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APC1 X APJ1 –A promising bivoltine silkworm (*Bombyx Mori* L.) hybrid for coastal region

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Abstract
There is a dearth of bivoltine silkworm hybrids specific for seasons and regions. In this line APSSRDI has made an attempt in identification of silkworm hybrids for high temperature and high humidity tolerance. The experiment all the silkworm genetic stocks with high productivity and temperature tolerance were selected for screening the initial parents. These stocks were exposed to high temperature (36 °C) and high humidity (85-90%) for identification of resource material. Among the breeds ten promising stocks, five each of oval and peanut have been selected as breeding resource material on the basis of their tolerance to high temperature and high humidity. By utilizing these breeds, 100 combinations were prepared by following complete diallel method and evaluated. Accordingly 28 hybrid combinations were short listed for targeted traits and in subsequent trials, most promising single hybrid, APC1 x APJ1 was identified for further studies.

Keywords: Bivoltine hybrid, Breeding, Evaluation, Screening, High temperature, High humidity, Tolerance.

1. Introduction
Tropical sericulture is characterized by crop instability, poor productivity coupled with inferior quality largely due to inadequate moisture and organic matter in the soils for healthy mulberry growth, lack of hardy and superior breeds for various locations and seasons, prevalence of pathogens due to continuous/overlapping rearings without proper hygiene etc. Since, sericulture is becoming more and more tropical based in recent past, it becomes imperative to overcome the prevailing weak links and production constraints as far as bivoltine sericulture is concerned. Even though, India occupies second position in the global production of raw silk, the quality of raw silk remained short of International standards as bulk silk production is of polyvoltine x bivoltine type. This necessitated the development of bivoltine sericulture in the country and more emphasis is laid to improve qualitative bivoltine silk production. The tropical bivoltine sericulture that remained as an enigma for the silk industry up to 90's in the country, made significant progress with the re-orientation of breeding approaches in increasing the quality raw silk production through the development of productive bivoltine hybrids suitable for prevailing tropical conditions in general and region and season specific in particular during the last decade (Basavaraja *et al*., 1995) [1].
Several Chinese and Japanese breeders have achieved remarkable progress in the improvement of several quantitative and qualitative traits of economic value in silkworm, *Bombyx mori* L. (Yokoyama, 1979; Yang Mingguan, 1982; Mano *et al*., 1991; Chen *et al*., 1994) [18, 17, 10, 3]. Attempts in this direction by the silkworm breeders in India at different research institutions contributed to the development of many bivoltine breeds/hybrids over years (Narasimhanna *et al*., 1976; Datta, 1984; Trag *et al*., 1992; Ramesh Babu *et al*., 2003; Siddique *et al*., 2003) [11, 4, 16, 13, 14]. However, there remains considerable dearth for region and season specific productive bivoltine silkworm hybrids for commercial utilization. In this line APSSRDI has made an attempt in identification of silkworm hybrids for high temperature and high humidity tolerance especially for tropical regions.

2. Materials and Methods

Under the experiment all the silkworm genetic stocks with high productivity and temperature tolerance were selected from the germplasm repository of APSSRDI for screening the initial parents. These stocks were exposed to high temperature (36 °C) and high humidity (85-90%) for identification of initial parents. Among all the breeds ten promising stocks, five each of oval (APS45Y, APDR105, APC1, APSHTO2 & APS101) and peanut (APS12C, APJ1, APS20, CTIPP & APS112) were selected as breeding resource material on the basis of their tolerance to high temperature and high humidity.

