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Identification of Superior Polyvoltine Hybrids (polyvoltine × bivoltine) of Silkworm, *Bombyx mori* L.

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Ten promising polyvoltine mulberry silkworm strains (SDMG1, SDMG2, SDMG3, SDMG4, SDMW1, SDMW2, RMW1, RMW2, RMW3 and RMW4) that are superior in quantitative and qualitative traits have been synthesized in the polyvoltine breeding laboratory of Andhra Pradesh State Sericulture Research & Development Institute, Hindupur through systematic hybridization and appropriate selection methods. After the genotypes were found homozygous for the desired traits, they have been crossed with 3 bivoltine testers (APS8, APS4 and NB_4D_2) and thirty new hybrid combinations were developed for the assessment of their hybrid performance. Phenotypic expressions of economically important quantitative and qualitative traits of fist filial generation were measured and subjected for statistical analysis. Evaluation Index and Subordinate Function methods were employed for the assessment of hybrid performance since they are widely used in silkworm hybrid evaluation. Total of seven poly × bivoltine combinations, which ranked high in both the methods, were selected as potential combinations for further field test. These combinations also ranked significantly higher than the control hybrid (APM1 × APS8).

Key words: Silkworm, Polyvoltine, Crossbreed, Evaluation index, Subordinate function

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Introduction

Polyvoltine silkworm hybrids (polyvoltine × bivoltine) play very important role in India. Ninety percent of the silk produced in the country comes from polyvoltine hybrids which are reared mainly in Karnataka, Andhra Pradesh, West Bengal and Tamil Nadu regions of India, because of their better adaptability to tropical conditions. Polyvoltines are relatively low yielding varieties with high adoptability where as bivoltines are high yielding with low adoptability to tropical climatic conditions (Nagaraju *et al.*, 1996; Chandrashekaraiah 2003). Since the performance of heterozygotes is always better than homozygotes in both plants and animals, silkworms are being exploited for hybrid vigour since almost a century. During the past four decades, polyvoltine varieties are significantly improved by crossing them with exotic high yielding bivoltine males as per the suggestions of Tazima (1958). Subsequently many polyvoltine hybrids (polyvoltine ♀ × bivoltine ♂) with improved productivity and silk quality were evolved (PM × NB_4D_2, PM × NB18, PM × NB7, PM × KA and many more). Even though many polyvoltine hybrids have been developed with improved metric traits, the quantity and quality of silk produced remain unsatisfactory. Very limited number of polyvoltine cross breeds (APM1 × APS8) are available with all desired traits, which are not sufficient to meet the present day demand. Some of the breeds and hybrids already developed have become inconsistent in expressing the desired traits under various environmental conditions or seasons. Silkworm breeds which can satisfy both the farmers and, reelers are limited. At this juncture, there is a need for the development of quantitatively and qualitatively superior polyvoltine breeds and hybrids with high genetic plasticity to cater various climatic conditions of the tropics. New breed and hybrid development and their improvement are the continuous processes in pursuit of enhancing the comprehensive economic merit of silk productivity in terms of quantity and quality (Chandrashekaraiah, 2001).

Keeping the constraints and demands in view, ten promising polyvoltine silkworm strains which are superior in quantitative and qualitative parameters have been developed in the polyvoltine breeding laboratory of APSSRDI, through planned hybridization and systematic selection methods. After the fixation of alleles for the desired traits, the inbred lines are crossed with potential bivoltine parents (testers) and thirty different hybrid (polyvoltine and bivoltine) combinations were developed for the assessment of their hybrid performance. Quantitative traits of these new hybrids are measured and assessed using Evaluation Index (Mano *et al.*, 1993) and Subordinate Function (Gower, 1971) methods. In the present study most promising and high yielding polyvoltine hybrid combinations have been identified for further field trails and onward commercial purpose.

