breeds.

Breed	Eggs per laying (No.)	Egg recovery (%)	Egg yield /kg cocoon (g)	Eggs / gram (No.)	Pupal mortality (%)	Non diapausing eggs (%)	Unfertilised eggs (%)
Oval							
CSR2	553	34.00	62.00	1745	3.50	1.00	2.17
CSR17	536	32.00	61.00	1805	3.90	2.00	3.50
CSR21	538	31.00	51.00	1770	4.70	1.80	3.20
CSR27	548	32.60	61.60	1748	4.20	2.00	2.80
CSR46	523	28.00	50.20	1830	5.20	2.67	4.57
Mean	540	31.5	57.2	1780	4.30	1.89	3.25
CD at 5%	16.87	2.62	2.70	21.20	0.57	NS	NS
CV%	1.72	4.57	2.59	0.65	0.98	2.62	6.04
Dumbbell							
CSR4	531	32.00	59.00	1734	4.20	2.50	3.60
CSR6	507	31.50	58.00	1765	3.20	2.33	3.80
CSR26	511	30.50	56.00	1794	4.60	1.90	4.80
CSR47	505	30.00	55.00	1824	5.30	8.20	5.20
GEN2	473	27.40	50.00	1865	5.90	6.80	6.17
Mean	505	30.3	55.6	1796	4.64	4.35	4.82
CD at 5%	17.92	NS	1.82	26.85	1.51	1.15	1.17
CV%	1.86	1.86	1.79	0.82	6.84	5.71	4.86

Table II : Egg yield parameters of Foundation crosses.

Foundation crosses	Eggs per laying (No.)	Egg recovery (%0	Egg yield per kg cocoon (g)	Eggs per gram (No.)	Pupal mortality (%)	Non diapausing eggs (%)	Unfertilised eggs (%)
Oval FC	*						
CSR2x CSR21	677	40.00	72.80	1660	2.07	1.40	2.00
CSR17xCSR21	639	38.00	71.50	1688	2.33	2.00	2.27
CSR17xCSR46	631	36.50	70.40	1685	3.50	1.60	3.80
CSR27xCSR46	659	39.00	72.60	1670	2.40	1.50	2.20
CSR46xCSR2	631	36.00	64.00	1702	3.80	1.90	4.60
CSR46xCSR21	571	35.00	63.00	1708	3.60	2.00	4.20
Mean	635	37.4	69.1	1686	2.95	1.73	3.18
CD at 5%	20.96	2.24	4.62	24.25	NS	NS	NS
CV%	1.86	3.38	3.75	0.81	4.20	2.22	3.29
Dumbbell FC	*						
CSR4xCSR26	596	38.40	70.80	1625	2.20	1.00	3.20
CSR6 x GEN2	574	35.50	65.70	1658	2.90	1.20	3.40
CSR26x CSR47	594	36.60	70.60	1644	3.70	2.30	4.20
CSR26 x GEN2	582	36.20	68.50	1656	3.60	1.80	3.60
CSR47xCSR26	568	35.30	65.00	1678	5.10	5.60	4.80
GEN2xCSR26	558	34.50	62.00	1734	5.80	7.60	5.80
Mean	579	36.10	67.10	1666	3.88	3.25	4.17
CD at 5%	8.93	NS	3.43	23.09	NS	2.55	NS
CV%	0.87	2.48	2.87	0.78	4.91	4.42	3.58
Parents vs FC							
CD at 5%	15.29	2.14	3.11	21.89	2.07	2.22	2.80
CV%	1.63	3.82	3.02	0.77	9.43	7.92	5.80

* : Fecundity of the FC after Sib mating.

Table III : Heterosis and overdominance for egg yield parameters in Foundation crosses.