2.1 Screening of breeds for high temperature and high humidity: 100 healthy larvae of 5^{th} instar were subjected for high temperature (36 °C) and high humidity (85-90%) from the3rd day to till mounting (Suresh Kumar *et al*., 1999) [15]. Five replications were maintained per each breed. The survival and reproductive characteristics were expressed on the basic number of larvae tested. On the basis of number of DFLs produced, individual bench marks were set for the stress condition to select the potential parents for hybridization programme. Among all the genetic stocks, 10 promising stocks, five each of oval (APS45Y, APDR105, APC1, APSHTO2 & APS101) and peanut (APS12C, APJ1, APS20, CTIPP & APS112) have been selected as breeding resource material on the basis of their tolerance to high temperature and high humidity. Ten selected parents were utilized for the hybridization programme and for identification of the most promising hybrid with thermal tolerance. By involving these 10 shortlisted parental breeds 100 combinations were prepared by following complete diallel method.

3. Results and Discussion

These 100 combinations were reared for evaluating the performance of these hybrids under targeted stress conditions for thrice. Accordingly 28 hybrid combinations were short listed in first trial based on the cocoon characters and performance of the hybrids by following Evaluation Index. In the further trials 15 single hybrids were short listed based on the performance and cocoon characters. In further trials, one single hybrid *i.e.* APC1 x APJ1 was identified for high temperature and high humidity. It also showed consistency in other quantitative and qualitative parameters.

The analysis of variance (Table 2) was carried out to study the significance of the difference for various characters under study, among 100 combinations. The ANOVA revealed significant difference among all the combinations ($P<0.001$) for all the traits studied. The significant difference ($P<0.05$) is also recorded among the parents for all the traits except yield by no. The significant difference ($P<0.001$) was also observed among 90 hybrid combinations and the interaction between the parents and hybrids. The F1 and reciprocal effects were also recorded to be significant for all the traits under the study. The perusal of the ANOVA indicated significant ($P<0.001$) General Combining Ability (GCA) effects, Specific Combining Ability (SCA) effects and reciprocal effects for all the traits.

Realizing the significant impact of silkworm hybrids for increased quantitative and qualitative productivity of silk besides crop stability on commercial scale, many silkworm breeders in the Sericultural countries succeeded in the development of bivoltine silkworm hybrids by exploiting the hybrid vigour that reflected in the improvement of several qualitative and economic traits (Harada, 1961; Mano *et al*., 1982; He *et al*., 1991; Chen *et al*., 1994) [7, 9, 8, 3]. Successful silkworm breeding efforts also contributed in the evolution of many productive and qualitatively superior bivoltine hybrids for commercial exploitation in India during the last decade (Basavaraja *et al*., 1995; Datta *et al*., 2000; Chandrashekharaiah and Ramesh Babu, 2003) [1, 6, 13].

Since the breeding is a continuous process, the goal is to improve the silk yield continuously suiting to the requirements of the industry. For successful hybrid, the quantitative and qualitative characters need to be improved in the parents so as to achieve superior hybrids. Moreover, the prevailing high temperature causes severe damage to the cocoon production. The best way to reduce crop losses is by utilizing the breeds which shows tolerant to high temperature and high humidity. In this direction, intensive work has been carried out on silkworm breeding at APSSRDI, Hindupur, India has resulted in the development of the productive bivoltine hybrid APC1 x APJ1that showed improvement over ruling hybrid CSR2 x CSR4. Besides the qualitative and quantitative merit of the parental breeds in the present investigation due emphasis is also laid on the selection of initial parents with thermal tolerance (36 °C) and tolerance to high humidity for hybridization programme. By utilizing these novel parents 5 hybrid combinations *viz.,* APS45Y x APS12C, APC1 x APJ1, APDR105 x APS20, APDR105 x APS112 and APS45Y x APS110 were identified as promising towards the yield and other qualitative parameters (Table 3). Further, one most promising bivoltine single hybrid, APC1 x APJ1 was short-listed among the five hybrids understudy.

It can be observed from the present study that there is considerable improvement in silk yield contributing traits such as filament length, shell weight, fecundity and raw silk % compared to the control hybrid, CSR2 x CSR4 corroborating the earlier observations. These observations corroborate with the findings of Datta *et al*., (2000a&b) [6], Suresh Kumar *et al*., (1999) [15]. Considering the overall economic merit for the fitness, quantitative and qualitative traits besides the stable and better performance under stress conditions (high temperature and high humidity) the new bivoltine hybrid APC1 x APJ1 is adjudicated as the most promising combination for coastal region.

