Int. J. Indust. Entomol. Vol. 1, No. 2, 2000, pp. 103~109

International Journal of *Industrial Entomology*

Evaluation of Two Promising Hybrids Viz., HSP1 (A3×935 E) and HSP2 (A3×916 B) in the Silkworm, *Bombyx mori* L.

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(Received 11 June 2000; Accepted 21 August 2000)

To evolve silkworm hybrids with higher survival and better cocoon characters, evaluation of seven hybrids in the laboratory (short-listed out of 143 hybrids) resulted in the identification of two promising hybrids, A3×935 E (HSP1) and A3×916 B (HSP2). The hybrids were evaluated at three different Regional Sericultural Research Stations of Central Silk Board during 1997-1998 and also tested with the farmers along with two control hybrids, KA×NB4D2 and PM×NB4D2. Evaluation of the hybrids indicated that these hybrids can be reared in all the seasons, especially during summer season. These hybrids show shorter larval duration (22 days 17 hrs against 23 days in control KA×NB4D2 and better cocoon characters as compared to the crossed breed, PM×NB4D2).

Key words : Hybrid evaluation, Field test, Silkworm, *Bombyx mori* L.

Introduction

Commercial exploitation of heterosis in silkworm has revolutionised the silk production in India to a great extent (Sreerama Reddy *et al.*, 1994). Toyoma (1906) first introduced hybrid rearing of silkworm in Japan while in India hybrid rearing began during 1920s (Ghosh, 1949; Datta,1984). During 1960s, cross breeding programme was introduced with the objective of improving the polyvoltine races (Tazima, 1988). Since then, polyvoltine hybrids were reared till 1970. Though the hybrids were found to be superior to parental races, increased productivity was not achieved because the parents were polyvoltine with poor quantitative characters. During late seventies, bivoltine breeds namely KA, NB7, NB18 and NB4D2 were bred and the bivoltine males were utilized in the cross breed preparation (Krishnaswami and Tikoo, 1971). Eventhough there was an increased silk productivity, minimum larval mortality and low renditta except for the silk quality remained poor due to inherent defects of the polyvoltine races being passed on to hybrids. High quality, international grade silk can be achieved only by rearing bivoltine silkworms. Due to temperature fluctations, poor management practices, poor mulberry quality, frequent bivoltine crop losses are often witnessed with farmers. Therefore, there is an urgent need to breed bivoltine silkworm breeds which can withstand the tropical climatic conditions prevailing in India. Keeping in view of the field constraints and the requirement of the silk industry a breeding plan was initiated. Six breeding lines viz., 931D, 933A, 934A1, 934B, 934D1 and 935E were isolated in a Line × Tester crossing programme (Naseema *et al.*, 1997). The hybrids were evaluated in the laboratory of Central Sericultural Research and Training Institute, Mysore, at the Regional Sericultural Research Stations of Central Silk Board and in the field.

Materials and Methods

Considering the average index value of > 50, seven hybrids viz., A3 × 935A, A3 × 935E, A3 × 916B2, A3×916B, A25 × 935E, A25 × 916A2 and A25 × 35A, were short-listed out of 143 hybrids. These hybrids were reared six times in the laboratory along with two control hybrids KA × NB4D2 and PM × NB4D2, to study the seasonal effects. The standard rearing practices were followed (Krishnaswami, 1978). The following observations were made: total larval period, cocoon yield by number, cocoon yield by weight, cocoon weight, shell weight, shell ratio %, filament length, raw silk %, reelability %

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and neatness points. In each hybrid combination, 500 g cocoons were reeled on Japanese multiend reeling machine at the Reeling and Fibre Technology Division of Central Sericultural Research and Training Institute, Mysore.

After successful evaluation of the above seven hybrids in the laboratory, two hybrids A3 × 935 E and A3 × 916 B, were selected and evaluated at the three Regional Sericultural Research Stations of Central Silk Board viz., Kodathi (Karnataka), Salem (Tamil Nadu) and Anantapur (Andhra Pradesh) for one year during 1997 - 1998 covering summer and rainy seasons. Thereafter, these

Table 1. Rearing and reeling performance of the selected hybrids at the laboratory

