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Development of Polyvoltine×Bivoltine Hybrids of Mulberry Silkworm, *Bombyx mori* L. Tolerant to BmNPV

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ABSTRACT

In the silkworm rearing, the usage of commercial silkworm hybrids resistant/tolerant to silkworm diseases is economical and better option particularly in tropical countries, where inadequate disinfection methods are practiced. Among the major silkworm diseases, grasserie caused by *Bombyx mori* Nuclear Polyhedrosis Virus (BmNPV) is controlled by polygens. In the present study, an attempt was made to develop BmNPV tolerant polyvoltine × bivoltine hybrids by utilizing newly evolved BmNPV tolerant polyvoltine breeds viz., AKP 1, AKP 2 and AKP 3 as lines and bivoltine breeds viz., AKB 6, AKB 7 and AKB 8 as testers by employing Line×Tester analysis. Nine hybrid combinations were compared with the control hybrids viz., Pure Mysore×CSR 2 and APM 1×APS 8. Total score of positive traits of Specific Combing Ability (SCA), mid Parental Heterosis (MPH) and Better Parent Heterosis (BPH) was observed maximum in case of AKP 1×AKB 6 with 20 fallowed by AKP 1×AKB 8 (19), AKP 2×AKB 7 (13), AKP 3×AKB 6 (13). Least total score was observed in the case of AKP 1×AKB 7. Based upon the total scores (SCA, MPH and BPH), over dominance and E.I values, AKP 1×AKB 6 and AKP 1×AKB 8 were identified as promising tolerant hybrids against BmNPV with productive merits. These tolerant hybrids can be suggested to the farmers for utilization after conducting large scale trials.

Key words: BmNPV, *Bombyx mori* L., polyvoltines, bivoltines, polyvoltine×bivoltine hybrids

INTRODUCTION

Silkworm diseases form major constraint in realizing full potential of the silkworm hybrids. Among all the silkworm diseases that cause damage, viral diseases are most serious (Samson *et al.*, 1990; Subba *et al.*, 1991; Sivaprakasam and Rabindra, 1995). Nuclear polyhedrosis (BmNPV) belongs to Baculoviridae, causes nuclear polyhedrosis (grasserie) in silkworms which is most common viral disease and is prevalent in almost all the sericulture areas in India. Grasserie disease accounts for about 50% of total crop loss due to viral diseases (Samson, 1992).

Under above circumstances, among many measures of silkworm disease control and prevention, the utilization of disease resistant/tolerant silkworm breed/hybrid along with the disinfection would be the most effective step in the direction of the disease prevention (Sivaprasad and Chandrashekharaiah, 2003). Breeding as an important tool has been used by many breeders for exploiting the inherent heterosis. The aim of the most breeding programmes is to improve the yield potential of the breeds/hybrids over the existing which has played a vital role in increasing the productivity in sericulture (Reddy *et al*., 2008, 2009a-c, 2010a; Seshagiri *et al*., 2009). Silkworm hybrids show improved reeling performances over pure races (Reddy *et al*., 2010b, 2009c). The silkworm *Bombyx mori* L. forms one of the very important insects of choice with large number of strains which is best exemplified for utilization of heterosis by crossing them in different combinations (Datta and Nagaraju, 1987).

Though, inter-strain/breed differences in susceptibility or relative tolerance to a number of silkworm viruses have been reported (Watanabe, 1987; Nataraju, 1995; Sen *et al*., 1997, 2000; Jiang *et al*., 1997; Sivaprasad *et al*., 1997; Flora *et al*., 2000; Sivaprasad *et al*., 2003; Sivaprasad and Chandrashekharaiah, 2003). But, only a handful of silkworm hybrids viz., Tasei (Japan), Kong 1 (China) and Kalpatharuvu, Hemavathy and Swarnandhra (India) were identified for resistance to the BmDNV 1 (Huang, 1986; Watanabe, 1994; Sivaprasad *et al*., 2003).

However, no report is available on development of polyvoltine×bivoltine silkworm hybrids tolerant to BmNPV, especially under Indian tropical conditions. Thus, in the present study an attempt was made to develop BmNPV tolerant cross breed for commercial exploitation.

