Journal of
Entomology

ISSN 1812-5670

Academic
Journals Inc.

www.academicjournals.com

Journal of Entomology 6 (4): 188-197, 2009
ISSN 1812-5670
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Evaluation and Identification of Superior Polyvoltine Crossbreeds of Mulberry Silkworm, *Bombyx mori* L.

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Abstract: In the present study, the existing polyvoltine germplasm resource material of the Silkworm Breeding and Research and Development Institute (APSSRDI), screened for the desired qualitative and quantitative traits. After fixation of the desired traits, 5 inbred parental breeds (APM4, APM6, APM8, APM10, APM12) utilized as Lines for the preparation of 25 crosses in Line×Tester method with the five bivoltine breeds (SDD1, SDD2, SDD3, APS12, APS105) as Testers. The hybrid testing was conducted and assessed for three different seasons for their performance on eight important economical genetic traits. The data obtained on the traits such as fecundity, yield per 10,000 larvae by number, single cocoon weight, shell weight, shell ratio, filament length and reliability was analyzed with the assistance of statistical tools. Based on two popular evaluation methods such as multiple traits Evaluation Index (EI) and Sub-ordinate Function (SF) methods, the 5 new hybrid combinations (APM12×APDR105, APM6×APS12, APM4×PDR105, APM10×SDD1 and APM10×SDD3) shown above 50 EI values with SF values varied from 5.663 to 7.596 were identified as superior over the control hybrid and recommended for large scale in laboratory trail. Further, based on the lab and field performance promising crossbreed will be identified and adjudicated for the commercial exploitation at farmers level.

Key words: Silkworm, hybrid, evaluation index, subordinate function

INTRODUCTION

The silkworm breeds plays an imperative role to make sericulture as a successful occupation through sustainable cocoon yield with superior quality silk. Before the introduction of hybrids, pure lines were used for the production of silk. Since, the pure lines were giving lower yield and poor quality of silk, hybrids were brought into field for commercial purpose. For the ancient times, silkworm hybrids are playing significant role in tropical sericulture industry (Chandrashekharaiah and Babu, 2003; Choudhary and Ravindra Singh, 2007). Advantage of hybrid vigor has been exploited in American corn and Japanese scientists in silkworm, since almost a century ago for commercial utilization. Since, the hybrids heralded better performance than parents and exploitation of hybrid vigor was initiated as early as 1906 in silkworm breeding (Toyama, 1906). In tropical country like India, polyvoltine hybrids (polyvoltine x bivoltine) play important role in the production of silk.

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Commercial utilization of hybrid vigor in the domesticated silkworm, heralded a new era in silkworm which substantially contributed to the increase of silk yield. Through conventional breeding, many promising silkworm hybrids have been developed with improved quantitative and qualitative traits.

Hybrid vigor is an important tool in increasing cocoon production, evaluation, maintenance of inbred lines and identification of promising hybrids for commercial exploitation (Nagaraju *et al.*, 1996). Based on the importance of hybrids requirement in the field, they were extensively developed and evaluated by the silkworm breeders. Some of them have survived for long time and few of them have stirred out with in few years of introduction in the field. The main challenge for the breeder is to prioritize the order of important characters for improvement in the resultant population. Besides, it is more important for the breeder to determine important factors responsible for the animal to survive and reproduce to its full potential (Nagaraju *et al.*, 1989). The main objective of silkworm breeding is to synthesize new genotypes with more plasticity to different climates and to select sustainable silkworm hybrids for commercial exploitation. Scientists are making constant efforts in the synthesis of superior varieties to meet the demand of sericulture farmers and silk reelers.

In the changing scenario of the globe, for the developing countries, there is a great need to develop potential silkworm hybrids of higher quality and quantity to sustain the sericulture industry since, the polyvoltine or crossbreed silkworm are well adopted for tropical climate. India being a tropical country, several factors influences the success of cocoon crops of which biotic and abiotic factors play a vital role (Basavaraja *et al.*, 2003). The present attempt has been made to identify superior polyvoltine hybrid (polyvoltine×bivoltine) with improved quantitative and qualitative genetic traits through conventional breeding approach.

