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Evaluation of F_1 Hybrids Between RD_1 and Bivoltine Breeds of the Silkworm (*Bombyx mori* L.) for Exploitation in Dry Zones

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With the main objective to know the feasibility of exploitation of F_1 hybrids in semi arid and arid climatic conditions of India, the present study was carried out by utilising RD_1 as female parent and six bivoltine silkworm breeds *viz.*, CSR_2, CSR_4, CSR_5, CSR_{17}, CSR_{18} and CSR_{19} along with NB_4D_2 as male parents. Different hybrids exhibited their superiority for various economic characters during different seasons. Among F_1 hybrids, $RD_1 \times CSR_5$ was adjudicated as the best hybrid in terms of expression of significant positive hybrid vigour over mid parental value for five economic characters namely hatching %, cocoon yield, cocoon weight, cocoon shell weight and filament size, highest multiple trait average evaluation index value of 56.77 and comparatively uniform cocoon size with coefficient of variation (CV%) of 3.80 and Standard Deviation (SD) of 7.99 during September - October 2003. Results of the present study revealed that the F_1 hybrid $RD_1 \times CSR_5$ can be successfully exploited on commercial in semi arid and arid climatic conditions in India.

Key words: *Bombyx mori* L., Hybrid vigour, Mulitiple trait evaluation index, Cocoon size variability

Introduction

Extensive studies have been made on the utilization of hybrid vigour in silkworm (Tayade, 1987; Nagaraju *et al.*, 1989; Subba Rao and Sahai, 1989; Ravindra Singh *et al.*, 1990, 1992, 1994, 1998a; Raghavendra Rao *et al.*, 2001; Narayanswamy *et al.*, 2002a; Rajanna and Puttaraju, 1998). In India, till 1920s, pure polyvoltine silkworm breeds were exploited for silk production on gangetic plains of West Bengal and some parts of South India. PM × C.Nichi and PM × HS_6 were commonly used hybrids. PM × C.Nichi is still reared in rainfed areas of Chamarajanagar. Some efforts were made and a few polivoltine breeds like MY_1, PCN, G were developed (Sengupta *et al.*, 1974; Datta, 1984).

It is very important to evaluate silkworm breeds / hybrids which can perform well and produce better cocoon yield even under fluctuating eco-climatic conditions (Rao *et al.*, 1998). During the recent years, some attempts were made on the evaluation of poltivoltine × bivoltine (Rajanna *et al.*, 1999; Ravindra Singh *et al.*, 2001; Mal Reddy *et al.*, 2002; Raghavendna Rao *et al.*, 2003). Attempts have been made on variability in cocoon size in parental silkworm breeds and hybrids (Nakada, 1994, 1998; Ravindra singh *et al.*, 1998b). Information on evaluation of robust polyvoltine × bivoltine hybrids adaptable to semi and arid conditions of South India is meagre (Rajanna *et al.*, 1999). With the main objective to improve cocoon characters, evaluate and identify promising F_1 polyvoline × bivoltine hybrids adaptable to dry zones and to know the variability in cocoon size in F_1 hybrids, the present study was carried out in Multivoltine Breeding Laboratory at Central Sericultural Research and Training Institute, Mysore.

Materials and Methods

The present study on heterosis in F_1 hybrids between RD_1 and CSR breeds was carried out at Multivoltine Breeding Laboratory, Central Sericultural Research & Training Institute, Mysore. Three polyvoltine silkworm breeds *viz.*,

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RD_1, Pure Mysore and C.Nichi were utilized in the present study. RD_1 was crossed with six bivoltine breeds namely CSR_2, CSR_4, CSR_5, CSR_{17}, CSR_{18} and CSR_{19} along with NB_4D_2. Rearing of these breeds / hybrids were conducted twice during the month of September - October and November - December, 2003. PM × C.Nichi was reared as control. Three replications were reared in each breed / hybrid and 300 larvae were retained after III moult. Rearing of young age silkworms was carried out at 28 ± 1°C room temperature and 85 ± 5% relative humidity (R.H.). Similarly, the rearing of late age silkworms was carried out at 25 ± 1°C room temperature and 75 ± 5% relative humidity (R.H.). Data were recorded for hatching %, 5th instar larval duration, total larval duration, yield/10,000 larvae both by number and weight, cocoon weight, cocoon shell weight, cocoon shell ratio, renditta, raw silk % and filament length.