MATERIALS AND METHODS

The study was carried out in the year 2008-09 at Andhra Pradesh State Sericulture Research and Development Institute, Hindupur, A.P., India. Newly evolved BmNPV tolerant breeds, three polyvoltines (AKP 1, AKP 2 and AKP 3) as lines and three bivoltines (AKB 6, AKB 7 and AKB 8) as testers were utilized for the present study. By employing the Line×Tester analysis method, a total of nine new hybrid combinations (AKP 1×AKB 6, AKP 1×AKB 7, AKP 1×AKB 8, AKP 2×AKB 6, AKP 2×AKB 7, AKP 2×AKB 8, AKP 3×AKB 6, AKP 3×AKB 7 and AKP 3×AKB 8) were prepared. These were challenged with the BmNPV at 1×10^{7} PIB mL^{-1} in newly moulted out III instar larvae and reared in three replications containing 300 larvae each by following the standard rearing techniques. The experiment was repeated for three times and the genetic expression of the hybrids on eight economic traits [fecundity, cocoon yield per 10,000 larvae by number, cocoon yield per 10,000 larvae by weight (kg), survival rate (%), cocoon weight (g), cocoon shell weight (g), cocoon shell ratio (%) and filament length (m)] were recorded and compared with control hybrids (PM×CSR 2 and APM 1×APS 8).

The average data was subjected to statistical methods (ANOVA) to find out the manifestation of heterosis and over dominance (Harada, 1961) with respect to each one of the traits. Further, General Combining Ability (GCA) of the lines and testers as well as the Specific Combining Ability (SCA) of the hybrids were analyzed to understand the performance of the newly evolved lines.

To evaluate the performance on multiple traits, all the hybrid combinations were subjected to Evaluation Index (EI) method. The indices were calculated for each of the selected traits and arrived at average cumulative index over the eight economic traits. Based on these values, the hybrid combinations were assigned ranks in descending order. The percentage improvement in the eight economic traits of newly developed tolerant hybrids over controls, APM 1×APS 8 and PM×CSR 2 was studied. Evaluation Index, number of traits with positive SCA, number of traits with positive mid parent heterosis and number of traits with positive overdominance and total score of positive SCA, MPH and BPH exhibited by each of the nine hybrid combinations were compiled for ultimate identification of promising hybrids (Goel, 2008).

RESULTS

Analysis of variance for combining ability recorded for 8 characters showed distinct variations among the parents, lines, testers, lines vs., testers, parents vs., hybrids and hybrids (Table 1). A

Table 1: ANOVA for combining ability for 8 characters in the silkworm, *B. mori* L.

Source of variations	df	Fecundity	Yield per 10,000 larvae No.	Yield per 10,000 larvae Wt.	Survival	Cocoon weight	Shell weight	Shell ratio	Filament length
Replications	2	304.956	10559.089	0.0480	0.842	0.000	0.000	0.063	219.800
Treatments	14	996.127**	236210.079**	4.656**	40.850**	0.036**	0.003**	5.676**	16403.086**
Parents	5	1179.289**	378328.856**	3.123**	48.339**	0.031**	0.003**	3.430**	3097.700**
Parents vs. hybrids	1	195.926*	872107.500**	16.643*	277.633**	0.084	0.002**	32.119**	28768.033**
Hybrids	8	981.676**	67898.667**	4.116**	6.571	0.032**	0.004**	3.775**	23173.333**
Lines	2	1521.000**	856688.445**	2.031**	118.268	0.001	0.001**	4.249**	4541.444**
Testers	2	733.778**	50127.444*	1.622**	1.894**	0.010**	0.001*	0.267*	2681.444**
Line×tester	1	1386.889**	78012.500*	8.313**	1.372**	0.133*	0.013**	8.118**	1042.722*
Error	28	42.217	7096.565	0.027	0.751	0.000	0.000	0.066	114.014

*Significant ($p<0.05$), **Significant ($p<0.01$)

Table 2: Percent contribution of lines, testers and lines×testers for different characters in silkworm, *Bombyx mori* L.