MATERIALS AND METHODS

Silkworm Breeds and Hybrid Combinations

Five promising polyvoltine breeds viz., APM12, APM4, APM6, APM8, APM10 and five bivoltine breeds viz., SDD1, SDD2, SDD3, APS12, APDR105 were drawn from the germplasm bank maintained in Silkworm Breeding and Molecular Genetics Laboratory, Andhra Pradesh State Sericulture Research and Development Institute (APSSRDI). By utilizing female component of the polyvoltine breeds as Lines and bivoltine breeds as Testers, 25 hybrid combinations (APM12×SDD1, APM12×SDD2, APM12×SDD3, APM12×APS12, APM12×APDR105, APM4×SDD1, APM4×SDD2, APM4× SDD3, APM4×APS12, APM4×APDR105, APM6×SDD1, APM6×SDD2, APM6×SDD3, APM6×APS12, APM6×APDR105, APM8× SDD1, APM8×SDD2, APM8×SDD3, APM8×APS12, APM8×APDR105, APM10×SDD1, APM10×SDD2, APM10×SDD3, APM10×APS12 and APM10×APDR105) were prepared by adopting Line×Tester method (Griffing, 1956). The popular crossbreed, APM1×APS8 was used as the control hybrid to compare new hybrid combinations.

Silkworm Rearing

The layings of all the new hybrid combinations were incubated in a thoroughly disinfected rearing house by maintaining 80-85% of relative humidity and 25°C temperature. Uniformly developed layings were selected, packed and covered with a black cloth to ensure uniform hatching. Newly hatched larvae were brushed on finely chopped fresh mulberry leaves. These new hybrid combinations were reread in three replications. The young silkworm larvae were reared at 26-28°C with relative humidity of 85-90% and 28°C temperature. After 3rd moult, 300 larvae were retained from each bed for further rearing and assessment. The late age silkworms were reared at 24-26°C with relative humidity of 70-75%. The larvae were fed with mulberry leaves brought from well-irrigated garden to the silkworm rearing house (Krishnaswami, 1978) during the year, 2007-2008 in Andhra Pradesh State Sericulture Research and Development Institute (APSSRDI), Hindupur, Andhra Pradesh, India. The disease free rearing atmosphere was maintained in the rearing house by using certain disinfectants like lime and bleaching powder. After the larvae attained maturity, they were mounted on plastic collapsiblemountages for spinning. Appropriate care was taken while mounting the worms for spinning as per the standard rearing protocol. The data pertaining to commercial important genetic traits viz., fecundity, cocoon yield/10,000 larvae by number, pupation rate, single cocoon weight, single shell weight, cocoon shell ratio were measured and analyzed. Further, important post cocoon parameters like single cocoon filament length and relabeled were estimated. The brief description of the genetic traits which are evaluated is given below.

Fecundity (No.)

The trait represents the number of eggs laid by a single moth and is important as it is directly associated with fitness of the individual. Fitness of individuals and of the population is often expressed in terms of reproductive success.

Cocoon Yield per 10,000 Larvae by Number

It is the total weight of live cocoons expressed in kilogram for unit number of larvae retained after 3rd moult and it is important as directly associated with the economics of cocoon crops.

$$\frac{\text{Actual No. of cocoons obtained}}{\text{Unit number of larvae retained after third moult (300)}} \times 10{,}000$$

Pupation Rate (%)

It is the number of cocoons with live pupae recovered out of the number of larvae retained after 3rd moult expressed in percentage.

$$\frac{\text{No. of good cocoons} + (\text{No. of double cocoons} \times 2)}{\text{Larvae retained after 3rd moult - Uzi infested cocoons}} \times 10{,}000$$

Cocoon Weight (g)

The average weight of 25 male and 25 female cocoons taken randomly on 6/7th day after onset of spinning and measured in gram.

$$\frac{\text{Weight of 25 male (g)} + \text{25 female cocoons (g)}}{50}$$

Cocoon Shell Weight (g)

The average weight of 25 male and 25 female cocoon shells of same cocoons taken randomly and measured in gram.

$$\frac{\text{Weight of 25 male (g)} + \text{25 female cocoon shells (g)}}{50}$$

Cocoon Shell Ratio (%)