Sl. No.	Hybrids	Larval Period (hrs)	Yield/10,000 larvae		Single Cocoon Weight(g)	Single shell Weight(g)	Shell ratio (%)	Average filament length(m)	Raw silk (%)	Reel-ability (%)	Neatness (pts)
			No.	Wt. (Kg)							
1	A3 × 935A	549.00	9069.00	14.54	1.67	0.35	21.39	964.28	13.90	87.30	90.00
		± 24.91	± 287.18	± 1.11	± 0.08	± 0.01	± 1.4	± 53.42	± 1.82	± 4.28	± 1.91
		*-2.37	7.37	2.72	4.32	11.51	7.21	4.79	7.91	1.05	1.45
		**-4.92	0.22	25.98	5.31	30.06	26.05	16.41	14.94	1.67	0.46
2	A3 × 935E	545.50	9252.00	15.32	1.66	0.35	21.12	1014.52	14.76	89.30	90.00
	++	± 34.26	± 250.06	± 2.28	± 0.01	± 0.02	± 0.99	± 74.65	± 1.26	± 2.95	± 1.11
		*-3.02	9.20	7.69	3.36	9.34	5.99	9.51	13.21	3.29	1.45
		**-5.59	2.20	29.76	4.36	28.35	25.00	20.55	19.80	3.90	0.46
3	A3 × 916B2	541.33	9135.00	14.68	1.60	0.32	20.08	950.56	14.37	89.42	90.50
		± 32.27	± 650.51	± 1.46	± 0.01	± 0.02	± 0.90	± 44.10	± 1.08	± 4.53	± 4.23
		*-3.82	8.04	3.65	0.07	1.20	1.15	3.42	10.85	3.38	2.00
		**-6.4	0.94	26.69	1.10	21.91	21.20	15.20	17.60	3.99	1.01
4	A3 × X916B	544.33	9588.00	16.84	1.73	0.35	20.08	960.97	14.31	88.89	91.00
	++	± 30.43	± 268.91	± 0.73	± 0.05	± 0.04	± 1.60	± 82.63	± 1.62	± 3.49	± 2.62
		*-3.25	12.38	16.03	7.62	9.05	1.12	4.47	10.47	2.80	2.53
		**-5.82	5.62	36.11	8.57	28.12	21.19	16.12	17.30	3.41	1.56
5	A25 × 935A	557.00	9132.00	15.22	1.68	0.35	20.84	919.47	13.43	89.71	91.00
		± 39.29	± 723.68	± 1.88	± 0.07	± 0.03	± 1.04	± 50.19	± 1.15	± 2.44	± 0.89
		*-0.9	8.01	7.05	4.78	9.32	4.75	0.15	4.63	3.69	2.53
		**-3.41	0.91	29.28	5.76	28.33	24.09	12.33	11.91	4.30	1.56
6	A25 × 935E	543.00	9088.00	14.93	1.68	0.34	20.25	952.16	13.99	91.08	91.42
		± 24.60	± 319.25	± 1.73	± 0.09	± 0.01	± 0.82	± 59.82	± 0.73	± 5.32	± 2.24
		* -3.50	7.57	5.29	4.71	6.57	1.95	3.58	8.42	5.14	2.98
		**-6.08	0.43	27.94	5.69	26.16	21.85	15.34	15.42	5.74	2.01
7	A25 × 16A2	554.00	9060.00	15.39	1.64	0.34	20.58	947.88	13.53	88.58	89.58
		± 25.02	± 703.63	± 1.25	± 0.04	± 0.01	± 0.99	± 48.88	1.09	± 1.23	± 0.45
		* -1.44	7.27	8.09	2.64	6.30	3.53	3.15	5.31	2.46	0.99
		**-3.97	0.12	30.07	3.64	25.94	23.11	14.96	12.54	3.08	0.01
Control	Ka × NB4D2	562.00	8401.00	14.14	1.60	0.32	19.85	918.06	12.81	86.40	88.69
		± 46.56	±1248.19	± 2.51	± 0.02	± 0.01	± 0.36	± 52.41	± 1.22	± 3.07	± 1.33
Control	PM × NB4D2	576.00	9049.00	10.76	1.58	0.25	15.82	806.08	11.83	85.85	89.58
		± 8.94	± 612.61	± 2.51	± 0.02	± 0.02	± 1.40	± 61.22	± 0.47	± 1.65	± 2.74

*Indicates percentage improvement over KA × NB4D2 and ** PM × NB4D2

++ Indicates selected hybrids

were also evaluated with the farmers during summer season (April - May) in 1998.