Source	Fecundity	Yield per 10,000 larvae No.	Yield per 10,000 larvae Wt.	Survival rate	Cocoon weight	Shell weight	Shell ratio	Filament length
Lines	48.24	69.77	46.51	67.31	35.17	46.95	49.37	60.12
Testers	22.02	10.01	32.39	12.19	38.86	33.75	23.19	15.20
Lines×testers	29.74	20.22	21.10	20.50	25.97	19.35	27.45	24.68

highly significant ($p<0.01$) variations were observed in treatments and parents for all the 8 characters followed by hybrids, lines for 7 characters and testers, line×tester for 5 characters, where as non significant variations were observed in replications for all 8 characters. A significant ($p<0.05$) variations were observed in testers and lines for 3 characters followed by parents vs. hybrids for 2 characters but no significant values were observed in case of hybrids, lines and replications.

Percent contribution of lines, testers and lines×testers is given in Table 2. Maximum percentage of contribution was observed for yield per 10,000 larvae by number (69.77%) followed by survival rate (67.31%) in the lines. Contribution of testers was found maximum for cocoon weight (38.86%) followed by shell weight (33.75%). Line×tester exhibited their superiority for fecundity (29.74%) followed by shell ratio (27.45%).

General Combining Ability (GCA) effect: Among the lines, analysis of GCA effects indicated superiority of the AKP 1 exhibiting highly significant GCA effects for all 8 characters but in case of AKP 2 and AKP 3 negative effects were observed for all 8 characters. The values ranged from 0.031(Shell Weight) to 166.667 (Yield per 10,000 Larvae by number) in AKP 1 (Table 3). Among testers AKB 6 and AKB 8 were found as good general combiners exhibiting highly significant GCA effects for 6 and 5 characters, respectively. The positive maximum GCA effect among testers was observed in filament length (30.222) of AKB 6 where as minimum value was observed in shell weight (0.011) of AKB 8. In the case of AKB 7 negative effects were observed for all 8 characters which indicated inferiority of the tester.

Specific Combining Ability (SCA) effect: Specific combining ability effects computed for 8 quantitative characters in 9 polyvoltine×bivoltine hybrids have been shown in the Table 4. The

Table 3: General combining ability effects in lines and testers for different characters

Parents	Fecundity	Yield per 10,000 larvae No.	Yield per 10,000 larvae Wt.	Survival rate	Cocoon weight	Shell weight	Shell ratio	Filament length
Lines								
AKP 1	16.593**	166.667**	1.064**	1.603**	0.082**	0.031**	0.943**	90.778**
AKP 2	-6.296*	-68.444*	-0.578**	-0.602	-0.046**	-0.010**	-0.070	-42.000**
AKP 3	-10.296**	-98.222**	-0.486**	-1.001**	-0.036**	-0.022**	-0.873**	-48.778**
SE	2.166	28.080	0.055	0.289	0.006	0.002	0.086	3.559
CD at 5%	4.591	59.527	0.117	0.612	0.012	0.004	0.182	7.545
CD at 1%	6.326	82.016	0.161	0.843	0.017	0.005	0.251	10.396
Testers								
AKB 6	10.815**	62.889*	0.543**	0.673*	0.050**	0.016**	0.451**	30.222**
AKB 7	-2.519	-38.889	-0.881**	-0.465	-0.086**	-0.027**	-0.712**	-44.778**
AKB 8	-8.296**	-24.000	0.338**	-0.207	0.036**	0.011**	0.261**	14.556**
SE	2.144	22.654	0.037	0.234	0.002	0.001	0.058	3.035
CD at 5%	4.256	45.601	0.075	0.471	0.004	0.002	0.117	6.109
CD at 1%	5.681	60.873	0.100	0.629	0.005	0.003	0.156	8.155

*Significant (p<0.05), **Significant (p<0.01)

Table 4: Specific combining ability effects of hybrid combinations for quantitative genetic traits