Heterosis over mid parent (MPH) and Better parent (BPH) was calculated by using the following formulae:

$$MPH = 100 \times (F1 - MPV)/MPV$$
$$BPH = 100 \times (F1 - BPV)/BPV$$

Where MPV and BPV refer to mid parent value and better parent value respectively.

Evaluation of promising F_1 hybrids was done through Multiple Trait Evaluation method suggested by Mano *et al.* (1993). Evaluation index (E. I.) for different characters was calculated by using the following formula:

$$E.\ I. = A - B/C \times 10 + 50$$

Where, A = Value obtained for a particular trait of a particular hybrid combination
B = Mean value of particular trait of all the hybrid combination
C = Standard deviation of particular trait of all the hybrid combinations
10 = Standard unit
50 = Fixed value

In order to know the variability in cocoon shape of F_1 hybrids, 100 cocoons were randomly picked up and three cocoon shape variables *viz.*, cocoon length, cocoon width and length / width ratio were determined. Length / width ratio was determined by following formula:

$$100 \times \text{Length} / \text{Width}$$

Measurement of cocoon length and cocoon width was done by using Vernier Callipers. Variability in cocoon shape was determined on the basis of standard deviation (SD). F_1 hybrids possessing less standard deviation and coefficient of variation (CV %) were considered uniform in cocoon shape.

Results

Performance of F_1 hybrids between RD_1 and bivoltine breeds

Promising F_1 hybrids between RD_1 and NB_4D_2 along with PM × C.Nichi (Control) were reared during September October and November - December, 2003 and data are presented in Table 1.

Total larval span (h): All the hybrids recorded shorter larval span of 456 hrs whereas in control PM × C.Nichi, it was 483 hrs during September - October, 2003. Larval span was 486 hrs in F_1 hybrids as against 504 hrs in control PM × C.Nichi during November - December, 2003.

Pupation rate: During September - October, $RD_1 \times CSR_4$

Table 1. Average performance of promising F_1 hybrids during September - October and November - December, 2003

Hybrid	Hatching %	Pupation rate	Yield/ 10,000 larvae (kg)	Cocoon weight (g)	Shell weight (cg)	Shell ratio %	Filament length (m)	Raw silk (%)	Reela-bility (%)	Neat ness (p)	Denier
September - October											
$RD_1 \times NB_4D_2$	96.8	83.0	14.5	1.71	30.0	17.5	704	13.11	83	87	2.88
$RD_1 \times CSR_5$	98.7	95.5	17.2	1.74	32.1	18.6	715	14.56	84	86	2.97
PM × C.Nichi	96.9	97.7	11.9	1.21	16.2	13.4	525	9.01	83	86	2.26
November - December											
$RD_1 \times NB_4D_2$	95.3	93.3	13.3	1.38	23.8	17.3	710	13.24	84	86	2.51
$RD_1 \times CSR_5$	97.1	94.0	13.9	1.45	26.1	18.2	660	13.18	85	86	2.49
PM × C.Nichi	91.1	91.2	9.9	1.09	14.2	13.0	352	7.52	82	84	2.13

recorded the highest pupation rate (98.5%) followed by control PM × C.Nichi (97.7%) and $RD_1 \times CSR_5$ and $RD_1 \times CSR_{19}$ where it was 95.5%. $RD_1 \times CSR_{19}$ recorded maximum pupation rate of 97.3% followed by $RD_1 \times CSR_2$ (94.9%) and $RD_1 \times CSR_4$ (94.3%) during November December, 2003.

Yield/10,000 larvae by weight (kg): $RD_1 \times CSR_5$ exhibited maximum cocoon yield/10,000 larvae by weight (17.2 kg) followed by $RD_1 \times CSR_2$ (16.8 kg) and $RD_1 \times CSR_4$ (18.4 kg) during September - October, 2003. $RD_1 \times CSR_4$ recorded maximum cocoon yield (15.1 kg) followed by $RD_1 \times CSR_2$ (14.7 kg) and $RD_1 \times CSR_{17}$ (14.3 kg) during November December, 2003.