Results and Discussion

Mean values and standard deviation were calculated for all the seven hybrids (Naseema *et al.*, 1999). The mean data (average of six trials) are presented in Table 1. Different hybrids exhibited higher values for different economic traits. In the selected promising hybrid A3 × 916 B, higher values were observed for yield/10000 larvae by number (9588) and by weight (16.84 Kg). The hybrid A3 × 935 E recorded highest average filament length (1015 m) and raw silk % (14.76%). Both the hybrids showed higher cocoon weight (1.73 g) and shell weight (0.35 g).

Both these hybrids were selected based on their percentage improvement in yield by number 9.20 to 12.38, yield by weight 7.69 to 16.03, cocoon weight 3.36 to 7.62, shell weight 9.05 to 9.34, shell ratio 1.12 to 5.99, average filament length 4.47 to 9.51, denier 1.88 to 5.09, raw silk % 10.47 to 13.21, reelability % 2.80 to 3.29 and neatness 1.45 to 2.53 points compared to the control, KA × NB4D2 (Table 1). The survival rate of the hybrids viz., A3 × 935 E (9252) and A3 × 916 B (9588) is comparable with PM × NB4D2 (9049).

After successful evaluation of these hybrids in the laboratory, these hybrids were tested at three Regional Sericultural Research Stations viz., Kodathi, Salem and Ananthapur. The results showed that the performance of the two hybrids reared at the different Regional Sericultural Research Stations during Summer and rainy were comparable with the control hybrid KA × NB4D2. However, the rainy season results of the hybrids were significantly different from those of the summer results (Table 2).

Commercial exploitation of hybrid vigour in silkworm commenced in Japan as early as 1902 (Hirobe, 1961). Subsequently, many Japanese workers have shown the importance of hybrid rearing (Yokoyama, 1957; Harada, 1949, 1961, 1969). Hybridisation studies have also been carried out in India (Krishnaswami *et al.*, 1964; Datta, 1984; Narashimhanna *et al.*, 1976; Sengupta *et al.*, 1974; Subba Rao, 1983; Ashoka and Govindan, 1990; Singh *et al.*,1990 and Rajeshekharagowda *et al.*, 1993). Higher hybrid vigour was observed in single crosses compared to three way and double crosses (Mukherjee *et al.*, 1994). Different seasons express different changes in the physical and biotic factors governing the expression of commercial characters in silkworm (Kobayashi *et al.*, 1986). Our study also showed similar results. The performance of the hybrids showed variations in respect of cocoon yield and other quantitative characters during summer and rainy seasons at the three Regional Sericultural Research Stations (Table 2). The hybrids HSP1 and HSP2 recorded cocoon yield of 43.2 Kg and 44.9 Kg during summer season when compared to 64.2 Kg and 65.9 Kg during rainy season.

Variation in different characters in spring and autumn indicating the influence of environment in the expression of heterosis was observed (Harada, 1961). In the present study, the hybrids reared during summer and late autumn at different eco-climatic regions showed distinct variation in yield and quatitative characters. The performance of these hybrids at the different Regional Sericultural Research Stations during rainy season was significantly better than those of summer results. Cocoon yield/100 dfls in HSP1 and HSP2 during summer was 43.2 Kg, 44.9 Kg against 64.2 Kg and 65.9 Kg in rainy season. Similarly the summer rearing performance in respect of cocoon weight, shell weight and shell ratio in HSP1 and HSP2 was 1.37 g, 1.33 g, 0.27 g, 0.27 g and 20.0%, 20.2% against 1.77 g, 1.75 g, 0.35 g, 0.35 g and 19.7%, 19.9% in rainy season. These results are in conformity with (Harada, 1961; Mano, 1992; Jaroonchai, 1972; Narashimhanna, 1976; Subramanya, 1985; Maribasetty, 1988; Rajanna, 1989; Kalpana, 1992; Raju, 1996). These clearly indicated the role of environment in the expression of heterosis on the economic traits.

During summer season cocoon crop loss is attributed to the occurrence of bacterial and viral diseases due to fluctuations in temperature and humidity (Savanurmath *et al.*, 1994). In the present study the hybrids HSP1 and HSP2 recorded cocoon yield of 43.2 Kg and 44.9 Kg against 39.0 Kg in KA × NB4D2 at Regional Sericultural Research Stations during summer. These results prove that the hybrids are tolerant to temperature and diseases. The Minimum and Maximum temperature and relative humidity during summer was 26°C - 33.9°C and 53.8% - 78.0%. The Minimum and Maximum temperature and relative humidity during rainy season was 27.1°C - 29.0°C and 64.0% - 70.3% respectively.

