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Studies On The Application Of Heterosis For Evaluation Of Bivoltine Silkworm Hybrids For Tropical Conditions

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Abstract— The main aim of silkworm breeders is to develop promising bivoltine breeds to suit to the tropical conditions of India. Ultimate results in silkworm breeding are judged by the excellence of the characters of the parental strains that appear in the F1 hybrid. In the present study, an attempt is made to evaluate the multivoltine hybrids, cross Breeds and Bivoltine hybrids from the Silkworm Breeding section of Andhra Pradesh State Sericulture Research and Development Institute, namely, viz., NP1 x APM1, FVB1 x MF4, APM2 x GD, (three Multi x Multi Hybrids), APM1 x APS45, APMG16 x APS12, APMG249 x HTO5 (Multi x Bi Cross Breeds) and APS45 x APS12, APS27 x APS50 and APS67 x APS20 (three Biv x Biv Hybrids). The hybrid vigor in the eight traits studies indicate that viz., NP1 x APM1 among Multi x Multi hybrids with 64.68 value and APMG249 x HTO5 with 97.19 value among Cross Breeds and APS67 x APS20 among bivoltine hybrids with 80.43 values are found to be promising hybrids for commercial exploitation in Sericulture industry.

Index Terms— Heterosis, Bombyx mori, Sericulturists, Hybrid vigour, Cocoon traits, Hybrids, MPH (Mid Parental Heterosis).

1. Introduction

Silkworm Bombyx mori L., a lepidopteron insect of commercial importance has been extensively used in several countries for production of silk. On the basis of its pattern of distribution in different parts of the world it has differentiated into a number of geographical races which show distinct differences in their ethological, biochemical, physiological and morphological traits (Yokoyama, 1957; Hirobe, 1968). In view of its economic importance, it is being extensively utilized as a tool for various experimental studies. Even though, India occupies the second position in the global silk production, the unit production and the quality of silk produced is much lower than the sericulturally advanced countries like China and Japan situated in the temperate belt.

Apart from the climatic conditions, the genetic potential of the silkworm breeds play a vital role in the quality and quantity of the silk produced. The bivoltine silkworm races are known for their high productivity and are well acclimatized to temperate climatic conditions, while multivoltine races are known for their high viability and poor productivity under tropical climatic conditions. As a result, bivoltine races are being extensively utilized in the silk producing countries situated in temperate belt and multivoltine races are being commercially exploited in most of the tropical countries, as in India. As a result, the sericulture industry in India still remains to be multivoltine oriented.

Continuous efforts made to introduce bivoltine silkworm races for commercial exploitation in India have met with little success in view of the instability in the rearing performance of bivoltine races under tropical climatic conditions. Further, limitation in the number of silkworm races is one of the constraints for overall development of the industry. Therefore, it is of paramount importance to develop and improve bivoltine silkworm races which can be commercially exploited in order to increase the quality and quantity of the silk. It is possible to evolve and evaluate bilvoltine silkworm races which can yield desired results, responding favorably to the tropical climatic conditions, by designing appropriate breeding strategies for reorganizing the genetic background with an emphasis on the cumulative and permanent nature of the genetic improvement.

Ultimate results in silkworm breeding are judged by the excellence of the characters of the parental strains that appear in the F1 hybrid. Unlike in many plant species where highly inbred lines are used for commercial exploitation, in the silkworm, only the hybrids of highly inbred lines or of different breeds are used (Yokoyama, 1979; Gamo and Hirabayashi, 1983). Even if the characters of both the parental strains have not much value. After inbreeds are developed they are crossed with other inbreeds and their productiveness in single, three-way and

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four-way cross combinations is evaluated. Some inbreeds combine satisfactorily with a large number of other inbreeds to give high yielding hybrid progenies; certain other inbreeds combine with few or no inbreeds (Allard, 1976).

The main aim of silkworm breeders is to develop promising bivoltine breeds to suit to the tropical climatic conditions of India. The success of silkworm breeds developed so far with great caution by the silkworm breeders mainly depends on its combining ability.

Geneticists and breeders have tried to uncover these complex relationships which have given rise to important insights to increase the silk productivity and quality. In the present study, an attempt is made to evaluate the identified Multivoltine hybrids, Cross Breeds and Bivoltine hybrids from the Andhra Pradesh State Sericulture Research and Development Institute, Hindupur, namely viz., NP1 x APM1, FVB1 x MF4, APM2 x GD (three Multi x Multi hybrids), APM1 x APS45, APMG16 x APS12, APMG249 x HTO5 (Multi x Bi Cross Breeds) and APS45 x APS12, APS27 x APS50 and APS67 x APS20 (three Biv. x Biv. Hybrids).