The trait depicts the total content of shell available in the cocoons. It is the average ratio of 25 male and female cocoon shells to the total cocoon weight and assessed in percentage.

$$\frac{\text{Cocoon shell weight}}{\text{Cocoon weight}}\times 100$$

Silk Filament Length (m)

It represents the length of unwound silk filament from the cocoon which is represented in meters.

$$\frac{\text{Length of raw silk}\times\text{Average number of reeled cocoons}}{\text{Number of reeling cocoons}}$$

Relabeled (%)

It is the efficiency of reeling/unwinding of the silk from the total number of cocoon and expressed in percentage.

$$\frac{\text{Number of reeling cocoon}}{\text{Number of feeding end}}\times 100$$

Where:

No. of reeling cocoon = Testing cocoons No. of unreeled cocoons No. of carry over conversion cocoons

No. of feeding end = Measurement of feeding end+No. of carry over cocoons No. of carry over conversion cocoons

Multiple Evaluation Index Method

Evaluation index values were obtained for the each genetic trait with the assistance of following formulae adopted by Mano *et al*. (1993).

$$\text{Evaluation index (E I)} = A-B/C\times 10+50$$

Where:

A = Mean of particular trait

B = Overall mean of particular trait

C = Standard deviation

10 = Standard

50 = Constant

Subordinate Function Method

For each genetic trait, subordinate function values are obtained with the assistance of the following formula (Gower, 1971).

$$X_u = (X_i-X_{min})/(X_{max}-X_{min})$$

Where:

X_u = Sub-ordinate function

X_i = 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 evaluation index values were calculated for each of the trait and the mean value was taken into consideration. Values obtained on subordinate function method for each trait were added per each combination and ranked based on the cumulative values. The average cumulative value on the number of traits was analyzed and ranked the hybrid which possessing with highest value was ranked first and accordingly each rank was allotted to each hybrid combination.

RESULTS AND DISCUSSION

Fecundity was ranged between maximum of 529 (APM12×APDR105) and minimum of 482 (APM4×APDR105) control with 470 and Standard Deviation (SD) of 15 was observed. Maximum yield/10,000 larvae by number was in APM12×APDR105 (9511) where as minimum in APM6×SDD1 (8733) was recorded. Higher pupation rate was recorded in APM10×SDD1 (94.89) lower was observed in APM6×SDD1 (86.44). The highest single cocoon weight was observed in APM12×APDR105 (1.952 g) and lowest in APM12×SDD2 (1.599 g) with the standard deviation of 0.112 g among the hybrid combinations. With regarding to cocoon shell ratio, maximum in APM6×APS12 (19.95%) and minimum was found in APM8×APDR105 (17.29) with an average of 19.15%. Maximum filament length in APM12×APDR105 (936 m) where as minimum in APM6×SDD3 (709 m) with an average of 786 m has been revealed. Highest relabeled percentage in APM12×APDR105 (90.10) and lowest was recorded in APM6×APDR105 (76.90%) with an average of 86.23%. Among all the hybrid combinations, for the trait single shell weight more CV (7.94%), which was followed by filament length (7.52%) and single cocoon weight (6.49%) (Table 1). It is established that most of the genetic

Table 1: Silkworm performance of the new hybrid combinations on economically important genetic traits