Hybrid combination	Fecundity	Yield per 10,000 larvae No.	Yield per 10,000 larvae Wt.	Survival rate	Cocoon weight	Shell weight	Shell ratio	Filament length
AKP 1×AKB 6	0.407	11.222	0.277*	-0.218	0.032**	0.010**	0.251	23.889**
AKP 1×AKB 7	-13.593**	-103.667*	-0.746**	-0.87	-0.065**	-0.025**	-0.708**	-79.111**
AKP 1×AKB 8	13.185**	92.444	0.468**	1.089*	0.034**	0.014**	0.457**	55.222**
AKP 2×AKB 6	2.963	29.667	-0.352**	0.533	-0.052**	-0.018**	-0.541**	-20.000**
AKP 2×AKB 7	-2.037	64.778	0.954**	0.354	0.098**	0.018**	0.040	51.333**
AKP 2×AKB 8	-0.926	-94.444	-0.602**	-0.887	-0.046**	0.001	0.500**	-31.333**
AKP 3×AKB 6	-3.37	-40.889	0.074	-0.315	0.021	0.008*	0.29	-3.889
AKP 3×AKB 7	15.630**	38.889	-0.208*	0.516**	-0.033**	0.007*	0.668**	27.778**
AKP 3×AKB 8	-12.259**	2.000	0.134	-0.201	0.012	-0.015**	-0.957**	-23.889**
SE	3.7513	48.6366	0.0952	0.5002	0.0101	0.0032	0.1486	6.1648
CD at 5%	7.9524	103.1043	0.2019	1.0603	0.0213	0.0067	0.315	13.0687
CD at 1%	10.9567	142.0559	0.2782	1.4609	0.0294	0.0093	0.434	18.0059

*Significant (p<0.05), **Significant (p<0.01)

hybrid, AKP 1×AKB 8 was found good specific combiner expressing highly significant SCA effects for 6 out of 8 characters studied followed by the hybrid AKP 3×AKB 7 showing highly significant SCA effects for 4 characters. The positive maximum SCA effect among hybrids was observed in yield per 10,000 larvae by number (92.444) of AKP 1×AKB 8 where as minimum value was observed in shell weight (0.001) of AKP 2×AKB 8. Different hybrids exhibited differential response to SCA for various characters studied. The hybrids AKP 3×AKB 7 (for fecundity, survival and SR%), AKP 1×AKB 8 (for yield per 10,000 larvae by number and filament length) and AKP 2×AKB 7 (for yield per 10,000 larvae by wt., cocoon wt. and shell wt.) were found as good specific combiners for specific parameters as mentioned in the bracket.

Hybrid vigor: The hybrid, AKP 1×AKB 6 was found promising possessing highly significant hybrid vigor over mid parent value for 7 out of 8 characters (Table 5). Two hybrids (AKP 1×AKB

Table 5: Heterosis over mid and better parent values in silkworm hybrid combinations for the quantitative genetic traits