2. MATERIALS AND METHODS

Detailed Evaluation of available parental oval and dumbbell bivoltine breeds is undertaken and rearing is conducted in three replications by following the standard rearing techniques. A group of 20 bivoltine silkworm parental breeds, 10 Oval and 10 peanut races, with known history and genetic background were chosen from the germplasm bank maintained at APSSRDI, Hindupur for evaluation and selection out of them. The performance of these breeds was evaluated for the expression of different metric traits such as fecundity (No.), survival rate (%), cocoon yield per 10,000 larvae by weight (kg), cocoon weight (g), cocoon shell weight (g), cocoon shell ratio (%), filament length (m) and neatness (p). The generated data of three replications were pooled in order to analyze their stability in the performance.

In addition, the overall superiority of the breeds was established by short-listing them on the basis of dependent characters as well by multiple trait evaluation index system. On the basis of the results of four breeds, oval breeds APS5, APS45, 871 and HTO5 and dumbbell breeds APS4, APS12, APS14 and 872 which were found to be superior than other races were short-listed and selected as the potential parental breeds for cross breeding.

All possible hybrids of single cross, three-way cross and double hybrid crosses with oval / dumbbell foundation crosses were prepared and reared along with their parents. The hybrid vigour for different quantitative traits were evaluated and promising hybrids of all the combinations was evaluated, identified and short listed.

In this direction, an attempt has been made to evaluate the performance of available bivoltine silkworm genetic stocks maintained at APSSRDI, Hindupur under tropical conditions and to identify suitable breeds for their utilization in evaluation of silkworm bivoltine breeds/hybrids performance.

Twenty bivoltine silkworm genetic stocks of the working bivoltine germplasm maintained at Andhra Pradesh State Sericulture Research and Development Institute (APSSRDI), Hindupur constitutes the experimental material. Among the 20 bivoltine silkworm genetic stocks for identification of initial parents, 10 breeds viz., APS45, APS5, APS871, HTO5, APS11, APS9, APS7, APS19, APS27, APS25, APS19 and CSR2 spin oval type of white cocoon. Among them APS871, APS11, APS9, APS7, APS19, and APS27 are of Chinese origin, HTO5, APS45, APS5, and CSR2 are of Japanese origin and APS25 are indigenous. The rest of the 10 peanut genetic stocksviz.,APS4, APS12, APS14, APS872, APS18, APS6, APS60, APS24, APS20, APS16, and CSR4 spin white peanut cocoons. Among these breeds, APS872, APS18, APS24, APS20, are of Chinese origin, APS4, APS12, APS14, APS16, and CSR4 are of Japanese origin.

All the genetic stocks were reared during Feb., 2014 at high temperature (28 °C to 30 °C) and low humidity (65 to 70 % RH) conditions. The rearings are conducted as per the procedure detailed by Krishnaswami, et al.,(1964) except for the exposure of the larvae to the target environmental conditions. Each replication consists of 300 larvae which were uniform in size and healthy after 3rd moult were maintained till spinning. Silkworm breeds were fed with V1 variety of mulberry leaves. Cocoons were harvested on 6th / 7th day of spinning and subjected for general cocoon assessment including weighment of cocoons. The survival percentage was calculated based on the number of live pupae available for 300 larvae retained after 3rd moult. Observations were recorded for eight characters viz., fecundity (No.), survival rate (%), cocoon yield per 10,000 larvae by weight (kg), cocoon weight (g), cocoon shell weight (g), cocoon shell ratio (%), filament length (m) and neatness (p).

2.1 Rearing Methodology:

The standard rearing techniques of Yokoyama (1974), Krishnaswami et al.,(1973) were followed. During the period of rearing, two feeds of V1 mulberry leaf was utilized daily until the onset of spinning, except during the larval moult period.

The layings were incubated at 25 ± 1° C with 80 ± 5% humidity, 16 hours light and 8 hours dark and subjected to black boxing 48 hours before hatching. Chawki rearing was conducted under optimum rearing climatic conditions (28 ± 1°C and 90 ± 5% and 27 ± 1°C and 85 ± 5% of temperature and RH for I and II instars respectively). The late age rearing was done as per the standard techniques

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by following the methodology and providing bed disinfectants and maintaining suitable temperature, RH conditions.

After third moult, 300 larvae were retained in each replicate for each breed. The bivoltine cocoons were harvested 6th / 7th day after spinning and harvested cocoons were subjected for quality assessment. The pupation rate was calculated based on the number of live pupae recorded out of 300 larvae retained after 3rd moult.

Brief description of the economic traits and methodology employed to evaluate the resultant data pertaining to the performance of the breed / hybrids is given below.

3. RESULTS:

3.1 Performance of Multi x Multi hybrids

The performance of the Multi x Multi hybrids indicated superiority for four characters in the hybrid NP1 x APM1 for the traits fecundity (521 eggs /laying), cocoon yield per 10000 larvae (9400), cocoon yield per 10000 larvae by weight (14.884 kg), pupation rate (93.17%) and the other hybrid APM2 x GD performed better in the traits viz., cocoon weight (1.606 g), shell weight (0.271g) and shell ratio (16.87).