After evaluation in the laboratory and at the Regional Sericultural Research Stations these hybrids were tested with the farmers along with KA × NB4D2 and PM × NB4D2 as control during summer. The rearing performance of the new hybrids along with the control is presented in Table 3. At Salem, the average cocoon yield/100 dfls in HSP2 was 49.63 Kg against 10.72 Kg in KA × NB4D2 and 30.36 kg in PM × NB4D2. At Kodathi the yield/100 dfls in HSP1 was 40 Kg against 28.50 Kg in KA × NB4D2 and 30.57 Kg in PM × NB4D2. At Ananthapur, the yield/100 dfls in HSP1 was 46.20 Kg and

Table 2. Performance of the two hybrids at Regional Sericultural Research Stations

Centre	Season	Larval period (hrs)	Yield/ Lar No.	10,000 vae Wt. (Kg)	Yield/ 100 dfls (Kg)	Cocoon Weight (g)	Shell weight (g)	Shell ratio (%)	Average Filament length(m)	Raw silk (%)	Reela-bility (%)
	Summer Trial			**Hybrid :**	**HSP1**						
KODATHI	Apr-May'97	567	8650	12.23	48.92	1.479	0.298	20.00	631	9.05	89.6
SALEM	Apr-May'97	466	8616	12.18	48.74	1.476	0.301	20.48	852	9.65	86.6
ANANTHAPUR	Apr-May'97	524	9380	11.60	46.40	1.275	0.236	18.55	951	10.3	92.2
KODATHI	Apr-May'98	606	8424	11.06	44.24	1.408	0.300	21.30	845	13.7	86.6
SALEM	Apr-May'98	480	6180	9.33	37.33	1.485	0.295	20.17	909	15.2	87.6
ANATHAPUR	Apr-May'98	524	7732	8.43	33.72	1.108	0.216	19.49	665	12.2	91.2
	AVG	527.83	8163.67	10.81	43.22	1.372	0.274	20.00	808.83	11.68	88.97
	STD	47.93	1009.09	1.44	5.76	0.14	0.03	0.85	119.53	2.22	2.20
	CV%	9.08	12.36	13.32	13.32	10.11	12.66	4.24	14.78	19.04	2.47
	Rainy Trial			**Hybrid :**	**HSP1**						
KODATHI	Jul-Aug '97	588	8716	14.54	58.16	1.731	0.346	19.96	1047	14.5	89.5
SALEM	Jul-Aug '97	476	9860	18.80	75.22	1.902	0.394	20.72	699	10.2	76.7
ANANTHAPUR	Jul-Aug '97	498	9224	14.81	59.23	1.667	0.308	18.49	763	8.00	80.4
	AVG	520.67	9266.67	16.05	64.20	1.77	0.35	19.72	836.33	10.90	82.20
	STD	48.45	468.01	1.95	7.80	0.10	0.04	0.93	151.24	2.70	5.38
	CV%	9.31	5.05	12.15	12.15	5.63	10.09	4.69	18.08	24.76	6.54
	Summer Trial			**Hybrid :**	**HSP2**						
KODATHI	Apr-May'97	566	9364	13.80	55.22	1.519	0.303	19.95	902	10.7	87.4
SALEM	Apr-May'97	460	8520	12.36	49.45	1.420	0.286	20.17	904	8.88	88.9
ANANTHAPUR	Apr-May'97	524	9396	10.42	41.68	1.147	0.219	19.08	789	9.57	84.2
KODATHI	Apr-May'98	606	8512	10.92	43.68	1.381	0.300	21.70	739	13.5	77.6
SALEM	Apr-May'98	480	8020	11.42	45.69	1.475	0.297	20.16	865	14.3	77.9
ANANTHAPUR	Apr-May'98	524	8300	8.51	34.05	1.049	0.209	19.97	506	10.5	84.4
	AVG	526.67	8685.33	11.24	44.96	1.332	0.269	20.17	784.17	11.24	83.40
	STD	49.12	518.68	1.64	6.55	0.17	0.04	0.78	137.97	1.99	4.32
	CV%	9.33	5.97	14.57	14.57	12.99	14.62	3.85	17.59	17.67	5.18
	Rainy Trial			**Hybrid :**	**HSP2**						
KODATHI	Jul-Aug '97	588	9172	15.14	60.56	1.684	0.345	20.42	994	13.2	85.3
SALEM	Jul-Aug '97	476	9872	19.00	75.98	1.890	0.396	20.98	674	9.35	69.6
ANANTHAPUR	Jul-Aug '97	528	9208	15.34	61.38	1.678	0.310	18.47	806	10.8	86.7
	AVG	530.67	9417.33	16.49	65.97	1.751	0.350	19.95	824.67	11.12	80.53
	STD	45.76	321.83	1.77	7.09	0.10	0.04	1.08	131.30	1.59	7.75
	CV%	8.62	3.42	10.74	10.74	5.62	10.10	5.40	15.92	14.28	9.63
	Summer Trial			**Control :**	**(KA × NB4D2)**						
KODATHI	Apr-May'97	570	8988	11.89	47.56	1.430	0.293	20.40	938	9.41	88.9
SALEM	Apr-May,97	460	8416	12.10	48.42	1.393	0.279	20.03	868	8.83	87.1
ANANTHAPUR	Apr-May'97	524	9388	11.18	44.70	1.260	0.234	18.60	822	9.44	93.3
KODATHI	Apr-May'98	606	7368	9.380	37.52	1.385	0.278	20.00	668	10.9	78.6