Materials and Methods

Using the newly developed ten superior polyvoltine silkworm breeds or parental strains (SDMG1, SDMG2, SDMG3, SDMG4, SDMW1, SDMW2, RMW1, RMW2, RMW3 and RMW4) and three potential bivoltine strains known as testers (APS8, APS4 and NB_4D_2), thirty different new hybrid combinations were prepared from the selected cocoons, along with a popular control hybrid (APM1 × APS8). The disease free egg layings of these new hybrid combinations were incubated in a properly disinfected rearing house, maintaining 80 – 85% of relative humidity and 25°C temparature. Uniformly developed layings were selected and packed in a butter paper and covered with a black cloth to ensure uniform hatching. Newly hatched larvae were brushed on finely chopped mulberry leaves. Each hybrid combination was reread in three replications. Young silkworms (Chawki) were reared at the temperature of 26 – 28°C with a relative humidity of 85 – 90%. After 3rd moult, 300 larvae were counted and retained from each bed for the further rearing. The late age silkworms (4th and 5th instars) were maintained at 24 – 26°C with relative humidity of 65 – 75% and the larvae were fed with mulberry leaves of well-irrigated garden in the standard silkworm rearing environmental conditions (Krishnaswami, 1976). The disease free rearing environment was maintained in the rearing house by applying timely lime and bleaching powder. After the larvae attained maturity, they were transferred to plastic mountages for spinning. Proper care was taken while mounting the worms for spinning as per the standard rearing protocol. The data pertainining to commercial traits *viz.*, fecundity, cocoon yield /10,000 larvae by weight, pupation rate, single cocoon weight, single shell weight, cocoon shell percentage were measured and recorded. For estimation of important post cocoon parameters like single cocoon filament length, reelability, raw silk %, neatness, 300 cocoons from each hybrid combination were subjected for reeling. Rearing performance data (Table 1) from all the hybrids was analyzed by using Evaluation Index and Subordinate Function Index methods. The performance of these new hybrids were also compared with the performance of APM1 × APS8, a popular ruling cross breed. Important quantitative parameters of the hybrids were measured as per the following formulae.

$$\text{Cocoon yield/10,000 larvae By weight} = \frac{\text{weight of cocoons obtained} \times 10{,}000}{\text{Larvae retained after 3 rd moult (300)}}$$

$$\text{Pupation rate (\%)} = \frac{\text{No. of good cocoons} + (\text{no. of double cocoonsx2}) \times 100}{\text{Larvae retained after 3 rd moult} - \text{Uzi infestated cocoons}}$$

$$\text{Single cocoon weight (gm)} = \frac{\text{Wt. of 25 male} + \text{25 female cocoons (gm.)}}{50}$$

$$\text{Single cocoon shell weight (gm)} = \frac{\text{Wt. of 25 male} + \text{25 female cocoon shells (gm.)}}{50}$$

$$\text{Cocoon shell ratio (SR\%)} = \frac{\text{Single Cocoon shell weight} \times 100}{\text{Single Cocoon weight}}$$

Silk filament length (mt.) = Revolutions of approvate × circumference of wheel (mt.)

The performance of hybrids was analyzed by using both Evaluation Index and Subordinate Function methods as detailed below.

Evaluation index method

Evaluation index (E I) = A – B/C × 10 + 50

Where,

A = Mean of particular trait
B = Overall mean of particular trait
C = Standard deviation
10 = Standard
50 = Constant

By using the above formula, evaluation index values were calculated for each of the trait and the mean value was taken into consideration. The average cumulative index over a number of traits was analyzed and ranked accordingly. The hybrid which is possessing with highest value is ranked first.