Cocoon weight (g): During September - October, maximum cocoon weight of 1.75 g was obtained in $RD_1 \times CSR_2$ followed by $RD_1 \times CSR_{17}$ (1.75 g) and $RD_1 \times CSR_5$ (1.72 g). During November - December, $RD_1 \times CSR_{17}$ recorded maximum cocoon weight (1.56 g) followed $RD_1 \times CSR_2$ (1.56 g) and $RD_1 \times CSR_4$ (1.54 g).

Cocoon shell weight (cg): Maximum cocoon shell weight of 30.8 cg was recorded in $RD_1 \times CSR_2$ and $RD_1 \times CSR_{17}$ followed by $RD_1 \times CSR_{18}$ (30.6 cg) and $RD_1 \times NB_4D_2$ (30.0 cg) during September - October. Hybrids showing maximum cocoon shell weight in succession were $RD_1 \times CSR_{17}$ (28.5 cg), $RD_1 \times CSR_5$ (26.1 cg) and $RD_1 \times CSR_{18}$ (26.0 cg) during November - December, 2003.

Cocoon shell ratio: During September - October, $RD_1 \times CSR_{18}$ recorded the highest cocoon shell ratio (18.7%) followed by $RD_1 \times CSR_5$ (18.6%) and $RD_1 \times CSR_4$ and $RD_1 \times CSR_{19}$ (18.2%). During November - December, $RD_1 \times CSR_{17}$ exhibited the highest cocoon shell ratio (18.2%) followed by $RD_1 \times CSR_5$ (18.2%) and $RD_1 \times CSR_{19}$ (17.5%) respectively.

Filament length: During both the seasons, longer filament length was observed in $RD_1 \times CSR_{18}$ which varied in the range of 858 m and 834 m during September October and November - December respectively. Other hybrids showing longer filament length were $RD_1 \times CSR_2$ (718 m) and $RD_1 \times CSR_5$ (715 m) during September - October and $RD_1 \times NB_4D_2$ (710 m) during November - December.

Raw Silk Percentage: During September - October, maximum raw silk percentage was observed in $RD_1 \times CSR_5$ (14.55%) followed by $RD_1 \times CSR_{18}$ (13.72%) and $RD_1 \times NB_4D_2$ (13.11%). During November - December, two hybrids $RD_1 \times CSR_{17}$ and $RD_1 \times CSR_{18}$ recorded maximum raw silk percentage of 13.22% followed by $RD_1 \times NB_4D_2$ (13.24%) and $RD_1 \times CSR_5$ (13.17%).

Reelability: $RD_1 \times CSR_2$ recorded maximum reelability percentage of 87 in both seasons. $RD_1 \times CSR_{17}$ expressed 86% and $RD_1 \times CSR_{18}$ exhibited 84% reelability during September - October. During November - December, $RD_1 \times CSR_5$ showed 85% and $RD_1 \times CSR_4$ recorded 84% reelability.

Studies on analysis of hybrid vigour

Hybrid vigour over mid parent and better parent value for some important characters in promising F_1 hybrids between RD_1 and NB_4D_2 and CSR_5 along with control PM × C. Nichi during September - October and November - December, 2003 have been presented in Table 2.

Yield/10,000 larvae by weight: During both the seasons, maximum and highly significant ($P < 0.01$) heterosis was recorded by $RD_1 \times CSR_5$ (38.22 and 38.99%) and (35.75 and 24.51%) over mid parent and better parent value respectively. Three hybrids *viz.*, $RD_1 \times CSR_{18}$, $RD_1 \times CSR_{19}$ and $RD_1 \times CSR_4$ recorded higher and significant ($P < 0.01$) hybrid vigour over mid parent value in the range of 32.78, 32.24 and 29.45% respectively.

Cocoon weight: During both the seasons, $RD_1 \times CSR_5$ recorded maximum and highly significant ($P < 0.01$) hybrid vigour over mid parent value (26.02 and 22.34%) and better parent value (22.36 and 6.93%) respectively. During September - October, hybrids with highly significant ($P < 0.01$) hybrid vigour were $RD_1 \times CSR_{18}$ (22.03 and 20.68%) and $RD_1 \times CSR_2$ (21.72 and 13.03%) over mid parent and better parent values respectively. Besides, three hybrids *viz.*, $RD_1 \times CSR_{17}$, $RD_1 \times CSR_4$ and $RD_1 \times CSR_{18}$ showed highly significant ($P < 0.01$) hybrid vigour over mid parent value in the range of 21.18, 19.28 and 18.28% respectively during November - December, 2003.