Table 2. Continued

Centre	Season	Larval period (hrs)	Yield/ Lar No.	10,000 vae Wt. (Kg)	Yield/ 100 dfls (Kg)	Cocoon Weight (g)	Shell weight (g)	Shell ratio (%)	Average Filament length(m)	Raw silk %	Reela-bility %
	Summer Trial			**Control :**	**(KA × NB4D2)**						
SALEM	Apr-May,98	486	5916	6.80	27.20	1.255	0.239	19.06	575	11.0	70.0
ANANTHAPUR	Apr-May'98	548	7360	8.08	32.32	1.118	0.232	20.74	726	13.2	91.7
	AVG	532.37	7905.92	9.91	39.62	1.307	0.259	19.81	766.17	10.46	84.93
	STD	49.19	1167.17	1.98	7.94	0.11	0.02	0.74	123.02	1.46	8.16
	CV%	9.24	14.76	20.04	20.04	8.21	9.52	3.75	16.06	13.96	9.60
	Rainy Trial										
KODATHI	Jul-Aug '97	596	8568	15.04	60.16	1.732	0.356	20.50	937	11.2	93.7
SALEM	Jul-Aug, '97	480	9896	18.96	75.84	1.867	0.366	19.55	802	9.71	82.3
ANANTHAPUR	Jul-Aug '97	534	9208	14.47	57.89	1.605	0.294	18.30	797	11.6	83.2
	AVG	536.67	9224.00	16.16	64.63	1.735	0.339	19.45	845.33	10.84	86.40
	STD	47.39	542.27	2.00	7.98	0.11	0.03	0.90	64.85	0.81	5.17
	CV%	8.83	5.88	12.35	12.35	6.17	9.40	4.63	7.67	7.50	5.99

Table 3. Rearing performances of two bivoltine hybrids at farmers level (April - May, 1998)

Centre	Hybrid	No. of dfls	Actual yield (Kg)	Yield/100 dfls (Kg)	Rate/Kg (Rs.)	Return/1000 dfls (Rs.)
SALEM	HSP1	115	57.10	49.63	213	10571.19
SALEM	KA× NB4D2	100	10.72	10.72	206	2208.32
SALEM	PM × NB4D2	100	30.36	30.36	-	-
*				362.97		
**				63.47		
KODATHI	HSP1	100	40.00	40.00	219	8760.00
KODATHI	KA × NB4D2	25	8.50	34.00	132	4488.00
KODATHI	KA × NB4D2	75	20.00	26.66	133	3545.78
KODATHI	PM × NB4D2	100	30.57	30.57	-	-
*				40.35		
**				30.85		
ANANTAPUR	HSP1	100	46.20	46.20	500	23100.00
*				74.80		
**				48.74		
ANANTAPUR	HSP2	100	35.26	35.26	500	17630.00
*				33.41		
**				13.52		
ANANTAPUR	KA × NB4D2	100	26.43	26.43	500	13215.00
ANANTAPUR	PM × NB4D2	100	31.06	31.06		
TRG.DIV, *CSRTI*, MYSORE	*HSP1*	100	48.00	48.00	155	7440.00
T.NARSIPUR	HSP1	100	48.37	48.37	158	7642.46