Table 1. Mean performance of the polyvoltine hybrids

Sl. no.	Hybrid	Fecundity	Yield/ 10000 larvae wt. (kg)	Pupation rate	Cocoon Asssessment SC wt. (g)	SS wt. (g)	SR %	Filament length (m)	Raw silk%	Reelability %	Neatness
1	SDMG1 × APS8	457	16.760	94.00	1.786	0.348	19.49	854	12.04	92.85	88
2	SDMG1 × APS4	453	17.276	94.13	1.834	0.341	18.62	789	6.91	86.21	85
3	SDMG1 × NB_4D_2	463	18.563	93.47	1.992	0.356	17.87	795	9.88	87.35	90
4	SDMG2 × APS8	473	15.144	94.13	1.610	0.330	20.48	606	11.36	98.01	83
5	SDMG2 × APS4	479	15.713	94.80	1.665	0.293	17.59	736	8.53	88.92	90
6	SDMG2 × NB_4D_2	481	18.868	94.27	1.988	0.335	16.85	747	11.64	87.35	88
7	SDMG3 × APS8	458	16.261	94.80	1.720	0.345	20.04	791	12.45	86.45	83
8	SDMG3 × APS4	451	18.432	93.07	1.977	0.375	18.97	985	16.27	84.72	94
9	SDMG3 × NB_4D_2	454	16.497	93.33	1.761	0.327	18.59	819	8.00	88.09	88
10	SDMG4 × APS8	463	15.147	93.87	1.624	0.309	19.05	909	11.42	89.45	82
11	SDMG4 × APS4	451	15.841	94.40	1.683	0.294	17.45	770	13.63	89.15	73
12	SDMG4 × NB_4D_2	443	18.897	92.40	2.035	0.349	17.18	794	14.31	79.24	89
13	SDMW1 × APS8	492	18.181	95.33	1.907	0.382	20.01	949	11.18	86.25	88
14	SDMW1 × APS4	487	17.002	94.13	1.814	0.336	18.52	939	11.40	88.51	83
15	SDMW1 × NB_4D_2	495	17.691	94.40	1.868	0.356	19.08	948	13.43	76.96	79
16	SDMW2 × APS8	499	18.201	94.93	1.915	0.363	18.95	790	10.21	86.58	78
17	SDMW2 × APS4	501	17.419	94.40	1.848	0.339	18.33	852	12.27	87.76	81
18	SDMW2 × NB_4D_2	483	19.483	94.67	2.066	0.358	17.35	850	11.70	90.18	76
19	RMW1 × APS8	468	15.383	90.53	1.721	0.340	19.76	871	12.05	89.56	74
20	RMW1 × APS4	459	16.160	90.00	1.718	0.320	18.62	804	12.21	88.88	78
21	RMW1 × NB_4D_2	466	17.173	92.40	1.860	0.334	17.98	850	10.29	82.48	82
22	RMW2 × APS8	485	15.374	92.13	1.674	0.309	18.45	951	11.45	87.45	83
23	RMW2 × APS4	481	16.856	94.00	1.786	0.316	17.69	975	12.96	96.58	80
24	RMW2 × NB_4D_2	492	19.400	93.47	2.075	0.333	16.02	863	13.40	84.65	88
25	RMW3 × APS8	495	16.322	94.13	1.738	0.335	19.25	888	11.34	87.05	82
26	RMW3 × APS4	479	15.485	94.93	1.641	0.319	19.45	889	11.69	85.84	88
27	RMW3 × NB_4D_2	486	17.755	94.80	1.887	0.314	16.62	970	12.88	83.19	76
28	RMW4 × APS8	459	16.715	94.00	1.781	0.345	19.35	862	12.04	88.16	73
29	RMW4 × APS4	452	17.006	95.87	1.790	0.333	18.58	928	12.50	83.09	89
30	RMW4 × NB_4D_2	461	17.470	94.80	1.849	0.328	17.76	852	10.61	91.10	88
31	APM1 × APS8	472	18.187	93.7	1.774	0.329	18.55	825	13.2	85.24	89
Mean		472	17.118	93.85	1.819	0.335	18.47	853	11.72	87.33	83.55
SD		17	1.271	1.27	0.130	0.021	1.06	83.5	1.83	4.20	5.73
Min.		443	15.144	90.00	1.610	0.293	16.02	606	6.91	76.96	73.00
Max.		501	19.483	95.87	2.075	0.382	20.48	985	16.27	98.01	94.00

SC wt: Single cocoon weight; SS wt: Single cocoon shell weight; SR %: Cocoon shell ratio.

Subordinate function index method

For each trait, subordinate function values are obtained by applying the following formula.

$Xu = (Xi - X_{min})/(X_{max} - X_{min})$

Where,

Xu = Subordinate function

Xi = Measurement of character of tested breed

X_{min} = Minimum value of the character among all the tested hybrids

X_{max} = Maximum value of the character among all the tested hybrids

The values obtained for each of the trait were added per each combination and the ranked based on cumulative values