The heterosis values in Multi x Multi hybrids indicate that, in NP1 x APM1 higher heterosis values were observed for fecundity (11.56%) and the hybrid FVB1 x MF4 showed better performance in four traits, cocoon yield per 10000 larvae (1.82%), cocoon yield per 10000 larvae by weight (17.12%), pupation rate (0.715%), cocoon shell weight (12.3%), APM2 x GD hybrid showed maximum heterosis values for two traits namely, cocoon weight (1.606%) and cocoon shell ratio (0.75%).

3.2 Performance of Bivoltine hybrids

Different hybrids indicated superiority for different characters viz., APS67 x APS20 for fecundity (585 eggs/laying), cocoon yield per 10000 larvae by no. (9746), cocoon yield per 10000 larvae by weight (16.770), pupation rate (95.70), cocoon shell weight (0.429) where as APS27 x APS50 showed better performance in the trait cocoon weight (1.907) and APS45 x APS12 with cocoon shell ratio (22.76%) showed maximum value.

Further, manifestation of hybrid vigour in the hybrids was also studied. Highly significant heterosis was observed in APS67 x APS20 for the traits cocoon yield per 10000 larvae by no. (9.29) and pupation rate (3.45), shell weight (0.429) where as in APS27 x APS50 highest heterosis value for cocoon yield per 10000 larvae by weight (8.89) was observed. For the traits fecundity and shell ratio, the hybrid APS45 x APS12 showed maximum heterosis value of 13.119 and 9.16 respectively.

3.3 Performance of Cross breeds

Among the F1 (Multi x Bi hybrids) crosses, the fecundity is maximum in APM1 x APS45 (506 eggs/laying), cocoon yield by 10000 larvae by no. is maximum in APMG16 x APS12 (9400) where as APMG249 x HTO5 recorded higher values in the traits cocoon yield per 10000 larvae by weight (17.26 kg), pupation rate (94.1%), cocoon weight (1.835g) and cocoon shell weight (0.358g). Maximum cocoon shell ratio of 19.90% is recorded in the hybrid APMG16 x APS12. Out of all the hybrids, APMG249 x HTO5 performed better in most of the traits.

The heterosis values were maximum for the trait fecundity in APM1 x APS45 with 4.76 heterosis %. The breed APMG16 x APS12 performed better in the traits cocoon yield per 10000 larvae by number (4.02%) and shell ratio (11.23%). Maximum heterosis value is observed in APMG249 x HTO5 for the traits cocoon yield per 10000 larvae by weight (27.9%), pupation rate (2.17%), cocoon weight (19.3%) and shell weight (0.358%).

4. DISCUSSION:

Sericulture conceived to play a major role in economic up-liftment of rural poor in the country especially in the major silk producing states of southern India i.e., Karnataka, Andhra Pradesh, Tamil Nadu and Kerala as it is aptly suit to the prevailing agro-climatic, socio-economic conditions. Andhra Pradesh the second largest silk producer in the country after Karnataka offer greater potential for sericulture development. Since the farming systems vary suiting to the different agro-ecological conditions and adoption level by the farmers the yield levels are not consistent in different area. The economic values of silkworm breeds/hybrids depends on its silk productivity which is a complex character and is attributed by more than one parameter (Thiagarajan et al., 1993). Sericulturally advanced countries such as Japan, China and South Korea have made commendable progress in the development of silkworm, Bombyx mori L., breeds with high productivity suiting to sericultural practices of both temperate and topical situations through conventional breeding techniques. However, in India since last few decades different bivoltine breeds have been developed through different breeding techniques resulting in the development of productive bivoltine breeds (Basavaraja et al., 1995, Datta et al., 2000, Reddy et al., 2002,), robust breeds with medium productivity (Rajanna, 1989; Raju, 1990; Kalpana, 1992; Maribashetty, 1991 and Nirmal Kumar, 1995) and some of the breeds have been commercially exploited which are giving beneficial results at farmers level.

The economic values of silkworm breeds/hybrids depends on its silk productivity which is a complex character and is attributed by more than one parameter (Thiagarajanet al., 1993). Sericulturally advanced countries such as Japan, China and South Korea have made commendable progress in the development of silkworm, Bombyxmori L.,

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breeds with high productivity suiting to sericultural practices of both temperate and topical situations through conventional breeding techniques. However, in India since last few decades different bivoltine breeds have been developed through different breeding techniques resulting in the development of productive bivoltine breeds (Basavaraja et al., 1995, Datta et al., 2000), robust breeds with medium productivity (Rajanna, 1989; Raju, 1990; Maribashetty, 1991 and Nirmal Kumar, 1995) and some of the breeds have been commercially exploited which are giving beneficial results at farmers level.