*Indicates percentage improvement over KA × NB4D2 and ** PM × NB4D2

35.26 Kg in HSP2 against 26.43 Kg in KA × NB4D2 and 31.06 Kg in PM × NB4D2.

Field evaluation of these hybrids revealed that these can be reared similar to cross breed (PM × NB4D2) especially during summer season. Cocoon yield in a place is influenced not only by the season but also by many factors viz., the soil fertility, mulberry leaf quality and techniques followed during silkworm rearing (Thiagarajan, 1994). In the present study the rearing places differed in terms of eco-climatic conditions. The cocoon yield in these hybrids reared with the farmers clearly indicated the potency to withstand the temperature fluctuations. Salem, being a hot place in South India recorded an yield of 49.63 Kg against 10.71 Kg in KA × NB4D2 and 30.36 Kg in PM × NB4D2. Similarly the cocoon yield was higher in all the places tested compared to control hybrids. The hybrid HSP1 was found to be stable with an yield of 45 Kg/100 dfls with the highest yield of 49.63 Kg/100 dfls at Salem (Table 3).

Keeping in view of the field constraints and the requirement of the industry, there is a need to develop farmer friendly, easy rearing hybrids similar to cross breed. Accordingly, a breeding plan was initiated, lines isolated, hybrids prepared and evaluated in the laboratory and in the field. Based on the performance of the hybrids at the laboratory, farm and with the farmers, these hybrids can be recommended for summer and autumn rearing.

References

Ashoka, J and R. Govindan (1990) Heterosis for pupal and related traits in single and double cross hybrids of Bivoltine silkworm, *Bombyx mori* L. *Entomon.* **15**, 203-206.

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

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

Harada, C. (1949) On the hybrid effect of economic characters in the silkworm, *J. Seric. Sci. Jpn.* **18**, 120-121.

Harada, C. (1961) Heterosis of the quantitative characters in the silkworm, *Bull. Seric. Expt. Stn.* **17**, 50-52.

Harada, C. (1969) Present aspects and problem on the breeding of quantitative characters in the silkworm (JAP), *Proc. Symp. soc. Jpn. Breeding xth.* 72-77.

Hirobe, T. (1961) On the application and study of heterosis in the silkworm *Japan. J. Breed* **11**, 98-100.

Jaroonchai, J. (1972) Batch selection of Thai polyvoltine silkworm races 15K and 15KY. *Bull. Thai. Seric. Res. Train. Cent.* **2**, 56-58.

Kalpana, G. V. (1992) Breeding of superior races of silkworm, *Bombyx mori* L. for tropical climates. Ph.D thesis, Univ. of Mysore, Myosre. p 288.

Kobayashi, T., H. E. Edinuma and N. Kobayashi (1986) The effect of temperature on the diapause egg production in the tropical race of silkworm, *Bombyx mori. J. Seric. Sci. Jpn.* **55(4)**, 345-348.

Krishnaswami, S., M. S. Jolly and S. Subba Rao (1964) Diallel analysis of quantitative characters in multivoltine races of silkworm. *Indian J. Genet.* **24(3)**, 213-222.

Krishnaswami, S. (1978) New technology of silkworm rearing. Bulletin No.2 Central Silk Board, Bangalore, Ministry of Industry, Government of India, pp. 1-23.

Krishnaswami, S. and B. L. Tikoo (1971) A comparative study of the performances of the pure races currently under rearing in Mysore State. *Indian J. Seric.* **10**, 66-69.

Krishna Rao, S., M. L. Shivamallu and Venkataramu (1996) Evaluation of bivoltine races for high temperature tolerance. In : Seric Sci facing 21st Cent, Internatl. Symp Seric. Sci. Hangzhou, China. Oct 6-10, p. 90.

Mano, Y., S. Nirmal Kumar, H. K. Basavaraja, N. Malreddy and R. K. Datta (1993) A New method to select promising silkworm breeds/combinations. *Indian Silk* **31**, 53.