Results and Discussion

For each hybrid combination, three replicates were maintained and a total of 93 beds were reared for 30 hybrids along with one control for assessing hybrid performance. Rearing performance data of 31 hybrid combinations was analyzed using Evaluation Index method and subordinate function methods. It is well established that most of the traits in silkworm are under polygenic control, under the influence of environmental factors and nutrition (Miyagawa and Sato, 1954; Ueda and Lizuka, 1962; Arai, N. and T. Ito, 1963, 1967; Yokoyama, 1979). Hence all the hybrid combinations were reared at a time and fed with the same variety of leaf. During the rearing, important quantitative traits were measured for the analysis of hybrid performance. Mean rearing performance of 30 hybrid combinations along with a control hybrid is presented in Table 1. Fecundity was ranged between a maximum of 501 (SDMW2 × APS4) and a minimum of 443 (SDMG4 × NB_4D_2) with a standard deviation of 17. Maximum yield/10000 larvae was in SDMW2 × NB_4D_2 (19.83 kg) where as minimum was observed in SDMG2 × APS8 (15.144 kg). Higher pupation % was recorded in RMW4 × APS4 (95.87) where as the minimum was observed in RMW1 × APS4 (90.00). Maximum single cocoon weight was observed in RMW2 × NB_4D_2 (2.075 g) and minimum

Table 2. Evaluation Index of polyvoltine hybrids

Sl. no.	Hybrid	Fecundity	Yield/ 10000 larvae	Pupation rate	Cocoon Asssessment			Filament length	Raw silk %	Reelability %	Neatness	Total	Mean
					SC wt.	SS wt.	SR %						
1	SDMG1 × APS8	40.9	47.2	51.2	47.5	56.2	59.6	50.1	51.8	63.1	57.8	525.2	52.5
2	SDMG1 × APS4	38.5	51.2	52.2	51.2	53.0	51.4	42.3	23.8	47.3	52.5	463.5	46.3
3	SDMG1 × NB_4D_2	44.5	61.4	47.0	63.3	60.0	44.4	43.0	40.0	50.0	61.3	514.8	51.5
4	SDMG2 × APS8	50.5	34.5	52.2	33.9	47.3	69.0	20.4	48.0	75.4	49.0	480.3	48.0
5	SDMG2 × APS4	54.1	38.9	57.5	38.1	29.6	41.8	36.0	32.6	53.8	61.3	443.5	44.4
6	SDMG2 × NB_4D_2	55.3	63.8	53.3	63.0	49.8	34.7	37.3	49.6	50.0	57.8	514.6	51.5
7	SDMG3 × APS8	41.5	43.3	57.5	42.4	54.6	64.8	42.5	54.0	47.9	49.0	497.5	49.7
8	SDMG3 × APS4	37.3	60.3	43.9	62.1	69.2	54.8	65.8	74.8	43.8	68.2	580.2	58.0
9	SDMG3 × NB_4D_2	39.1	45.1	46.0	45.6	46.2	51.1	45.9	29.7	51.8	57.8	458.2	45.8
10	SDMG4 × APS8	44.5	34.5	50.1	35.0	37.6	55.5	56.7	48.4	55.0	47.3	464.6	46.5
11	SDMG4 × APS4	37.3	40.0	54.3	39.6	30.0	40.4	40.0	60.4	54.3	31.6	427.9	42.8
12	SDMG4 × NB_4D_2	32.4	64.0	38.6	66.6	56.9	37.8	42.9	64.1	30.7	59.5	493.6	49.4
13	SDMW1 × APS8	61.9	58.4	61.7	56.8	72.3	64.5	61.5	47.1	47.4	57.8	589.3	58.9
14	SDMW1 × APS4	58.9	49.1	52.2	49.6	50.3	50.5	60.3	48.3	52.8	49.0	521.1	52.1
15	SDMW1 × NB_4D_2	63.7	54.5	54.3	53.8	60.2	55.8	61.4	59.3	25.3	42.1	530.4	53.0
16	SDMW2 × APS8	66.1	58.5	58.5	57.4	63.3	54.5	42.4	41.8	48.2	40.3	531.1	53.1
17	SDMW2 × APS4	67.3	52.4	54.3	52.2	51.7	48.7	49.8	53.0	51.0	45.6	526.0	52.6
18	SDMW2 × NB_4D_2	56.5	68.6	56.4	69.0	61.2	39.4	49.6	49.9	56.8	36.8	544.3	54.4
19	RMW1 × APS8	47.5	36.3	23.9	42.5	52.3	62.2	52.1	51.8	55.3	33.3	457.3	45.7
20	RMW1 × APS4	42.1	42.5	19.8	42.2	42.7	51.4	44.1	52.7	53.7	40.3	431.4	43.1
21	RMW1 × NB_4D_2	46.3	50.4	38.6	53.2	49.4	45.4	49.6	42.2	38.4	47.3	460.9	46.1
22	RMW2 × APS8	57.7	36.3	36.5	38.8	37.4	49.8	61.7	48.5	50.3	49.0	466.1	46.6
23	RMW2 × APS4	55.3	47.9	51.2	47.5	40.7	42.7	64.6	56.8	72.0	43.8	522.5	52.3
24	RMW2 × NB_4D_2	61.9	68.0	47.0	69.7	48.9	26.9	51.2	59.2	43.6	57.8	534.2	53.4
25	RMW3 × APS8	63.7	43.7	52.2	43.8	49.9	57.4	54.2	47.9	49.3	47.3	509.4	50.9
26	RMW3 × APS4	54.1	37.1	58.5	36.3	42.2	59.3	54.3	49.8	46.4	57.8	495.8	49.6
27	RMW3 × NB_4D_2	58.3	55.0	57.5	55.2	39.8	32.6	64.0	56.3	40.1	36.8	495.7	49.6
28	RMW4 × APS8	42.1	46.8	51.2	47.1	54.7	58.3	51.0	51.8	52.0	31.6	486.6	48.7
29	RMW4 × APS4	37.9	49.1	65.9	47.8	48.9	51.1	59.0	54.3	39.9	59.5	513.3	51.3
30	RMW4 × NB_4D_2	43.3	52.8	57.5	52.3	46.7	43.3	49.8	44.0	59.0	57.8	506.4	50.6
31	APM1 × APS8	49.9	58.4	48.8	46.5	47.0	50.7	46.6	58.1	45.0	59.5	514.1	51.4