Foundation crosses	Eggs or laying		Egg recovery		Egg yied /kg cocoon		No. of eggs / g	
	Heterosis	O.D.	Heterosis	O.D.	Heterosis	O.D.	Heterosis	O.D.
Oval FCs								
CSR2xCSR21	24.11	22.42	23.08	17.65	28.85	17.42	-5.55	-6.21
CSR17xCSR21	18.99	18.77	20.63	18.75	27.68	17.21	-5.57	-6.48
CSR17xCSR46	18.17	17.72	21.67	14.06	26.85	15.41	-7.29	-7.92
CSR27xCSR46	23.06	20.26	28.71	1.63	30.11	17.86	-6.65	-8.74
CSR46xCSR2	17.29	14.10	16.13	5.88	14.29	3.23	-4.78	-6.99
CSR46xCSR21	6.33	6.13	18.64	12.90	24.75	23.53	-5.11	-6.67
Dumbbell FCs								
CSR4xCSR26	14.40	12.20	22.90	20.00	23.13	20.00	-7.88	-9.42
CSR6xGEN2	17.14	13.20	20.50	12.70	21.67	13.28	-8.65	-11.10
CSR26xCSR47	16.93	16.20	21.00	20.00	27.21	26.07	-9.12	-9.67
CSR47xGEN2	18.29	13.90	25.00	18.69	29.25	22.32	-9.48	-11.21
CSR47xCSR26	11.81	11.20	16.70	15.74	17.12	16.07	-7.24	-8.00
GEN2xCSR26	13.41	9.20	19.20	13.11	16.98	10.71	-5.22	-7.02

For another important parameter, the egg yield, the heterosis in oval FCs ranged from 14.29 (CSR46 x CSR2) to 30.11% (CSR27 x CSR46) and overdominance from 3.23 (CSR46 x CSR2) to 23.53% (CSR46 x CSR21). The dumbbell FCs showed a range in heterosis from 16.98 (GEN2 x CSR26) to 29.25% (CSR26 x GEN2) and for over dominance from 10.71 (GEN2 x CSR26) to 26.07% (CSR26 x CSR47).

For the trait, the number of eggs per gram, the foundation crosses showed negative heterosis, which is desirable, being indicative of the improvement in the weight of eggs. In the oval FCs, the heterosis ranged from -4.78 (CSR46 x CSR2) to -7.29% (CSR17 x CSR46) and overdominance ranged from -6.21 (CSR2 x CSR21) to -8.74% (CSR27 x CSR46). In dumbbell FCs the heterosis showed a range from -5.22 (GEN2 x CSR26) to -9.48 (CSR26 x GEN2) and overdominance from -7.02 (GEN2 x CSR26) to -11.21% (CSR26 x GEN2).

DISCUSSION

In silkworm, selection for one character is found to result in correlated changes in other quantitative characters of economic importance (Kobari & Fujimoto, 1966). With the increase in quantitative traits beyond certain level, pupation rate and fecundity are affected to a great extent. Although pupation rate could be maintained in single cross hybrids, their parental breeds are poor in egg number. This apart, the cost of maintaining parental breeds, especially the strains with low fecundity and pupation rate, for supply of parental stock seed cocoons for preparing single hybrids, can be high. This situation has necessitated the development of foundation crosses, for identifying the double hybrid combinations enriched with the genetic content of four parental breeds and these hybrids could ensure sustainable cocoon yield. The study provides an emphatic base to the superiority of the foundation crosses over parental breeds particularly in respect of survival percentage and fecundity and the results are in conformity with the earlier studies (Rama Mohana Rao *et al.*, 1997; Nirmal Kumar *et al.*, 1998 & 2002). The results of the present investigation thus converge to an inference that, the foundation crosses yield considerably higher quantities of qualitatively superior eggs, as compared to the parental breeds. This is an added advantage, as the foundation crosses already have the status of being easy to rear, with uniform and robust larval growth, resulting in quality cocoon yield with better economic characters.