				Cocoon assessment				
Hybrid combinations	Fecun-dity (No.)	Yield/10,000 larvae (No.)	Pupa-tion (%)	Cocoon weight (g)	Shell weight (g)	Shell ratio (%)	FL (m)	Reliability (%)
APM12×SDD1	512	9422	94.00	1.704	0.340	19.95	785	84.19
APM12×SDD2	523	9400	93.11	1.599	0.316	19.76	790	86.16
APM12×SDD3	510	8922	90.44	1.793	0.355	19.80	810	85.09
APM12×APS12	498	9344	93.67	1.602	0.315	19.66	783	87.00
APM12×APDR105	529	9511	94.00	1.952	0.374	19.16	936	90.10
APM4×SDD1	495	9489	94.56	1.613	0.318	19.71	781	86.35
APM4×SDD2	499	9433	93.22	1.632	0.302	18.50	745	86.45
APM4×SDD3	511	9189	93.22	1.620	0.298	18.40	749	84.00
APM4×APS12	488	9400	93.78	1.749	0.348	19.90	789	85.09
APM4×APDR105	482	9322	93.67	1.848	0.367	19.86	889	89.45
APM6×SDD1	512	8733	86.44	1.681	0.329	19.57	710	88.15
APM6×SDD2	506	9367	93.44	1.687	0.318	18.85	778	81.00
APM6×SDD3	526	9467	93.44	1.624	0.282	17.36	709	86.25
APM6×APS12	511	9411	94.11	1.704	0.340	19.95	930	88.51
APM6×APDR105	503	8933	89.56	1.835	0.358	19.51	799	76.90
APM8×SDD1	487	9444	93.33	1.704	0.315	18.49	833	86.58
APM8×SDD2	483	9311	94.00	1.617	0.320	19.79	798	87.76
APM8×SDD3	491	8900	88.00	1.673	0.299	17.87	775	90.05
APM8×APS12	515	9433	89.56	1.722	0.314	18.23	755	89.56
APM8×APDR105	501	9478	93.89	1.787	0.309	17.29	793	88.88
APM10×SDD1	513	9500	94.89	1.937	0.366	18.90	749	82.48
APM10×SDD2	525	9200	91.89	1.625	0.318	19.57	762	87.45
APM10×SDD3	516	9378	93.56	1.759	0.351	19.95	799	85.00
APM10×APS12	501	9300	90.44	1.944	0.370	19.04	730	87.65
APM10×APDR105	501	9367	93.78	1.766	0.350	19.82	747	87.05
APM1×APS8 (C)	470	8900	88.00	1.604	0.305	19.01	721	84.80
Mean	504	9291	92.38	1.722	0.330	19.15	786	86.23
SD	15.00	226.00	2.35	0.112	0.026	0.81	59.00	2.98
CV (%)	2.97	2.43	2.54	6.490	7.940	4.23	7.52	3.46

C: Control; FL: Filament Length

traits in silkworm are under polygenic control, under the influence of environmental factors and nutrition as in other system (Miyagawa and Sato, 1954; Ueda and Lizuka, 1962; Arai and Ito, 1963, 1967; Yokoyama, 1979). Hence, all the hybrid combinations were reared in same environmental conditions, fed with the same variety of leaves and important quantitative traits were measured for the analysis of hybrid performance. When both the parental strains and hybrids are raised in unfavorable environmental conditions, performance of hybrids will be much superior to both the parental strains those used for the preparation of the hybrid (Nagaraju *et al*., 1996). Majority of silkworm breeders are especially interested in evolving breeds with productive merit by employing either conventional or mutation breeding (Kovalov, 1970). Crossbreeds provide great variability on which selection can be operated to isolate promising breed with new gene complexes. The primary objective of the breeder is to isolate robust silkworm hybrid with reasonably consistent levels of productivity, viability with improved post cocoon parameters.

Therefore, the objective of silkworm breeding is not only to synthesize new genotypes or hybrid combinations but also to identify sustainable silkworm hybrids for commercial exploitation by farmers. Selection of suitable parents and information on nature and magnitude of gene action of traits of economic importance determine the success of any crop (Chouhan *et al*., 2000). Critical assessment of variability present in the breeding materials is one of the pre-requisites for paving the way of combining most of the desirable traits present in different genotypes into a single hybrid combination. However, the per se performance of parental breeds is not always be the good reflection of the combining ability and its analysis therefore helps the breeders to understand the nature of gene action to identify prospective parents/hybrids (Narayanaswamy *et al*., 2002). In this context, Line×Tester studies assume significance so as to determine the nature of gene action involved in the expression of different economic traits besides identification of specific desirable combination (Choudhary and Ravindra Singh, 2007). Bhargava *et al*. (1995) recorded predominant role of non-additive gene action for the traits cocoon weight, cocoon shell weight, cocoon shell ratio, filament length and relabeled. Similar predominant role of non-additive gene action in the inheritance of cocoon yield by number, cocoon weight, cocoon shell weight, cocoon shell ratio and filament length was observed by Sudhakar Rao *et al*. (2001).