SC wt: Single cocoon weight; SS wt: Single cocoon shell weight; SR %: Cocoon shell ratio.

was observed in SDMG2 × APS8 (1.610). With regarding to cocoon shell ration%, maximum was observed in SDMG2 × APS8 (20.48) and minimum was found in RMW2 × NB_4D_2 (16.02) among the hybrids. Maximum filament length was observed in SDMG3 × APS4 (985 mts.) where as minimum was observed in SDMG2 × APS8 (606 mts.). Regarding to raw silk percentage, it was found highest in SDMG3 × APS4 (16.27 %) and lowest in SDMG1 × APS4 (6.91%). Among all the hybrids, maximum reelability percentage was recorded in SDMG2 × APS8 (98.01%) and minimum was recoded in SDMW1 × NB_4D_2 (76.96%). Highest neatness was recoded in SDMG3 × APS4 (94%) and lowest was observed in the combination RMW4 × APS8 (73%).

Assessment of multiple traits of the developed silkworm hybrids is an important task for predicting the potential hybrid combinations. Different statistical methods are applied for the analysis of hybrid performance in both plants and animals (Henderson, 1953, 1963, 1984; Hayman, 1954, 1960; Gower, 1971; Arunachalam and Bandhyopadhyay, 1984; Mano *et al.*, 1992). 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 trait analysis comprising of viable, quantitative and qualitative traits. In silkworms, a large number of hybrids are tested and promising ones are