The credit of introducing F1 hybrids with a clear demonstration of their superiority over parental strains goes to Toyoma (1906) of Japan. The hybrids, which were crosses of Chinese and Japanese origin, became so popular with the farmers there, that by 1919, over 90% of eggs produced was of hybrid origin, reaching 100% by 1928 (Yokoyama, 1956).

The discovery of 'Heterosis' coined by Shell in 1914 (increased vigour of cross breeds relative to their parents) has been recognized as one of the major landmarks in both plant and animal breeding. The heterosis breeding approach has now become almost a thoroughfare in breeding many crop species of plants, animals and insects like silkworm for commercial exploitation. Development in the efficiency of silk production in sericulturally advanced countries and also in India is due to heterosis breeding and hence, at present, majority of the sericulturists in various parts of the world raise the cocoon crops only from the hybrids.

Multibivoltine hybrid oriented mulberry sericulture is widely being followed under tropical conditions of India. With increasing demand for quality raw silk by power loom sector further necessitated boosting bivoltine raw silk production in the country. In line with this demand many sericulture research institutes have developed several bivoltine breeds laying primary emphasis for productivity wherein generally the survival rate has been low. This has evidently addressed the demand of races for the prevailing tropical conditions (Krishna Rao et al., 2003). In spite of the quantitative increase in the overall silk production in India over years through the exploitation of productive hybrids (Senguptaet al., 1971), there remains considerable dearth for potential bivoltine hybrids. Considering the obvious limitation with regard to productivity and quality of raw silk of crossbreed type, more emphasis was laid on to popularize bivoltine sericulture in a big way to improve the quality oriented quantitative silk production. The harsh tropical climate characterized primarily with wide and sudden climatic fluctuations coupled with poor quality mulberry leaf and low management by the farmers warrants more flexible genotypes for which proper identification of initial parents is very much essential. Since, the genetic improvement of multiple traits being the objective of evolving the productive bivoltine hybrids suitable for tropical climate, many breeders (Ramesh Babuet al., 2001, 2002) followed specific methods to identify the suitable breeding resource materials.

Accordingly, many productive and qualitative superior bivoltine hybrids have been developed, by utilizing Japanese commercial hybrids as breeding resource material (Basavaraja et al., 1995). The main objective of any silkworm-breeding program is simultaneous genetic improvement of multiple traits (Mano et al., 1993). Today, one of the most important issues Sericulture industry facing is the fluctuation in cocoon yield influenced by the genotype, the environment to which it is exposed and the rearing method followed. Across a diversity of these factors, sericulture industry is mainly confirmed with the problems of dependability and predictability of crop / cocoon yield (Nirmal Kumar et al., 1998).

More the divergent parents more the expression of hybrid vigour (Talebi and Subramanya 2009). The benefits of cross breeding in various species depend on the extent of heterosis for productive, reproductive and possibly paternal traits and on the breed differences. Complementarity between breeds for productive and reproductive traits is also of great importance for partners that promise to nick well i.e., where progeny have much heteosis, will be desirable (Nirmal Kumar et al., 2010). The main intension of the breeders in utilizing single cross breeding techniques is to explore maximum hybrid vigour with less co-efficient of variation that is expressed in F1 hybrid when compared to their parents.

The benefits of using three-way crosses were realized as early as 1933 in Japan silk Industry and further (Harada 1952) demonstrated the importance of both three-way and four-way cross hybrids. (Pannegpet et al.,1975) established the ease in three-way and four-way cross egg production involving single cross hybrids as parents and recorded higher fecundity and reduction in cost of egg production. Further, (Harada 1961) noticed shorter larval duration, higher survival rate and cocoon shell ratio with a slightly dissatisfactory value in whole cocoon weight in specific combinations.

In the present study, the Multi x Multi hybrid NP1 x APM1 has performed well and can be grown in primitive Sericulture belts such as West Bengal where Nistari rearing is practiced. As it is well understood from the results that cocoon yield by weight is 14.884 Kg for 10,000 larvae. So, cocoon yield can be obtained from 64 to 70 Kgs with increased productivity.

Further, for unfavorable conditions of Summer. Cross breeds are reared by the farmers. Form the present study, APMG249 x HTO5 with 94.1 % pupation rate has

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showed better performance and can be recommended to farmers. Similarly, the target for increased bivoltine silk production can be achieved by new bivoltine hybrid APS67 x APS20 for better cocoon yield and productivity.