Cocoon shell weight: $RD_1 \times CSR_{18}$ recorded the highest and highly significant ($P < 0.01$) hybrid vigour for cocoon shell weight over mid parent value (33.04%) followed by $RD_1 \times CSR_5$ (23.70%) and $RD_1 \times CSR_2$ (19.46%) during September - October. During November - December, $RD_1 \times CSR_5$ and $RD_1 \times CSR_{18}$ expressed the highest and significant hybrid vigour over mid parent value in the range of 17.74 and 16.50% respectively.

Cocoon shell ratio: During September - October, the highest and highly significant ($P < 0.01$) hybrid vigour for cocoon shell ratio was recorded by $RD_1 \times CSR_{18}$ (9.32%) followed by $RD_1 \times CSR_4$ (3.74%) and $RD_1 \times CSR_{19}$ (2.25%). During November - December, hybrids exhibiting highly significant ($P < 0.01$) hybrid vigour were $RD_1 \times CSR_{19}$ (4.82%), $RD_1 \times NB_4D_2$ (3.80%) and $RD_1 \times CSR_{18}$ (3.17%) respectively.

Filament length: During both the seasons, $RD_1 \times CSR_{18}$ revealed maximum hybrid vigour for filament length over mid parent value in the range of 52.90 and 36.39% during September - October and November - December respectively. $RD_1 \times CSR_2$ and $RD_1 \times NB_4D_2$ recorded highly significant ($P < 0.01$) hybrid vigour over mid parent value in the range of 22.77 and 19.79% respectively during November - December, 2003.

Table 2. Heterosis over mid parent value and better parent value in promising F_1 hybrids during September - October and November - December, 2003

Hybrid	Hatch-ing %	Total larval duratio	5th age larval duratio	Pupa-tion Rate	Yiled/ 10,000 larvae	Cocoon weight	Shell weight	Shell ratio	Filament length	Raw silk	Reel-ability	Neat-ness	Denier
September - October													
$RD_1 \times NB_4D_2$													
MPH	1.13	-3.18	-2.56	-11.10	7.10	15.74**	15.24**	1.94**	15.41	15.34	3.14	2.35	26.22**
BPH	-1.12	-1.30	0.00	-12.94	-2.25	4.94	-13.21	-17.19	-19.36	-14.50	1.61	-2.97	83.83
$RD_1 \times CSR_5$													
MPH	3.21*	-7.88	-5.00	2.86	38.22*	26.02**	23.70**	-1.45**	9.95	11.68	5.57	0.19	26.47**
BPH	0.95	-1.30	0.00	0.17	35.75*	22.36**	-6.69	-24.23	-25.00	-22.03	2.54	-5.84	89.57
PM × C.Nichi													
MPH	-0.51	-6.40	-26.67	10.50	28.39	15.49	11.60	-2.66	43.64	24.94	9.43	3.22	27.92
BPH	-1.86	0.63	-17.50	6.42	26.70	11.80	-3.95	-13.92	43.31	8.12	9.39	2.60	55.15
November - December													
$RD_1 \times NB_4D_2$													
MPH	-0.45	-2.41	0.00	4.33	21.95	12.97	12.95**	3.80**	19.79**	16.18**	4.69	-0.77	11.49**
BPH	-1.95	0.00	0.00	4.32	2.97	-3.35	-18.93	-16.29	-17.56	-15.55	2.24	-5.17	63.12
$RD_1 \times CSR_5$													
MPH	1.82	-5.20	2.22	10.66	38.99**	22.34**	17.74**	0.92**	9.09	1.18	6.60	-1.53	6.57**
BPH	0.66	-3.53**	9.52**	5.09	24.51**	6.93**	-17.23	-22.15	-25.48	-30.40	3.53	-6.55	61.82
PM × C.Nichi													
MPH	3.35	-4.00	-11.59	9.69	25.20	15.24	10.25	-3.39	-1.12	4.23	7.45	5.20	22.06
BPH	0.00	5.00	27.08	8.92	11.38	6.03	-6.39	-11.58	-4.43	-10.01	6.53	4.55	45.89

*;** denotes significantly different at 5% & 1% respectively.