Table 3. Subordinate Function values of polyvoltine hybrids

Sl. no.	Hybrid	Fecundity	Yield/ 10000 larvae	Pupation rate	Cocoon Asssessment			Filament length	Raw silk %	Reelability %	Neatness	Sum
					SC wt.	SS wt.	SR %					
1	SDMG1 × APS8	0.241	0.372	0.681	0.378	0.622	0.777	0.654	0.548	0.755	0.714	5.744
2	SDMG1 × APS4	0.172	0.491	0.704	0.482	0.548	0.582	0.483	0.000	0.439	0.571	4.474
3	SDMG1 × NB_4D_2	0.345	0.788	0.591	0.821	0.711	0.415	0.499	0.317	0.494	0.810	5.789
4	SDMG2 × APS8	0.517	0.000	0.704	0.000	0.416	1.000	0.000	0.475	1.000	0.476	4.589
5	SDMG2 × APS4	0.621	0.131	0.818	0.117	0.000	0.353	0.343	0.173	0.568	0.810	3.933
6	SDMG2 × NB_4D_2	0.655	0.858	0.727	0.813	0.474	0.185	0.372	0.505	0.494	0.714	5.798
7	SDMG3 × APS8	0.259	0.257	0.818	0.237	0.585	0.902	0.488	0.592	0.451	0.476	5.064
8	SDMG3 × APS4	0.138	0.758	0.522	0.789	0.927	0.662	1.000	1.000	0.369	1.000	7.164
9	SDMG3 × NB_4D_2	0.190	0.312	0.568	0.325	0.389	0.576	0.562	0.116	0.529	0.714	4.281
10	SDMG4 × APS8	0.345	0.001	0.659	0.031	0.187	0.680	0.799	0.482	0.593	0.429	4.205
11	SDMG4 × APS4	0.138	0.161	0.750	0.158	0.011	0.321	0.433	0.718	0.579	0.000	3.267
12	SDMG4 × NB_4D_2	0.000	0.865	0.409	0.913	0.638	0.259	0.496	0.791	0.108	0.762	5.242
13	SDMW1 × APS8	0.845	0.700	0.909	0.639	1.000	0.894	0.905	0.456	0.441	0.714	7.503
14	SDMW1 × APS4	0.759	0.428	0.704	0.439	0.486	0.560	0.879	0.480	0.549	0.476	5.759
15	SDMW1 × NB_4D_2	0.897	0.587	0.750	0.554	0.717	0.687	0.902	0.697	0.000	0.286	6.076
16	SDMW2 × APS8	0.966	0.704	0.840	0.655	0.789	0.657	0.485	0.353	0.457	0.238	6.144
17	SDMW2 × APS4	1.000	0.524	0.750	0.511	0.517	0.518	0.649	0.573	0.513	0.381	5.935
18	SDMW2 × NB_4D_2	0.690	1.000	0.795	0.980	0.738	0.298	0.644	0.512	0.628	0.143	6.427
19	RMW1 × APS8	0.431	0.055	0.090	0.239	0.532	0.838	0.699	0.549	0.599	0.048	4.080
20	RMW1 × APS4	0.276	0.234	0.000	0.232	0.306	0.583	0.522	0.566	0.566	0.238	3.525
21	RMW1 × NB_4D_2	0.397	0.468	0.409	0.538	0.464	0.440	0.644	0.361	0.262	0.429	4.410
22	RMW2 × APS8	0.724	0.053	0.363	0.138	0.182	0.545	0.910	0.485	0.498	0.476	4.375
23	RMW2 × APS4	0.655	0.395	0.681	0.378	0.261	0.375	0.974	0.646	0.932	0.333	5.631
24	RMW2 × NB4D2	0.845	0.981	0.591	1.000	0.453	0.000	0.678	0.693	0.365	0.714	6.321
25	RMW3 × APS8	0.897	0.272	0.704	0.275	0.475	0.725	0.744	0.473	0.479	0.429	5.472
26	RMW3 × APS4	0.621	0.079	0.840	0.067	0.295	0.770	0.747	0.511	0.422	0.714	5.064
27	RMW3 × NB_4D_2	0.741	0.602	0.818	0.596	0.239	0.135	0.960	0.638	0.296	0.143	5.167
28	RMW4 × APS8	0.276	0.362	0.681	0.368	0.588	0.747	0.675	0.548	0.532	0.000	4.778
29	RMW4 × APS4	0.155	0.429	1.000	0.388	0.453	0.574	0.850	0.597	0.291	0.762	5.499
30	RMW4 × NB_4D_2	0.310	0.536	0.818	0.514	0.401	0.391	0.649	0.395	0.672	0.714	5.400
31	APM1 × APS8	0.500	0.701	0.630	0.353	0.408	0.567	0.578	0.597	0.393	0.857	5.659

SC wt: Single cocoon weight; SS wt: Single cocoon shell weight; SR %: Cocoon shell ratio.

selected based on the economic traits (Singh and Subba Rao, 1993). The present data was analyzed by giving equal weight age to all the important economic traits, using both evaluation index method (Mano *et al.*, 1992) and subordinate function method (Gower, 1971). These methods were successfully employed by many breeders to evaluate the silkworm hybrids (Singh and Subba Rao, 1993; Sudhkara Rao *et al.*, 2001; Ramesh Babu *et al.*, 2002).