In the present study an attempt was being made to identify the superior crossbreed through conventional breeding approach by assessment on multiple traits of the developed silkworm hybrids as an important task in predicting the potential hybrid combinations. Different statistical methods are applied for the analysis of hybrid performance in both plants and animals (Hayman, 1954, 1960; Henderson, 1953, 1963, 1984; Gower, 1971; Arunachalam and Bandhyopadhyay, 1984). 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 silkworm, good numbers of hybrids are evaluated and promising ones are selected based on the economic traits (Singh and Subba Rao, 1993). The present data was analyzed with equal weight to all the important economic traits using both multiple evaluation index (Mano *et al*., 1993) and subordinate function methods (Gower, 1971). These methods were successfully employed by many silkworm breeders for evaluation of the silkworm hybrids (Krishnaswami *et al*., 1964; Singh and Subba Rao, 1993; Sudhakar Rao *et al*., 2001; Ramesh Babu *et al*., 2002; Rao *et al*., 2006; Ramesha *et al*., 2008).

The multiple evaluation index values obtained for each of the trait on fecundity, yield/10,000 larvae by number, pupation rate, cocoon weight, shell weight, shell ratio, filament length and relabeled with an average value presented in Table 2. Average evaluation index

Table 2: Multiple evaluation index values on economically important genetic traits of the new hybrid combinations

Hybrid combinations	Fecun-dity	Yield/ 10,000 larvae	Pupa-tion	Cocoon assessment Cocoon weight	 Shell weight	 Shell ratio	FL	Reela-bility	Avg. EI-values
APM12×SDD1	55.25	55.83	56.87	48.36	53.86	59.90	49.79	43.17	52.88
APM12×SDD2	62.59	54.85	53.09	38.97	44.70	57.54	50.64	49.77	51.52
APM12×SDD3	53.91	33.67	41.73	56.32	59.59	58.00	53.96	46.18	50.42
APM12×APS12	45.90	52.37	55.47	39.24	44.31	56.32	49.51	52.58	49.46
APM12×APDR105	66.60	59.77	56.87	70.54	66.85	50.11	75.33	62.97	63.63
APM4×SDD1	43.90	58.80	59.26	40.22	45.46	56.96	49.06	50.41	50.51
APM4×SDD2	46.57	56.31	53.55	41.92	39.35	42.03	42.97	50.74	46.68
APM4×SDD3	54.58	45.50	53.55	40.85	37.82	40.68	43.65	42.53	44.89
APM4×APS12	39.23	54.85	55.94	51.02	56.92	59.21	50.41	46.18	51.72
APM4×APDR105	35.22	51.39	55.47	61.24	64.18	58.74	67.32	60.80	56.79
APM6×SDD1	55.39	25.29	24.70	46.30	49.66	55.19	37.05	56.44	43.75
APM6×SDD2	51.41	53.39	54.49	46.84	45.46	46.29	48.66	32.48	47.38
APM6×SDD3	64.26	57.82	54.49	41.21	31.71	27.96	36.94	50.07	45.56
APM6×APS12	54.55	55.34	57.34	48.36	53.86	59.90	74.31	57.65	57.66
APM6×APDR105	49.09	34.15	37.98	60.07	60.74	54.42	52.16	18.73	45.92
APM8×SDD1	38.81	56.80	54.02	48.36	44.31	41.80	57.85	51.18	49.14
APM8×SDD2	35.89	50.91	56.87	40.58	46.22	57.88	51.93	55.13	49.43
APM8×SDD3	41.18	32.69	31.34	45.59	38.20	34.23	48.04	62.81	41.76
APM8×APS12	56.97	56.31	37.98	49.97	43.93	38.70	44.72	61.16	48.72
APM8×APDR105	47.91	58.31	56.41	55.78	42.02	27.06	51.20	58.89	49.70
APM10×SDD1	55.92	59.28	60.66	69.19	63.79	46.85	43.76	37.44	54.61
APM10×SDD2	63.93	45.99	47.90	41.30	45.46	55.16	45.90	54.09	49.96
APM10×SDD3	57.92	53.88	55.00	53.28	58.06	59.91	52.10	45.88	54.50
APM10×APS12	47.91	50.42	41.73	69.82	65.36	48.61	40.43	54.76	52.38
APM10×APDR105	47.91	53.39	55.94	53.90	57.68	58.24	43.31	52.75	52.89
APM1×APS8 (C)	27.21	32.69	31.34	39.42	40.49	48.32	39.02	45.21	37.96