Hybrid combination	Heterosis	Fecundity	Yield per 10,000 larvae No.	Yield per 10,000 larvae Wt.	Survival rate	Cocoon weight	Shell weight	Shell ratio	Filament length
AKP 1×AKB 6	MPV	0.39	2.87**	17.94**	4.06**	15.03**	9.46**	4.78**	21.86**
	BPV	-0.45	0.41	13.01**	1.11	8.42*	2.42	-5.53**	21.63**
AKP 1×AKB 7	MPV	-3.00**	0.80	1.54	2.18**	-0.03	-14.44**	-14.45**	-1.02
	BPV	-4.15**	-1.87*	-2.87**	-0.81	-6.46**	-19.54**	-14.90**	-1.47
AKP 1×AKB 8	MPV	2.22*	4.18**	22.91**	5.38**	17.33**	13.30**	-3.44**	28.38**
	BPV	0.01	0.35	22.62**	1.57	13.27**	9.94**	-3.93**	23.66**
AKP 2×AKB 6	MPV	0.24	1.84*	2.66**	6.31**	1.29	-8.40**	-9.26**	4.15**
	BPV	-4.40**	0.66	-1.41	5.54**	-3.77**	-17.87**	-14.65**	-0.91
AKP 2×AKB 7	MPV	-1.42	1.38*	1.69*	4.90**	1.31	-10.25**	-11.15**	3.94**
	BPV	-4.12**	-0.06	-2.50**	4.24**	-4.47**	-19.15**	-15.37**	-0.87
AKP 2×AKB 8	MPV	-1.37	0.88	3.93**	4.54**	3.52**	-0.11	-3.36**	4.29**
	BPV	-3.10*	-1.62*	3.92**	4.44**	0.75	-7.29**	-7.97**	2.75*
AKP 3×AKB 6	MPV	-1.87	5.25**	11.46**	8.62**	7.16**	-2.88*	-9.00**	2.42*
	BPV	-6.41**	1.95*	1.89*	4.12**	1.00	-13.67**	-14.51**	0.30
AKP 3×AKB 7	MPV	1.42	5.29**	-0.59	8.37**	-5.20**	-16.87**	-11.99**	-3.09**
	BPV	-1.35	2.26**	-9.27**	3.97**	-11.31**	-25.75**	-16.28**	-4.85**
AKP 3×AKB 8	MPV	-4.59**	6.23**	15.44**	8.65**	8.60**	-8.47**	-15.57**	1.29
	BPV	-6.27**	4.28**	9.63**	4.98**	4.83**	-15.81**	-19.69**	-0.23

*Significant ($p<0.05$), **Significant ($p<0.01$)

8 and AKP 3×AKB 8) revealed highly significant vigour over better parent values for 4 characters. Though different hybrids exhibited variable heterotic effects for different characters, majority of the hybrids excelled in their performance particularly for survival rate and yield per 10,000 larvae by weight (Table 5). Highly significant hybrid vigor values were recorded in AKP 1×AKB 8 for the parameters viz., yield per 10,000 larvae by weight (22.90%), cocoon weight (17.33%), shell weight (13.33%) and filament length (28.38%). Maximum hybrid vigor value for parameter yield per 10,000 larvae by number and shell ratio was observed in AKP 3×AKB 8 (6.23%) and AKP 1×AKB 6 (4.78%), respectively.

Improvement of new hybrids over controls: The percentage improvement in the economic traits of newly developed hybrids over controls (APM 1×APS 8 and PM×CSR 2) indicated highly significant percentage improvement (Table 6) for all characters by AKP 1×AKB 6 and AKP 1×AKB 8. The maximum percentage improvement among hybrids was observed in AKP 1×AKB 8 of filament length with 31.39 and 33.41 over controls APM 1 × APS 8 and PM × CSR 2, respectively. The minimum improvement over the control PM×CSR 2 was observed in AKP 2×AKB 8 of yield per 10,000 larvae by number with 0.01% whereas in the case of APM 1×APS 8 control minimum improvement was observed in AKP 2×AKB 7 of cocoon weight with 0.10%. The hybrids AKP 1 × AKB 6 (for fecundity, yield per 10,000 larvae by number, yield per 10,000 larvae by wt., cocoon wt. and shell wt.) and AKP 1×AKB 8 (for survival, S.R% and filament length) have shown maximum percentage improvement over the controls for specific parameters as mentioned in the bracket.

Selection of promising hybrid combinations based on SCA, MPH, BPH and EI: Total number of positive traits of SCA, MPH and BPH obtained in different hybrids ranged from 11 (AKP 2×AKB 8 and AKP 3×AKB 7) to 20 (AKP 1×AKB 6) (Table 7). Average EI value in different

Table 6: Percentage improvement in the economic traits of new hybrids over controls