Indices generated from multiple trait evaluation index are presented in Table 2. The indices obtained for each of the trait (fecundity, yield/10,000 larvae by weight, pupation rate, cocoon weight, shell weight, shell ratio, filament length, reelability and neatness), and the indices obtained for all the traits were combined to get a single mean value, which is actually the evaluation index. The evaluation index values among the 31 hybrid combinations ranged to a maximum of 58.9 (SDMW1 × APS8) with a minimum of 42.9 (SDMG4 × APS4) where as control hybrid recorded 51.5 (APM1 × APS8). Based on these values, the hybrids were ranked accordingly. The hybrid combination SDMW1 × APS8 (58.9) assigned first rank followed by SDMG3 × APS4 (58.0), SDMW2 × NB_4D_2 (54.4), RMW2 × NB_4D_2 (53.5), SDMW2 × APS8 (53.1), SDMW1 × NB_4D_2 (53.0), SDMW2 × APS4 (52.6) etc, where as the control hybrid stood in 13^{th} position.

Table 4. Comparative ranking of the polyvoltine hybrids

Sl. no.	Hybrids	Mean	Hybrids	Sum
1	SDMW1 × APS8	58.9	SDMW1 × APS8	7.503
2	SDMG3 × APS4	58.0	SDMG3 × APS4	7.164
3	SDMW2 × NB_4D_2	54.4	SDMW2 × NB_4D_2	6.427
4	RMW2 × NB_4D_2	53.5	RMW2 × NB_4D_2	6.321
5	SDMW2 × APS8	53.1	SDMW2 × APS8	6.144
6	SDMW1 × NB_4D_2	53.0	SDMW1 × NB_4D_2	6.076
7	SDMW2 × APS4	52.6	SDMW2 × APS4	5.935
8	SDMG1 × APS8	52.6	SDMG2 × NB_4D_2	5.798
9	RMW2 × APS4	52.3	SDMG1 × NB_4D_2	5.789
10	SDMW1 × APS4	52.1	SDMW1 × APS4	5.759
11	SDMG1 × NB_4D_2	51.5	SDMG1 × APS8	5.744
12	SDMG2 × NB_4D_2	51.5	APM1 × APS8	5.659
13	APM1 × APS8	51.5	RMW2 × APS4	5.631
14	RMW4 × APS4	51.4	RMW4 × APS4	5.499
15	RMW3 × APS8	51.0	RMW3 × APS8	5.472
16	RMW4 × NB_4D_2	50.7	RMW4 × NB_4D_2	5.400
17	SDMG3 × APS8	49.8	SDMG4 × NB_4D_2	5.242
18	RMW3 × APS4	49.6	RMW3 × NB_4D_2	5.167
19	RMW3 × NB_4D_2	49.6	SDMG3 × APS8	5.064
20	SDMG4 × NB_4D_2	49.5	RMW3 × APS4	5.064
21	RMW4 × APS8	48.7	RMW4 × APS8	4.778
22	SDMG2 × APS8	48.1	SDMG2 × APS8	4.589
23	RMW2 × APS8	46.7	SDMG1 × APS4	4.474
24	SDMG4 × APS8	46.5	RMW1 × NB_4D_2	4.410
25	SDMG1 × APS4	46.4	RMW2 × APS8	4.375
26	RMW1 × NB_4D_2	46.2	SDMG3 × NB_4D_2	4.281
27	SDMG3 × NB_4D_2	45.9	SDMG4 × APS8	4.205
28	RMW1 × APS8	45.8	RMW1 × APS8	4.080
29	SDMG2 × APS4	44.5	SDMG2 × APS4	3.933
30	RMW1 × APS4	43.3	RMW1 × APS4	3.525
31	SDMG4 × APS4	42.9	SDMG4 × APS4	3.267

The values obtained for individual trait by applying subordinate function method are added and these values are considered as subordinate function values (Table 3) and these values ranged between a maximum of 7.503 (SDMW1 × APS8) to a minimum of 3.267 (SDMG4 × APS4) where as control hybrid obtained the value of 5.659 (APM1 × APS8). Based on subordinate function values, the hybrid combinations were ranked accordingly. Among all the hybrids, SDMW1 × APS8 stood first and the control hybrid occupied 12th rank.

The index values of hybrids obtained from both the methods were arranged in a rank wise (Table 4). Seven hybrid combinations (poly × bivoltine) which stood high in both Evaluation index and Subordinate Function methods were selected as potential combinations for further field test. These combinations were also ranked higher than the control hybrid (APM1 × APS8).

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