C: Control; FL: Filament length; EI: Evaluation Index

values ranged to the maximum of 63.63 (APM12×APDR105) followed by 57.66 (APM6×APS12), 56.79 (APM12×APDR105) with minimum 41.76 (APM8×SDD3) among the hybrid combinations where as control hybrid recorded 37.96 (APM1×APS8). Based on the evaluation index values, the new hybrid combinations were ranked accordingly and APM12×APDR105 (63.63) assigned first rank followed by APM6×APS12 (57.66), APM4×APDR105 (56.79), APM10×SDD1 (54.61) and APM10×SDD3 (54.50) where as the control hybrid placed in the last position. Further, the cumulative values obtained for individual trait by applying subordinate function method (Table 3) were ranged to the maximum of 7.596 (APM12×APDR105) and minimum of 2.652 (APM8×SDD3) where as control hybrid obtained the value of 1.963 (APM1×APS8). Based on cumulative values, the hybrid combinations were ranked accordingly and APM12×APDR105 (7.596) stood first followed by APM6×APS12 (6.254), APM4×APDR105 (6.152), APM10× SDD1 (5.788), APM10×SDD3 (5.663) and the control hybrid occupied last rank as the method followed by Ramesh Babu *et al*. (2002) and Rao *et al*. (2006).

With both the statistical methods of average evaluation index and cumulative subordinate function values were arranged in descending order and accordingly given ranks to each hybrid (Table 4). Top ranked five new hybrid combinations viz., APM12×APDR105, APM6×APS12, APM4×APDR105, APM10×SDD1 and APM10×SDD3) which stood high in both evaluation index and subordinate function methods were identified as potential hybrid combinations. These short listed hybrid combinations were also ranked higher than the control hybrid (APM1×APS8).

Table 3: Subordinate function values on economically important genetic traits of the new hybrid combinations

				Cocoon assessment					
Hybrid combinations	Fecun-dity	Yield/ 10,000 larvae	Pupa-tion	Cocoon weight	Shell weight	Shell ratio	FL	Reela -bility	Cum. SF-values
APM12×SDD1	0.71	0.89	0.89	0.30	0.63	1.00	0.33	0.55	5.31
APM12×SDD2	0.90	0.86	0.79	0.00	0.37	0.93	0.36	0.70	4.90
APM12×SDD3	0.68	0.24	0.47	0.55	0.79	0.94	0.44	0.62	4.74
APM12×APS12	0.47	0.79	0.86	0.01	0.36	0.89	0.33	0.77	4.47
APM12×APDR105	1.00	1.00	0.89	1.00	1.00	0.70	1.00	1.00	7.60
APM4×SDD1	0.42	0.97	0.96	0.04	0.39	0.91	0.32	0.72	4.73
APM4×SDD2	0.49	0.90	0.80	0.09	0.22	0.46	0.16	0.72	3.84
APM4×SDD3	0.69	0.59	0.80	0.06	0.17	0.41	0.17	0.54	3.44
APM4×APS12	0.31	0.86	0.87	0.42	0.72	0.98	0.35	0.62	5.12
APM4×APDR105	0.20	0.76	0.86	0.71	0.92	0.96	0.79	0.95	6.15
APM6×SDD1	0.72	0.00	0.00	0.23	0.51	0.86	0.00	0.85	3.17
APM6×SDD2	0.61	0.81	0.83	0.25	0.39	0.59	0.31	0.31	4.10
APM6×SDD3	0.94	0.94	0.83	0.07	0.00	0.03	0.00	0.71	3.52
APM6×APS12	0.69	0.87	0.91	0.30	0.63	1.00	0.97	0.88	6.25
APM6×APDR105	0.56	0.26	0.37	0.67	0.83	0.83	0.40	0.00	3.91
APM8×SDD1	0.29	0.91	0.82	0.30	0.36	0.45	0.54	0.73	4.41
APM8×SDD2	0.22	0.74	0.89	0.05	0.41	0.94	0.39	0.82	4.47
APM8×SDD3	0.35	0.21	0.18	0.21	0.18	0.22	0.29	1.00	2.65
APM8×APS12	0.76	0.90	0.37	0.35	0.35	0.35	0.20	0.96	4.24
APM8×APDR105	0.53	0.96	0.88	0.53	0.29	0.00	0.37	0.91	4.47
APM10×SDD1	0.73	0.99	1.00	0.96	0.91	0.60	0.18	0.42	5.79
APM10×SDD2	0.93	0.60	0.64	0.07	0.39	0.86	0.23	0.80	4.53
APM10×SDD3	0.78	0.83	0.84	0.45	0.75	1.00	0.40	0.61	5.66
APM10×APS12	0.53	0.73	0.47	0.98	0.96	0.66	0.09	0.81	5.22
APM10×APDR105	0.53	0.81	0.87	0.47	0.74	0.95	0.17	0.77	5.31
APM1×APS8 (C)	0.00	0.21	0.18	0.01	0.25	0.65	0.05	0.60	1.96