			Yield per 10,000 larvae						
Hybrid combination	Control	Fecundity	No.	Wt.	Survival rate	Cocoon weight	Shell weight	Shell ratio	Filament length
AKP 1×AKB 6	APM1×APS8	12.27**	4.82**	16.47**	4.10**	11.82**	25.92**	12.61**	29.23**
	PM×CSR2	13.10**	4.70**	20.47**	4.00**	14.61**	28.36**	12.00**	31.22**
AKP 1×AKB 7	APM1×APS8	6.28**	2.44**	0.46	2.11*	-1.99*	-2.14	-0.17	4.69**
	PM×CSR2	7.06**	2.32**	3.91**	2.02*	0.45	-0.24	-0.71	6.30**
AKP 1×AKB 8	APM1×APS8	10.88**	4.76**	16.38**	4.57**	11.10**	25.21**	12.70**	31.39**
	PM×CSR2	11.70**	4.64**	20.37**	4.47**	13.86**	27.64**	12.09**	33.41**
AKP 2×AKB 6	APM1×APS8	7.82**	2.44**	1.61	2.49**	-0.75	0.98	1.74	4.87**
	PM×CSR2	8.61**	2.32**	5.09**	2.39**	1.72	2.93	1.19	6.49**
AKP 2×AKB 7	APM1×APS8	3.80**	1.71*	0.84	1.03	0.10	-1.66	-1.76	4.37**
	PM×CSR2	4.56**	1.59	4.30**	0.93	2.59**	0.24	-2.30	5.97**
AKP 2×AKB 8	APM1×APS8	2.78*	0.12	-1.37	-0.06	-1.18	5.59**	6.86**	1.15
	PM×CSR2	3.53**	0.01	2.02*	-0.15	1.28	7.64**	6.28**	2.71*
AKP 3×AKB 6	APM1×APS8	5.55**	1.34	5.00**	1.11	4.17**	6.15**	1.90	6.16**
	PM×CSR2	6.33**	1.22	8.60**	1.01	6.76**	8.21**	1.35	7.79**
AKP 3×AKB 7	APM1×APS8	6.79**	1.10	-6.16**	0.77	-7.07**	-9.69**	-2.82*	0.18
	PM×CSR2	7.58**	0.98	-2.95**	0.67	-4.76**	-7.94**	-3.35*	1.73
AKP 3×AKB 8	APM1×APS8	-0.58	0.86	4.06**	0.26	2.82**	-4.11*	-6.75**	1.24
	PM×CSR2	0.15	0.74	7.62**	0.16	5.38**	-2.25	-7.26**	2.80*

*Significant ($p<0.05$), **Significant ($p<0.01$)

Table 7: Selection of promising hybrid combinations based on SCA, MPH, BPH and EI

	Total No. of positive traits obtained					
Hybrid combination	SCA	MPH	BPH	Total score	Average EI value	Rank
AKP 1×AKB 6	7	7	6	20	65.52	1
AKP 1×AKB 7	2	3	4	9	47.24	5
AKP 1×AKB 8	7	6	6	19	65.32	2
AKP 2×AKB 6	3	6	3	12	49.14	4
AKP 2×AKB 7	7	5	1	13	45.29	6
AKP 2×AKB 8	2	5	4	11	43.96	7
AKP 3×AKB 6	4	5	4	13	49.62	3
AKP 3×AKB 7	6	3	2	11	41.66	9
AKP 3×AKB 8	3	5	4	12	42.26	8

SCA: Specific combining ability, MPH: Mid parent heterosis, BPH: Better parent heterosis, EI: Evalnation index

hybrids ranged from 41.66 (AKP 3×AKB 7) to 65.52 (AKP 1×AKB 6). Based on SCA, MPH, BPH and EI, the hybrids AKP 1×AKB 6 and AKP 1×AKB 8 scored first and second rank, respectively.

DISCUSSION

In the present study, newly developed BmNPV tolerant polyvoltine and bivoltine breeds were tested to identify promising BmNPV tolerant parents and hybrids through analysis of combining ability. Analysis of variance for combining ability computed for 8 quantitative characters clearly showed significant variation in the parents and hybrids for almost all the characters. This indicates the presence of both additive and non-additive genetic effects for expression of those characters. Highly significant variations in the parents may be ascribed to existence of wide genetic differences among the lines testers utilized. The degree of heterosis in the hybrid can be enhanced through creation of distinctly divergent gene pools in the parental silkworm races (Tangavelu, 1998). Percent contribution of lines was found greater than that of the testers and lines×testers except in cocoon weight. The percent contribution of lines×tester was occupied second place (Table 2). Among the lines AKP 1 showing positive GCA effects for eight economic characters, indicate that additive gene action in the inheritance of these characters. The results are in agreement with that of Datta and Pershad (1988) and Rao *et al.* (1998).