4. Results

Table 1. Morphological features of genetic stocks

Breed	Origin	Larval Character			Cocoon character		
		Marking	Body colour	Shape	Colour	Shape	Grain
MULTIVOLTINE							
APM1	Madagascar	Plain	BW	Robust	Light Greenish yellow	Oval	Medium
NP1	Indigenous	Plain	YW	Slender	Greenish yellow	EO	Fine
FVB1	Indigenous	Plain	BW	Robust	Light Greenish yellow	EO	Medium
APM2	Madagascar	Plain	YW	Robust	Light Greenish Yellow	Oval	Medium
GD	Indigenous	Plain	CW	Slender	Light yellow	Oval	Medium
APMG16	Madagascar	Marked	BW	Robust	Greenish yellow	EO	Medium
APMG249	Madagascar	Plain	CW	Robust	Greenish yellow	Oval	Coarse
BIVOLTINE							
APS45	Japanese	Plain	BW	Robust	White	EO	Medium
APS27	Indigenous	Plain	BW	Stout	White	Oval	Medium
APS67	Indigenous	Plain	BW	Robust	White	EO	Fine
APS12	Chinese	Plain	BW	Robust	White	MP	Medium
APS20	Chinese	Plain	CW	Slender	PW	Peanut	Medium
APS50	Indigenous	Plain	BW	Robust	White	Peanut	Medium
HTO5	Indigenous	Plain	BW	Robust	White	Oval	Medium
BW= Bluish white; CW; Creamish white; PW=Pale white; MP=Medium Peanut							

Table 2. Performance of Multivoltine parents

Breeds	Fecundity (No.)	Yield /10,000 Larvae		Pupation Rate (%)	Cocoon Weight (g)	Shell Weight (g)	Shell Ratio (%)	Filament Length (m)
		No.	Wt. (kg)					
NP1	475	9400	13.295	92.45	1.445	0.236	16.30	688
APM1	459	9100	12.604	93.50	1.409	0.231	16.39	721
MF4	484	9167	12.415	90.36	1.399	0.228	16.29	685
FVB1	490	9233	12.844	92.67	1.432	0.235	16.41	713
APM2	480	9200	12.806	91.33	1.419	0.246	17.34	729
GD	491	9033	12.525	92.00	1.398	0.238	17.02	736
Average	480	9189	12.748	92.05	1.417	0.236	16.63	712
SD	11.86	125.9	0.31	1.10	0.02	0.01	0.44	21.22
CV(%)	2.47	1.37	2.46	1.19	1.32	2.64	2.67	2.98

Table 3. Performance of Multivoltine x Multivoltine Hybrids

Hybrid	Fecundity (No.)	Yield /10,000 Larvae		Pupation Rate (%)	Cocoon Weight (g)	Shell Weight (g)	Shell Ratio (%)	Filament Length (m)
		No.	Wt. (kg)					
NP1 x APM1	521	9400	14.884	93.17	1.590	0.271	17.04	739
FVB1 x MF4	510	9367	14.781	92.17	1.589	0.260	16.36	701
APM2 x GD	495	9233	14.716	91.59	1.606	0.271	16.87	812
Average	509	9333	14.794	92.31	1.595	0.262	16.44	751
SD	13.05	88.44	0.08	0.80	0.01	0.01	0.39	56.41
CV%	2.57	0.95	0.57	0.87	0.60	2.96	2.38	7.51

Table 4. Hybrid vigour in Multivoltine x Multivoltine hybrids

Hybrid	Fecundity (No.)	Yield /10,000 Larvae		Pupation Rate (%)	Cocoon Weight (g)	Shell Weight (g)	Shell Ratio (%)	Filament Length (m)	Total Value
		No.	Wt. (kg)						
NP1 x APM1	11.56	1.62	14.94	0.215	11.42	15.82	4.22	4.89	64.68
FVB1 x MF4	4.72	1.82	17.12	0.715	12.25	12.3	0.061	0.286	49.27
APM2 x GD	1.95	1.27	16.24	0.245	14.02	11.98	0.75	10.86	57.31

Table 5. Performance of Bivoltine parents

Breeds	Fecundity (No.)	Yield /10,000 Larvae		Pupation Rate (%)	Cocoon Weight (g)	Shell Weight (g)	Shell Ratio (%)	Filament Length (m)
		No.	Wt. (kg)					
APS27	530	9149	15.210	93.2	1.840	0.387	21.03	951
APS45	507	9006	15.310	93.0	1.800	0.375	20.83	985
APS12	513	8840	15.140	92.0	1.735	0.362	20.86	989
APS67	504	8662	15.630	92.0	1.698	0.368	21.67	1168
APS20	539	9172	16.060	93.0	1.714	0.347	20.24	1003
APS50	499	9059	15.410	93.0	1.737	0.356	20.40	992
Average	515	8981	15.46	92.8	1.754	0.366	20.8	1015
SD	15.78	196.50	0.34	0.46	0.05	0.01	0.51	77.14
CV%	3.06	2.19	2.20	0.50	3.11	3.87	2.43	7.60