Table 3. Evaluation index values for different characters in F_1 hybrids between RD_1 and CSR breeds during September - October and November - December, 2003

Hybrid	Hatch ing %	Pupa tion rate	Yield/ 10,000 larvae (kg)	Cocoon weight (g)	Shell weight (g)	Shell ratio %	Filament length (m)	Raw silk (%)	Reel-ability %	Neat-ness (p)	Denier	AVI
September - October												
$RD_1 \times NB_4D_2$	53.54	31.19	45.65	55.14	52.85	50.20	52.88	55.77	49.02	60.79	58.79	51.52
$RD_1 \times CSR_2$	53.54	53.36	58.76	57.24	54.41	50.78	54.31	47.53	64.16	47.51	46.70	54.05
$RD_1 \times CSR_4$	53.54	60.22	56.56	50.14	52.06	54.49	45.20	53.58	34.42	54.15	61.17	51.23
$RD_1 \times CSR_5$	53.54	54.60	61.34	55.81	56.96	56.63	53.95	63.80	52.15	47.51	62.09	56.77
$RD_1 \times CSR_{17}$	53.54	47.74	52.34	57.02	54.41	50.39	47.44	44.61	61.11	40.87	51.47	50.85
$RD_1 \times CSRx_{18}$	53.54	39.62	46.41	50.98	54.02	57.22	68.55	59.16	51.30	40.87	39.38	50.92
$RD_1 \times CSR_{19}$	53.54	54.60	49.28	46.59	49.45	54.10	43.01	42.55	38.82	67.43	44.32	49.72
PM × C.Nichi	25.25	58.66	29.66	27.08	25.84	26.20	34.67	33.00	49.02	40.87	36.08	34.93
November - December												
$RD_1 \times NB_4D_2$	29.42	47.52	47.59	46.87	49.32	52.66	53.09	54.99	45.79	54.44	54.10	48.98
$RD_1 \times CSR_2$	47.5	55.49	56.67	58.15	52.88	49.03	59.45	52.17	68.62	54.44	42.18	54.31
$RD_1 \times CSR_4$	56.17	52.65	58.85	57.15	53.50	48.83	49.46	53.11	50.57	54.44	63.63	53.80
$RD_1 \times CSR_5$	49.76	50.94	51.86	51.32	54.59	57.91	49.65	54.68	53.71	54.44	53.20	52.55
$RD_1 \times CSR_{17}$	47.88	37.81	54.13	58.41	60.08	58.31	51.08	54.91	50.02	54.44	62.14	54.48
$RD_1 \times CSR_{18}$	55.42	50.96	53.37	54.50	54.35	52.86	61.55	54.91	49.52	54.44	39.35	52.41
$RD_1 \times CSR_{19}$	64.08	68.06	50.76	44.91	48.39	53.59	47.12	49.52	49.70	47.34	48.14	52.24
PM × C.Nichi	49.76	36.58	26.78	28.69	26.88	26.81	28.60	25.70	32.07	26.03	37.27	31.23

Studies on multiple trait evaluation index

Evaluation index for different characters in F_1 hybrids between RD_1 and CSR breeds during September - October and November - December, 2003 have been presented in Table 3.

It is clear from the Tables that $RD_1 \times CSR_5$ revealed maximum average evaluation index value of 56.77 followed by $RD_1 \times CSR_2$ (54.05) and $RD_1 \times NB_4D_2$ (51.52) during September - October (Table 3). During November - December, $RD_1 \times CSR_{17}$ expressed the highest average evaluation index value of 54.48 followed $RD_1 \times CSR_2$ (54.31) and $RD_1 \times CSR_4$ (53.80) respectively (Table 3).

Studies on cocoon size variability in F_1 hybrids

Cocoon shape variability in F_1 hybrids between RD_1 and CSR breeds during September - October and November - December have been presented in Table 4. Cocoon size variability for three variables cocoon length, cocoon width and cocoon length / width ratio were carried out. Results along with standard deviation and coefficient of variation are mentioned briefly as follows:

Cocoon length: During September - October, cocoon length in F_1 hybrids ranged from 32.23 to 37.42 mm whereas it ranged from 31.24 to 34.81 mm during November - December. $RD_1 \times CSR_5$ expressed the highest value for cocoon length (37.42 mm) followed by $RD_1 \times NB_4D_2$ (36.63 mm) during September - October but during November - December, $RD_1 \times CSR_4$ expressed the highest cocoon length (34.81 mm) followed by $RD_1 \times NB_4D_2$ (34.77 mm).