Maribasetty, V. G., P. J. Raju, G. S. Rajanna, G. V. Kalpana, G. Subramanya and G. Sreerama Reddy (1988) Evaluation of hardy bivoltine races of silkworm, *Bombyx mori* for tropics. *In Silkworm Breeding*. Sreerama Reddy (Ed.), pp. 102-118, Oxford and IBH, India.

Mukherjee, P. (1994) Hybrid vigour in different crossing systems in silkworm, *Bombyx mori. In Silkworm Breeding*. Sreerama Reddy (Ed.), pp. 186-196.Oxford and IBH, India.

Nagaraju, J., R. Urs and R. K. Datta (1996) Cross breeding and heterosis in the silkworm, *Bombyx mori*. A review. *Sericologia* **36**, 1-20.

Naseema Begum, A., S. K. Bhargava, M. M. Ahsan, R. K. Datta and D. Raghavendra Rao (1997) Line X Tester analysis for economic characters in the Bivoltine Silkworm, *Bombyx mori* L. *Korean J. Seric. Sci.* **39(2)**, 205-210.

Naseema Begum, A., M. M. Ahsan and R. K. Datta (1999) Breeding of two bivoltines, A3 x 935 E and A3 x 916 B of silkworm, *Bombyx mori* L for higher survival and moderate silk productivity. *Korean J. Seric. Sci.* **41(2)**, 94-101.

Narashimhanna, M. N., Chandrashekharaiah, R. G. Geetha Devi and G. Prabha (1976) Ecogenetic attributes of the newly evolved bivoltine hybrids "Nandi" in *Bombyx mori* L., *Donn-Dobzhanski. Sym. Genet.* 379-486.

Rajanna, G. S. (1989) Evolution of suitable bivoltine races of silkworm *Bombyx mori* L for tropics, Ph.D Thesis, University of Mysore, Mysore. p.231.

Raju, P. J. (1996) Studies on the hybridisation and synthesis of new breeds of silkworm, *Bombyx mori* L. Ph.D Thesis, University of Mysore, Mysore.

Rajashekharagowda, R., M. Gopalana, S. Jayaraj and N. Natarajan (1993) Heterosis in selected single cross hybrids of silkworm, *Bombyx mori* L. *J .Seric.* **1**, 50-55.

Savanurmath, C. J., S. Basavarajappa, S. B. Hinchigeri, S. S. Hingalhalli, K. K. Singh and R. D. Sanakal (1994) Relative incidence of the silkworm viral diseases in agro-climatic

zones of northern Karnataka, India. *Bull. Sericult. Res.* **5**, 51-55.

Sreerama Reddy, G. and P. J. Raju (1994) Exploitation of heterosis in silkworm, *Bombyx mori* L. In Silkworm Breeding. Sreerama Reddy (Ed.), pp. 186-196, Oxford and IBH, India.

Subramanya, G. (1985) Ecogenetic approach for the determination of high yielding breeds of silkworm, *Bombyx mori* L. Ph.D Thesis, University of Mysore, Mysore.

Subba Rao, G. (1983) Line × tester analysis of some characters in bivoltine silkworm. Abstract. *Natl. Sem. Silk. Res. and Develop. Bangalore.*.

Sengupta, K., M. R. Yusuf and S. P. Grover (1974) Hybrid vigour and Genetics analysis of quantitative traits in silkworm, *Bombyx mori* L. *Indian J. Genet.* **34A,** 249-256.

Singh Ravindra, J. Nagaraju, P. Rama Mohana Rao, V. Premalatha, K. Vijayaraghavan and S. K. Gupta (1990) Heterosis analysis in the silkworm, *Bombyx mori* L. *Sericologia* **30(3)**, 293-300.

Thiagarajan, V., S. Masilamani, M. M. Ahsan and R. K. Datta (1994) Stability analysis of economic traits in silkworm (*Bombyx mori*. L). *J. Genet. Breed.* **48**, 345-352.

Tazima, Y. (1988) A view point on the improvement of Mysore breeds. *Proc. Internatl. Congr. for Trop. Seric., Bangalore, India*, part IV, pp 1-5.

Toyama (1906) Breeding method of silkworm (Jap). *Sangyo Simpo.* **158**, 283-286.

Yokoyama, T. (1957) On the application of heterosis in Japanese sericulturr. Proc.Int.Genet.Symp.Supp.Vol. *Cytologia* 527-531