Table 6. Performance of Bivoltine x Bivoltine Hybrids

Hybrid	Fecundity (No.)	Yield /10,000 Larvae		Pupation Rate (%)	Cocoon Weight (g)	Shell Weight (g)	Shell Ratio (%)	Filament Length (m)
		No.	Wt. (kg)					
APS45 X APS12	564	9288	16.240	94.10	1.850	0.421	22.76	1160
APS27 X APS50	582	9710	16.672	95.00	1.901	0.414	21.78	1140
APS67 X APS20	585	9746	16.770	95.70	1.889	0.429	22.71	1094
Average	577	9581	16.56	94.9	1.880	0.421	22.42	1131
SD	11.36	254.67	0.28	0.80	0.03	0.01	0.55	33.84
CV%	1.97	2.66	1.70	0.84	1.42	1.78	2.46	2.99

Table 7. Hybrid vigour in Bivoltine x Bivoltine hybrids

Hybrid	Fecundity (No.)	Yield /10,000 Larvae		Pupation Rate (%)	Cocoon Weight (g)	Shell Weight (g)	Shell Ratio (%)	Filament Length (m)	Total Value
		No.	Wt. (kg)						
APS45 X APS12	13.119	4.09	6.66	1.72	4.63	14.09	9.16	17.52	70.98
APS27 X APS50	10.58	6.65	8.89	2.04	6.26	11.29	5.12	17.34	68.17
APS67 X APS20	12.17	9.29	5.83	3.45	10.73	19.83	8.35	10.78	80.43

Table 8. Performance of parents

Breeds	Fecundity (No.)	Yield /10,000 Larvae		Pupation Rate (%)	Cocoon Weight (g)	Shell Weight (g)	Shell Ratio (%)	Filament Length (m)
		No.	Wt. (kg)					
APM1	459	9100	12.604	93.50	1.409	0.231	16.39	721
APS 45	507	9006	15.310	93.00	1.800	0.375	20.83	985
APMG16	482	9233	12.321	93.67	1.300	0.194	14.92	674
APS12	513	8840	15.140	92.00	1.735	0.362	20.86	989
APMG249	438	9200	11.790	91.00	1.305	0.198	15.17	685
HTO5	535	9098	15.205	93.20	1.770	0.358	20.22	991
Average	489	9079	13.73	92.73	1.55	0.29	18.07	840.83
SD	36.24	142.5	1.65	1.03	0.24	0.09	2.87	162.34
CV(%)	7.41	1.57	12.05	1.11	15.44	30.49	15.89	19.31

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Table 9. Performance of Multivoltine x Bivoltine Hybrids

Hybrid	Fecundity (No.)	Yield /10,000 Larvae		Pupation Rate (%)	Cocoon Weight (g)	Shell Weight (g)	Shell Ratio (%)	Filament Length (m)
		No.	Wt. (kg)					
APM1xAPS45	506	9367	15.76	93.4	1.687	0.318	18.85	778
APMG16xAPS12	488	9400	16.40	93.8	1.749	0.348	19.90	789
APMG249XHTO5	491	9378	17.26	94.1	1.835	0.359	19.51	833
Average	499	9381	16.47	93.77	1.757	0.341	19.42	859
SD	7.64	16.80	0.75	0.35	0.07	0.02	0.53	22.27
CV%	1.53	0.18	4.57	0.37	4.23	6.10	2.73	2.59

Table 10. Hybrid vigour in Cross Breeds (Multivoltine x Bivoltine)

Hybrid	Fecundity (No.)	Yield /10,000 Larvae		Pupation Rate (%)	Cocoon Weight (g)	Shell Weight (g)	Shell Ratio (%)	Filament Length (m)	Total Value
		No.	Wt.(kg)						
APM1xAPS45	4.76	3.46	12.97	0.16	5.14	4.95	1.289	0.20	32.92
APMG16xAPS12	0.70	4.02	19.70	1.077	15.29	25.17	11.23	0.90	78.08
APMG249XHTO5	0.925	2.50	27.90	2.17	19.30	28.70	10.85	5.30	97.19