Cocoon width: During both the seasons, $RD_1 \times CSR_2$ recorded highest cocoon width of 21.05 mm and 19.75 mm during September - October and November - December respectively. Minimum cocoon width was recorded in control PM × C.Nichi 15.99 mm and 14.97 mm during September - October and November - December respectively.

Length / width ratio: The length / width ratio ranged from 163.44 to 209.75 and 167.97 to 208.56 during September - October and November - December respectively. During September - October, maximum value for length/width ratio was observed in $RD_1 \times CSR_5$ (209.75) and minimum was recorded in $RD_1 \times CSR_2$ (163.44). During November - December, maximum value was recorded in control PM × C.Nichi (208.56) and minimum was recorded again in $RD_1 \times CSR_2$ (167.97).

Standard deviation and coefficient of variation: Standard deviation calculated for cocoon length/width ratio in F_1 hybrids ranged from 6.51 in $RD_1 \times CSR_2$ to 16.56 in control PM × C.Nichi during September - October. During November - December, standard deviation ranged from 7.37 in $RD_1 \times CSR_2$ to 10.68 in the control PM × C.Nichi.

Table 4. Cocoon size variability in F_1 hybrids between RD_1 & CSR breeds during September - October and November - December, 2003

Hybrid	Cocoon length (mm)	Cocoon width (mm)	Length/width ratio	Coefficient of variation
September - October				
$RD_1 \times CSR_2$	34.42 ± 0.97	21.05 ± 0.80	163.44 ± 6.51	3.98
$RD_1 \times CSR_4$	36.22 ± 1.09	17.82 ± 0.72	203.72 ± 10.13	4.97
$RD_1 \times CSR_5$	37.42 ± 0.88	17.85 ± 0.62	209.75 ± 7.99	3.80
$RD_1 \times CSR_{17}$	34.47 ± 1.19	19.95 ± 0.75	172.80 ± 8.07	4.67
$RD_1 \times CSR_{18}$	34.79 ± 1.14	20.30 ± 1.04	171.91 ± 7.41	4.31
$RD_1 \times CSR_{19}$	35.73 ± 1.20	17.44 ± 0.82	205.09 ± 9.70	4.73
$RD_1 \times NB_4D_2$	36.63 ± 1.02	17.60 ± 0.53	208.85 ± 7.61	3.64
PM × C.Nichi	32.23 ± 1.70	15.99 ± 0.61	200.70 ± 16.56	8.25
November - December				
$RD_1 \times CSR_2$	33.08 ± 1.10	19.75 ± 1.07	167.97 ± 7.37	4.38
$RD_1 \times CSR_4$	34.81 ± 1.30	17.05 ± 0.52	204.19 ± 8.51	4.16
$RD_1 \times CSR_5$	34.66 ± 1.10	17.18 ± 0.77	202.14 ± 9.30	4.60
$RD_1 \times CSR_{17}$	33.11 ± 0.99	19.66 ± 0.96	169.00 ± 8.40	4.97
$RD_1 \times CSR_{18}$	32.41 ± 0.88	19.30 ± 0.88	168.33 ± 8.51	5.05
$RD_1 \times CSR_{19}$	33.81 ± 1.37	17.15 ± 0.71	197.22 ± 9.09	4.10
$RD_1 \times NB_4D_2$	34.77 ± 1.14	16.72 ± 0.59	207.84 ± 9.29	4.47
PM × C.Nichi	31.24 ± 1.10	14.97 ± 0.65	208.56 ± 10.68	5.12

Data are mean ± SD of 100 cocoons. Cocoon width was measured in the central region.

Minimum coefficient of variation (3.64) was recorded in $RD_1 \times NB_4D_2$ and maximum (8.25) in PM × C.Nichi during September - October whereas minimum CV% was observed in $RD_1 \times CSR_{19}$ (4.10) and maximum (5.12) in control PM × C.Nichi.

Discussion

As only hybrids are exploited commercially in silkworm, proper evaluation of hybrids which give stable cocoon crops even under fluctuating eco-climatic conditions is very important (Rao *et al.,* 1998). Though some attempts have been made on evaluation of polyvoltine and bivoltine hybrids (Rao *et al.*, 1998; Rajanna *et al.*, 1999; Ravindra Singh *et al.*, 2001; Mal Reddy *et al.*, 2002; Raghavendra Rao *et al.*, 2003), little information is available on the evaluation of robust polyvoltine × bivoltine hybrids adaptable to semi and arid conditions of South India.