As regards the heterosis for 'fecundity', 'egg recovery' and 'egg yield', the oval FCs showed overall improvement by 18.25, 21.50 and 25.42% and the dumbbell FCs. ' 15.34, 20.89 and 22.56%, respectively. Statistical analysis of these quantit· parameters revealed significant differences ($p<0.05$) between the FCs and the par. Gowda *et al.* (1989) have reported that variation in fecundity is due to differential pupal weight. The egg yield parameter depends on the quality of seed cocoons, sex ratio, percentage of pairs and of egg recovery, being the decisive factors of cost of seed production and are commercially important for a seed production center (Benchamin & Krishnaswami, 1981a & b). It was observed by Gupta *et al.* (1991) that the egg yield was higher in bivoltine as compared to multivoltine (pure) and multi x bivoltine hybrids owing to greater weight of cocoons, pupae and moths. Rich layings and heavy eggs are considered as indicative of good quality seed (Benchamin *et al.*, 1988). Fecundity and the number of eggs per gram represent these two parameters. In addition to considerable improvement in egg yield traits, the FCs showed an increase in the weight of the eggs, indirectly reflected in reduction in the number of eggs per gram, to the tune of -5.83% in the oval type and -7.93% in the dumbbell type. The negative heterosis thus is indicative of heavier eggs. The foundation crosses also showed reduction in the percentages of dead pupae, non-diapausing eggs and of unfertilized eggs, as compared to their respective parents. Significant differences ($p<0.05$) between the FCs and the parental breeds were recorded for these parameters.

The result thus substantiates the impact of the foundation crosses in the overall improvement of the quality of seed cocoons, which would ensure rich yield of the double hybrid eggs worth of high commercial importance. Summing up it can be stated that, the FCs are an essential and potential means of reducing the cost of seed production in comparison to the parental breeds. The twelve foundation crosses taken for the present study, were utilized for preparing the possible combinations of double hybrids to assess the inherited improvement, in terms of enhanced yield of quality eggs and sustainable production of the hybrid cocoons for better returns.

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REFERENCES

BASAVARAJA, H.K., NIRMAL KUMAR, S., SURESH KUMAR, N., MAL REDDY, N., KSHAMA GIRIDHAR., AHSAN, M.M. & DATTA, R.K.1995. New productive bivoltine breeds. *Indian Silk.* **34**(2) : 5-9.

BASAVARAJA, H.K. 1996. Studies on the synthesis of productive bivoltine silkworm strains of *Bombyx mori* L. through hybridization, selection and genetic evaluation. *Ph.D. Thesis, University of Mysore, Mysore.*

BENCHAMIN, K.V. & KRISHNASWAMI, S. 1981a. Studies on the egg production efficiency in silkworm. *Bombyx mori L.* on the various factors contributing to Egg production. *Proc. Seri. Symp. Seminar*, Tamil Nadu Agricultural University, Coimbatore, India. pp. 1-6.

BENCHAMIN, K.V. & KRISHNASWAMI, S. 1981b. Egg production efficiency in hybrid parents and its effective application. *Proc. Seri. Symp. Seminar*, Tamil Nadu Agricultural University, Coimbatore, India. pp. 7-14.

BENCHAMIN, K.V., KRISHNA REDDY, R. & NASEEMA BEGUM, A. 1988. Studies on the relationship between seed cocoon quality and egg yield in silkworm, *Bombyx mori* L. *Proc. Internat. Congress Tropical Sericulture Practices*, Part **-VI**. pp.25-34.

DATTA, R. K. 1984. Improvement of silkworm races (*Bombyx mori* L.) in India. *Sericologia.* **24**(3) : 393-415.

DATTA, R.K. & BASAVARAJA, H.K. 1994. Silkworm breeding in Japan, China and India, A comparative analysis. In : *Silkworm Breeding*, (Srirama Reddy, G. Ed.), Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, Calcutta, India. pp. 18-38.

DATTA, R.K., BASAVARAJA, H.K., MAL REDDY, N., NIRMAL KUMAR, S., AHSAN, M.M., SURESH KUMAR, N. & RAMESH BABU, M. 2000a. Evolution of new bivoltine hybrids, CSR2 x CSR4 and CSR2 x CSR5. *Sericologia* **40**(1) : 151-167.

GAMO, T. 1976. Recent concepts and trends in silkworm breeding, *Farming, Japan.* **10**(6) : 11-12.