Table 11. Evaluation Index values for the new hybrids of silkworm

Hybrid	Fecundity (No.)	Yield /10,000 Larvae		Pupation Rate (%)	Cocoon Weight (g)	Shell Weight (g)	Shell Ratio (%)	Filament Length (m)	Average EI value
		No.	Wt. (kg)						
Multivoltine x Multivoltine hybrids									
NP1 x APM1	59.20	57.58	61.25	60.75	45.00	44.00	41.28	47.87	52.12
FVB1 x MF4	50.77	53.84	48.38	48.25	44.00	48.00	47.95	41.14	47.79
APM2 x GD	39.27	38.69	40.25	41.00	61.00	59.00	61.03	60.81	50.13
Cross Breeds (Multivoltine x Bivoltine)									
APM1xAPS45	61.41	41.27	40.52	39.56	40.58	38.79	39.26	42.44	42.98
APMG16xAPS12	42.74	60.91	49.03	50.95	48.92	53.20	59.04	46.22	51.38
APMG249XHTO5	45.85	47.82	60.45	59.49	60.49	58.01	51.70	61.34	55.64
Bivoltine x Bivoltine hybrids									
APS45 X APS12	38.56	38.49	38.57	40.00	40.00	50.00	56.18	58.57	45.05
APS27 X APS50	54.40	55.07	54.00	51.25	57.00	43.00	38.36	52.66	50.72
APS67 X APS20	57.04	56.48	57.50	60.00	53.00	58.00	55.27	39.07	54.55

Fig.1. The chart showing cocoon yield per 10,000 larvae in hybrids

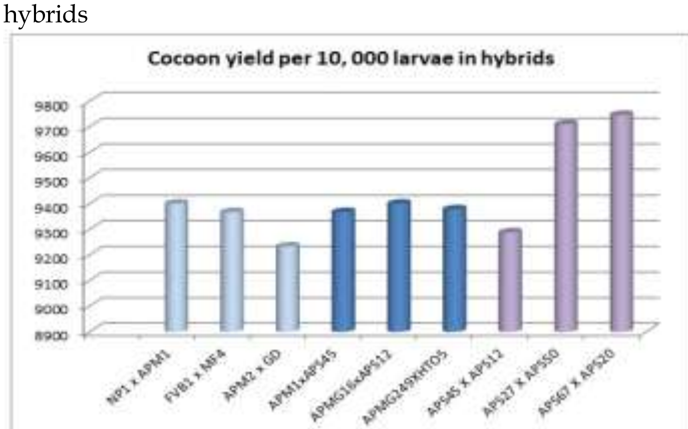
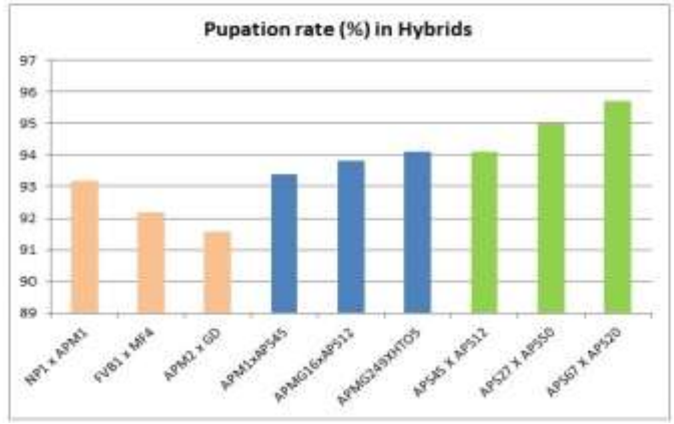


Fig.2. The chart showing pupation rate in hybrids



5. REFERENCES

[1] Allard, R. W. (1976) Implication of genotype environment interactions in applied plant breeding -Principles of plant breeding. Crop Sci.*4: 503-508.*

[2] Basavaraja, H.K.; Nirmal Kumar, S.; Suresh Kumar, N.; Mal Reddy, N.; Kshama, G. and Datta, R.K. (1995) New productive bivoltine hybrids. *Indian Silk* 34(2): 5-9.

[3] Datta, R.K. (2000) A break through in tropical bivoltine sericulture. *In: Nat. Conf. Strategies for Seric. Res. and Dev.* held on16-18, November (Souvenir) at *CSR & TI, Mysore,* India.pp. 21-25.

[4] *Gamo, T. and Hirabayashi, T. (1983)* Genetic analysis of growth rate, pupation rate and some quantitative characters by diallel crosses in silkworm, *Bombyx mori L.* Japan J. Breed.*33(2):178-190.*

[5] Harada, C. (1961) On the heterosis of quantitative characters in silkworm. *Bull. Seric. Expt. Stn.*17: 50-52.

[6] Hirobe, T. (1968) Evolution and breeding of the silkworm – the silk road, past and present Genetics in Asian countries. Proceeding of the 12th Int. Cong. Genet. *Tokyo, pp.25-26.*

[7] Krishnaswami, S.; Jolly, M.S. and Subba Rao, S. (1964) Diallel analysis of quantitative characters in multivoltine races of silkworm. *Indian J. Genet. Plant Breed.*24(3): 213-222.

[8] Krishnaswami, S., Narasimhanna, M.N., Surayanarayana, S.K., Kumararaj, S., (1973) Silkworm rearing. Food and Agriculture Organisation; Rome: Manual on sericulture. 54–88.