C: Control, FL: Filament length, Cum. SF: Cumulative subordinate function

Table 4: Ranking of new hybrid combinations in ascending order based on EI and subordinate values

Hybrid combinations	Average EI values	Rank	Hybrid combinations	Cum. SF-values	Rank
APM12×APDR105	63.63	1	APM12×APDR105	7.596	1
APM6×APS12	57.66	2	APM6×APS12	6.254	2
APM4×APDR105	56.79	3	APM4×APDR105	6.152	3
APM10×SDD1	54.61	4	APM10×SDD1	5.788	4
APM10×SDD3	54.50	5	APM10×SDD3	5.663	5
APM10×APDR105	52.89	6	APM12×SDD1	5.307	6
APM12×SDD1	52.88	7	APM10×APDR105	5.305	7
APM10×APS12	52.38	8	APM10×APS12	5.224	8
APM4×APS12	51.89	9	APM4×APS12	5.123	9
APM12×SDD2	51.52	10	APM12×SDD2	4.901	10
APM4×SDD1	50.51	11	APM12×SDD3	4.743	11
APM12×SDD3	50.42	12	APM4×SDD1	4.729	12
APM10×SDD2	49.96	13	APM10×SDD2	4.530	13
APM8×APDR105	49.70	14	APM8×SDD2	4.473	14
APM12×APS12	49.46	15	APM8×APDR105	4.470	15
APM8×SDD2	49.43	16	APM12×APS12	4.466	16
APM8×SDD1	49.14	17	APM8×SDD1	4.407	17
APM8×APS12	48.72	18	APM8×APS12	4.237	18
APM6×SDD2	47.38	19	APM6×SDD2	4.100	19
APM4×SDD2	46.68	20	APM6×APDR105	3.906	20
APM6×APDR105	45.92	21	APM4×SDD2	3.841	21
APM6×SDD3	45.56	22	APM6×SDD3	3.519	22
APM4×SDD3	44.89	23	APM4×SDD3	3.444	23
APM6×SDD1	43.75	24	APM6×SDD1	3.170	24
APM8×SDD3	41.76	25	APM8×SDD3	2.652	25
APM1×APS8 (C)	37.96	26	APM10×APS8	1.963	26

C: Control, EI: Evaluation index, SF: Subordinate function

CONCLUSION

Among all the hybrids tested in the laboratory, APM12×APDR105 was well performed and adjudicated for the commercial exploitation. The findings of this study prove the superiority of this new hybrid combination with improved productivity traits than the existing hybrids which are being commercially exploited in the field after large scale laboratory and field trails.

ACKNOWLEDGMENTS

Authors are thankful to Dr. Chandrashekharaiah, former Director, APSSRDI, Kirikera-515 211, Hindupur, A.P., India for his encouragement and support for the present investigation.

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