GOWDA, B.C.V., NARAYANASWAMY, T.K. & MUNIRAJAPPA, R. 1989. Impact of pupal weight on growth and development of the following generation in the Indian silkworm race NB7, *Bombyx mori* L. *Sericologia.* **29** : 477-480.

GUPTA, B.K., SINHA, A.K. & DAS, B.C. 1991. Studies on the egg yielding capacity of different races of silkworm, *Bombyx mori* L. *Geobios.* **18** : 173 -176.

KOBARI, K. & FUJIMOTO, N. 1966. Studies on the selection of cocoon filament size in *Bombyx mori* L. *Nissenzatsu.* **36** : 427-434.

KRISHNASWAMI, S. 1978 New technology of silkworm rearing. *Bull. No.***2**, Central Sericultural Research and Training Institute, Mysore, India. p. 23.

MAL REDDY, N., BASAVARAJA, H.K., SURESH KUMAR, N., NIRMAL KUMAR, S. &. KALPANA, G.V. 2005. Breeding of bivoltine double hybrid (CSR6 x CSR26) x (CSR2 x CSR27) of silkworm, *Bombyx mori* L. for commercial exploitation. In : *Advances in Tropical Sericulture* (Dandin, S.B., Mishra, R.K., Gupta, V.P. & Reddy, Y.S. Eds.), Central Sericultural Research and Training Institute, Mysore, India. pp. 58-62.

NIRMAL KUMAR, S. 1995. Studies on the synthesis of appropriate silkworm breeds (*Bombyx mori* L.) for tropics. *Ph.D. Thesis, University of Mysore, Mysore.*

NIRMAL KUMAR, S., RAMESH BABU, M., BASAVARAJA,, H.K., MAL REDDY, N. & DATTA, R.K. 1998. Double hybrids for improvement in silk production in silkworm *Bombyx mori* L. In : *Silkworm Breeding*, (Srirama Reddy, G. Ed.). Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, Calcutta, India, pp. 209-217.

DATTA, R.K. 1998. Double hybrids for improvement in silk production in silkworm *Bombyx mori* L. In : *Silkworm Breeding*, (Srirama Reddy, G. Ed.). Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, Calcutta, India, pp. 209-217.

NIRMAL KUMAR, S., SREENIVAS PRASAD, K., KISHOR KUMAR, C.M., BASAVARAJA, H.K. & DATTA, R.K. 2002. Studies on egg index in bivoltine silkworm strains and their foundation crosses. *Advances in Indian sericulture Research*, (Dandin, S.B. & Gupta, V.P. Eds.). Central silk Board, Bangalore. pp.123-128.

PALLAVI, S.N. & BASAVARAJA, H.K. 2007. Selection of suitable foundation crosses for utilization in double hybrid bivoltine silkworm, *Bombyx mori* L. *Indian J. Seric.* **46**(2) : 109-116.

RAMA MOHANA RAO, P., RAVINDRA SINGH, NAGARAJ, C.S. & VIJAYARAGHAVAN. (1997) Studies on foundation hybrids in silkworm *Bombyx mori* L. *Uttar Pradesh J. Zool.* **17**(1) : 75-81.

SURESH KUMAR, N., BASAVARAJA, H.K., KISHOR KUMAR, C.M., KISHOR KUMAR, N. & DATTA, R.K. On the breeding of "CSR18 x CSR19"- A robust bivoltine hybrid of silkworm, *Bombyx mori* L. for the tropics. *Int. J. Indust. Entomol.* **5**(2) : 153-162.

SAMSON, M.V., CHANDRASHEKARIAH, GOWDA, P. & BIRAM SAHEB, N.M. 1995. *Monograph on Silkworm Loose Egg Production*, Silkworm Seed Technology Laboratory, Central Silk Board, Bangalore, India.

YOKOYAMA, T. 1979. Silkworm selection and hybridization. Working papers, *Genetics in relation to insect management*, The Rockefeller Foundation, pp.71-83.