Table 1: Performance of the hybrids and their reciprocals

Sl. No.	Combination	Fecundity (No.)	Yield/10000 Larvae		Pupation Rate (%)	Cocoon Assessment		
			No.	Wt. (kg)		Cocoon Wt. (g)	Shell Wt. (g)	Shell %
1	APS45Y x APJ1	523	9456	16.04	92.3	1.784	0.395	22.1
2	APS45Y x APS20	489	9366	17.5	91.5	1.909	0.417	21.8
3	APS45Y x APS112	575	9678	16.2	93.4	1.737	0.377	21.7
4	APS45Y x APS110	505	9600	17.12	92.5	1.847	0.402	21.8
5	APS45Y x APS12C	499	9550	17.36	93.6	1.882	0.423	22.5
6	APS101 x APJ1	502	9670	17.08	93.9	1.846	0.420	22.8

7	APS101 x APS20	467	9120	15.18	86.2	1.833	0.405	22.1
8	APS101 x APS112	481	8930	16.33	91.9	1.766	0.389	22.0
9	APS101 x APS110	536	9086	16.46	88.9	1.713	0.392	22.9
10	APS101 x APS12C	567	9567	15.81	93.7	1.713	0.380	22.2
11	APSHTO2 x APJ1	446	9600	16.65	94.5	1.741	0.381	21.9
12	APSHTO2 x APS20	512	9100	15.55	89.9	1.780	0.399	22.4
13	APSHTO2 x APS112	501	9300	15.45	90.6	1.732	0.389	22.5
14	APSHTO2 x APS110	545	9167	15.1	84.9	1.807	0.386	21.4
15	APSHTO2 x APS12C	534	9459	16.22	92.6	1.777	0.392	22.1
16	APC1 x APJ1	610	9716	18.32	95.2	1.950	0.440	22.6
17	APC1 x APS20	557	9266	14.85	90.5	1.819	0.372	20.5
18	APC1 x APS112	602	9766	16.4	95.7	1.713	0.357	20.8
19	APC1 x APS110	576	9484	16.2	92.9	1.771	0.376	21.2
20	APC1 x APS12C	534	9671	16.83	93.8	1.821	0.415	22.8
21	APDR105 x APJ1	567	9567	16.28	95.1	1.738	0.386	22.2
22	APDR105 x APS20	608	9580	18.13	93.9	1.958	0.424	21.7
23	APDR105 x APS112	564	9678	16.29	93.7	1.707	0.393	23.0
24	APDR105 x APS110	586	9598	17.23	94.1	1.804	0.391	21.7
25	APDR105 x APS12C	478	9654	17.22	92.7	1.820	0.387	21.3
26	APJ1 x APS45Y	567	9854	18.20	95.7	1.921	0.436	22.7
27	APJ1 x 871 PO	578	9305	15.67	90.6	1.776	0.387	21.8
28	APJ1 x APSHTO2	550	9770	17.23	95.3	1.854	0.424	22.9
29	APJ1 x APC1	554	9886	16.56	96.4	1.762	0.384	21.8
30	APJ1 x APDR105	561	9786	17.61	97	1.861	0.425	22.8
31	APS20 x APS45Y	477	9906	17.51	96.6	1.857	0.432	23.3
32	APS20 x APS101	601	9855	16.57	96.1	1.769	0.398	22.5
33	APS20 x APSHTO2	508	9769	16.58	95.3	1.786	0.405	22.7
34	APS20 x APC1	478	8502	13.88	82.6	1.731	0.385	22.2
35	APS20 x APDR105	489	8541	13.90	83	1.725	0.381	22.1
36	APS112 x APS45Y	540	9368	16.21	91.2	1.824	0.407	22.3
37	APS112 x APS101	525	9702	16.01	94.6	1.738	0.385	22.2
38	APS112 x APSHTO2	532	9608	16.93	93.7	1.854	0.422	22.8
39	APS112 x APC1	487	9775	16.53	95.3	1.779	0.394	22.1
40	APS112 x APDR105	486	9825	17.83	95.8	1.906	0.429	22.5
41	APS110 x APS45Y	493	9814	17.41	95.7	1.865	0.421	22.6
42	APS110 x APS101	484	8965	14.45	87.2	1.705	0.379	22.2
43	APS110 x APSHTO2	541	8392	14.10	81.5	1.781	0.396	22.2
44	APS110 x APC1	570	9400	15.71	91.6	1.762	0.376	21.3
45	APS110 x APDR105	545	9622	16.64	93.8	1.820	0.388	21.3
46	APS12C x APS45Y	576	9700	17.09	94.6	1.853	0.413	22.3
47	APS12C x APS101	607	9685	15.83	94.4	1.722	0.375	21.8
48	APS12C x APSHTO2	553	9221	14.86	89.8	1.702	0.362	21.3
49	APS12C x APC1	497	8903	14.42	80.1	1.852	0.397	21.4
50	APS12C x APDR105	535	9079	15.75	88.4	1.830	0.404	22.1