Comparison of GCA effects of parents revealed that AKP 1 and AKB 6 of the parents were good general combiners for all the characters studied. Positive GCA effects for quantitative characters like cocoon weight and shell weight indicated additive gene action which is important for these characters and this study is in agreement with findings of Rajalakshmi *et al.* (1997). Specific combining ability effects have also been evaluated in the hybrids to identify promising specific combiners. Estimated values for specific combining ability in F_1 hybrids clearly revealed superiority of the hybrid AKP 1×AKB 8 exhibiting highly significant SCA effects for 6 out of 8 characters. AKP 3×AKB 7, AKP 2×AKB 7 and AKP 1×AKB 6 were found good specific combiners for at least 3 characters. Maximum highly significant SCA effects were exhibited by different hybrids for different characters indicating genetic potency of the parents utilized. In addition to the effects of additive×non-additive, both additive and non-additive gene actions were found important in the expression of some quantitative characters such as fecundity, cocoon weight, cocoon shell weight, cocoon shell%, filament length etc. (Singh *et al.*, 2000; Datta *et al.*, 2001).

Hybrid vigor has been largely exploited in the silkworm to identify promising hybrids (Rajalakshmi *et al.*, 1997; Rao *et al.*, 2002; Singh *et al.*, 2005). Manifestation of hybrid vigour over Mid Parent Value (MPV) and Better Parent Value (BPV) showed heterotic effects in different hybrids for various characters. Majority of the hybrids expressed their superiority particularly for survival, yield per 10,000 larvae by weight, yield per 10,000 larvae by number and filament length. Maximum, highly significant hybrid vigor values for the parameters viz. yield per 10,000 larvae by weight (22.91%), cocoon weight (17.33%), shell weight (13.30%) and filament length (28.38%) were recorded in AKP 1×AKB 8. Maximum highly significant hybrid vigour value for survival rate (8.65%) and shell ratio (4.78%) was observed in AKP 3×AKB 8 and AKP 1×AKB 6, respectively. AKP 1×AKB 6 possessed highly significant hybrid vigor over mid parent value for 7 out of 8 characters followed by AKP 1×AKB 8 with 6 out of 8 characters. Significant hybrid vigour over mid parent value for survival rate was observed in recently developed polyvoltine × bivoltine hybrids (Singh *et al.*, 2005). Among all newly developed tolerant hybrids, AKP 1×AKB 6 and AKP 1×AKB 8 have shown highly significant percentage improvement values in all 8 traits over controls (APM 1 × APS 8 and PM×CSR 2) which clearly indicates superiority of these hybrids. The multiple trait evaluation of the nine hybrid combinations revealed that two combinations viz., AKP 1 × AKB 6 and AKP 1×AKB 8 recorded cumulative index values above 50 and possess economic merit. Since the comprehensive merit of the hybrid over a range of traits depends on relative superiority of many individual traits, selection needs to be based on multiple traits contributing to overall silk output. These observations confirm the established fact as observed by Vidyunmala *et al.* (1998) and Babu *et al.* (2002) that superiority of one or a couple of characters may not reflect the overall merit of the hybrid.

CONCLUSION

Consideration of the performance of parental lines, their general combining ability as well as the performance of nine hybrid combinations, specific combining ability of F_1

hybrids, heterosis and over dominance has led to a complex situation in order to identify the promising hybrid combinations.

Employing a method on the performance evaluated through Evaluation index method, specific combining ability recorded by each of the hybrids as well as the manifestation of heterocyst and over dominance, two hybrid combinations, AKP 1×AKB 6 and AKP 1×AKB 8 were adjudicated as promising. These hybrids can be exploited commercially after conducting mass scale field trials at farmer level.

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