[9] Krishna Rao, S.; Govindaraju, S.T.; Mahadevappa, R.; Raghuraman and Bongale, U.D. (2003) Evolution of new productive bivoltine races for tropical conditions. *Ab: Natl. Conf. Trop.lSeric. Global Competitiveness,* November 5-7, Mysore, India. pp.19.

[10] Kalpana G. V (1992) Breeding of Superior races of silkworm, *Bombyxmori* L. for tropical climates. Ph.D Thesis University of Mysore, Mysore.

[11] Mano, Y. (1993) Observations on silkworm breeding in India. *A report*. pp. 1-2.

International Journal of Scientific & Engineering Research, Volume 12, Issue 5, May-2021
ISSN 2229-5518

[12] Maribashetty, V.G. (1991) Evolution of superior bivoltine races of silkworm *Bombyx mori* L. for tropics. *Ph.D Thesis*, *University of Mysore*, Mysore.

[13] Nirmal Kumar, S. (1995) Studies on the synthesis of appropriate silkworm breeds (*Bombyx mori* L.) for tropics. *Ph.D. Thesis, University of Mysore,* Mysore.

[14] Nirmal Kumar, S. and Sreerama Reddy, G. (1998) Evaluation and selection of potential parents for silkworm breeding. *In: Silkworm breeding (Ed. G. Sreerama Reddy) Oxford & IBH publishing co. pvt. Ltd. New Delhi, India.* 63 -78.

[15] Nirmal Kumar, S. Murthy, P. and Moorthy, S. M.(2010) Heterosis studies in selected quantitative traits in silkworm, *Bombyx mori*. L. African J. Basic & Applied Sciences,*2(5-6): 135-143.*

[16] Pennegpet, P. and Jaroonchai, J. (1975) Survey on the practical characters of Double cross hybrids of bivoltine silkworm crosses (2).Bull. Thai.Seri.Train. Centre.5: *85-86.*

[17] Rajanna, G. S. (1989) Evolution of suitable bivoltine races of silkworm, Bombyx mori, L. for tropics. Ph. D. Thesis, *University of Mysore, Mysore.*

[18] Raju, P.J. (1990) Studies on the hybridization and synthesis of new breeds of silkworm, *Bombyx mori* L. *Ph.D. Thesis*, *University of Mysore*, Mysore.

[19] Ramesh Babu, M.; Chandrashekharaiah; Lakshmi, H. and Prasad, J. (2001) Silkworm (*Bombyxmori* L.) genetic stocks – an evaluatory analysis. *Bull. Indian Acad. Seric*. 5: 9-17.

[20] Ramesh Babu, M.; Chandrashekharaiah; Lakshmi, H. and Prasad, J. (2002) Multiple trait evaluation of bivoltine hybrids of silkworm (*Bombyxmori* L.). *Int. J. Indust. Entomol*. 5(1): 37- 43.

[21] Reddy, P.L.; SankarNaik, S. and Sivarami Reddy, N. (2002) Implications of temperature and humidity on pupation patterns in the silkworm, *Bombyxmori* L. *Int. J. Indust. Entomol.* 5(1): 67-71.

[22] Sengupta, K. (1971) An analysis of genotype-environment interaction in some races of silkworm ***Bombyx mori*** L. ***Indian J. Seric***. 10: 6-13.

[23] Talebi, E. and Subramanya, G. (2009) Genetic distance and heterosis through evaluation index in the silkworm, *Bombyx mori (L.).* American J. App. Sciences.*6(12):1981-1987.*

[24] Thiagarajan, V.; Bhargava, S.K.; Ramesh Babu, M. and Nagaraj, B. (1993) Differences in seasonal performances of 26 strains of silkworm, *Bombyxmori* L. (*Bombycidae*). *J. Lepid. Soc*. 47: 321-337.

[25] Toyama, K.(1906) Breeding methods of silkworm. *Sangyo Shimpo.*158: 282-286.

[26] Thiagarajan V, Bhargava SK, Babu M R and Nagaraj B. (1993a), Differences in seasonal performance of twenty six strains of silkworm, *Bombyxmori*L. (Bombycidae) Journal of the Lepidopterists Society 47(4): 331:337

[27] Yokoyama, T. (1956) On the application of heterosis in Japanese sericulture*. Proc. Int. Genet. Symp. Cytologia*(*Suppl*.) (1): *527-531*.

[28] Yokoyama, T. (1957) On the application of heterosis in Japanese sericulture.*Proc.Int. Gent. Symp. Suppl. Vol., Cytologia, pp. 527-537.*

[29] Yokoyama, T. (1974) Utilization of heterosis in Japanese sericulture. *Indian J. Genet.(SABRAO)*34(a): 206-210.

[30] Yokoyama, T. (1979) Silkworm selection and hybridization. Working papers. The Rockfeller foundation Genetics in relation to insect management. *pp.71-83.*