Table 2: Analysis of Variance for complete diallel analysis for 100 combinations

Source of variation	DF	Mean sum of squares							
		Fecundity	**Hatching %**	**Yield / No.**	**Yield wt.**	**Pupation**	**Cocoon weight**	**Shell weight**	**SR %**
Replicates	2	684.36	118.343	8115.80	0.24	0.64	0.001	0.000	0.042
Treatments	99	11262.90 ***	456.36 ***	834169.00 ***	6.56 ***	83.53 ***	0.041 ***	0.003 ***	1.594 ***
Parents	9	14537.40 ***	103.87*	128367.6	5.46 ***	12.83	0.043 ***	0.003 ***	1.517 ***
Hybrids	89	10844.12 ***	484.88 ***	869721.80 ***	6.43 ***	87.12 ***	0.040 ***	0.003 ***	1.601 ***
Parent Vs.Hybrids	1	19064.24 ***	1090.24 ***	4022178.00 ***	27.64 ***	400.44 ***	0.035 **	0.000	1.666 *
F1's	44	6956.96 ***	288.83 ***	556830.50 ***	4.93 ***	55.89 ***	0.037 ***	0.002 ***	1.325 ***
Reciprocals	44	14874.01 ***	675.51 ***	1158346.00 ***	7.51 ***	115.83 ***	0.032 ***	0.002 ***	1.894 ***
F1 Vs Reciprocals	1	4563.33	723.74 ***	1937486.00 **	25.46 ***	197.66 **	0.552 ***	0.03 ***	0.917
Error	198	1615.36	42.85	181026.8	0.883	18.13	0.004	0.000	0.300
Total	299	4803.47	180.27	396128	2.76	39.67	0.016	0.001	0.727
**, ** Significant at P<0.05 and P<0.01 respectively*									

Table 3: Mean performance of the short-listed hybrids

Sl. No.	RACE	Fecun dity (No.)	Yield/ 10000 L by wt. (Kg)	Pupa tion (%)	Cocoon Wt.(g)	Shell Wt.(g)	Shell Ratio (%)	Reela bility (%)	Filament length (m)	Raw Silk %	EI
1	APS45Y x APS12C	565	18.67	96.40	1.931	0.440	22.79	86	1033	16.91	50.6
2	APC1 x APJ1	568	18.91	97.10	1.967	0.439	22.32	87	1106	17.44	58.6
3	APDR105 x APS20	610	18.76	96.12	1.921	0.425	22.12	87	992	17.02	50.4
4	APDR105 x APS112	590	18.55	95.80	1.934	0.419	21.66	86	1003	17.08	45.5
5	APS45Y x APS110	600	18.20	94.56	1.895	0.414	21.85	88	1005	17.02	44.4

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