In the present study, F_1 hybrids between RD_1 and bivoltine breeds authorised by Central Silk Board were reared in two different seasons and their performance has been compared. Different hybrids exhibited their superiority during different seasons for different characters. During September - October, 2003, $RD_1 \times CSR_5$ yielded maximum yield in terms of cocoon yield/10,000 larvae by weight and cocoon shell weight followed by $RD_1 \times CSR_2$ in terms of cocoon weight, cocoon shell weight and reelability. During November - December, $RD_1 \times CSR_{17}$ excelled in terms of cocoon weight, cocoon shell weight and cocoon shell ratio followed by $RD_1 \times CSR_{19}$ for hatching percentage and pupation rate. Comparative performance of polyvoltine × bivoltine hybrids during different seasons has been studied (Roy *et al.*, 1997; Rajanna *et al.*, 1999; Ravindra Singh *et al.*, 2001). Hybrid vigour study demonstrated that different hybrids exhibited significant positive heterosis for different economic characters in two seasons. It was interesting to note that during September - October, $RD_1 \times CSR_5$ expressed significant positive heterosis over mid parental value for five characters namely hatching %, cocoon yield, cocoon weight, cocoon shell weight and filament size followed by $RD_1 \times CSR_{19}$ and $RD_1 \times NB_4D_2$ expressing highly significant heterosis for four characters. During November - December, $RD_1 \times CSR_{18}$ showed its superiority by exhibiting significant positive hybrid for eight characters like hatching%, cocoon yield, cocoon weight, cocoon shell weight, cocoon shell ratio, filament length, raw silk% and denier followed by $RD_1 \times CSR_5$, $RD_1 \times CSR_{19}$ and $RD_1 \times NB_4D_2$ which expressed significant positive heterosis for five economic characters. Tayade (1987) has reported high heterosis for cocoon weight, cocoon shell weight, and cocoon yield in Hosa Mysore × NB_4D_2. Significant high heterosis for cocoon weight, cocoon shell weight and daily cocoon shell weight in 5th instar as well as higher hybrid vigour in polyvoltine × bivoltine hybrids have been observed as compared to bivoltine × bivoltine hybrids (Ravindra Singh *et al.*, 1998a). High hybrid vigour for cocoon weight, cocoon shell weight has been reported in a hybrid between recessive trimoulter and tetramoulter silkworm (Ravindra Singh *et al.*, 1990) and in hybrid between a parthenote and bisexual silkworm breed (Ravindra singh *et al.*, 1994). Rao *et al.* (1998) have reported high heterosis for cocoon weight and cocoon shell weight in F_1 hybrids between polyvoltine and bivoltine breeds.

Studies on multiple trait evaluation revealed that $RD_1 \times CSR_5$ with highest average evaluation index value of 56.77 was found promising followed by $RD_1 \times CSR_2$ (54.02) and $RD_1 \times NB_4D_2$ (51.52) during September - October. During November - December, $RD_1 \times CSR_{17}$ was adjudicated as most promising hybrid with average evaluation index of 54.48 followed by $RD_1 \times CSR_2$ (54.31) and $RD_1 \times CSR_4$ (53.80) respectively. Multiple trait evaluation index method advocated by Mano *et al.* (1993) has been used by several workers in order to identify promising polyvoltione × bivoltine hybrids (Vidyamala *et al.*, 1998; Mal Reddy *et al.*, 2002; Narayanswamy *et al.*, 2002b).

In the present study, two hybrids $RD_1 \times NB_4D_2$ and $RD_1 \times CSR_5$ exhibited less CV% of 3.60 and 3.80 and SD of 7.61 and 7.99 respectively during September - October were found relatively uniform in cocoon size. During November - December, two hybrids *viz.,* $RD_1 \times CSR_{19}$ and $RD_1 \times CSR_4$ exhibiting less CV% of 4.10 and 4.16 respectively were found relatively uniform in cocoon size though their SD values were more than 8. Cocoon size variability has been studied in F_1 hybrid between polyvoltine × bivoltine hybrids (Ravindra Singh *et al.*, 1998b, 2001; Mal Reddy *et al.,* 2002; Raghavendra Rao *et al,* 2003).

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