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Assessment of Single Cocoon Weight, Single Shell Weight and Shell Ratio of New Breeding Lines of Bombyx *mori* L

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Abstract: ***The main purpose of our study is to develop bivoltine breeds for our tropical climatic conditions by using silkworm breeds with known genetic backgrounds (KA, NB_{18} and PM) in various hybrid combinations and incorporating them over generations, followed by backcrossing and adequate selection of different generations with the objective of profitability and productivity. The isolated Bivoltin lines (R_1 and R_2) were reared with their parental races at different times of the year to evaluate their stability in the expression of commercial traits. For the present breeding program, the purebred Bivoltine Kalimpong - A (KA), which spin white oval cocoons, New Bivoltine$_{18}$ (NB_{18}) white cocoons with rotating dumbbells and Multivoltine Pure Mysore (PM), the yellow pointed cocoons of the mulberry silkworm Bombyx mori L., Selected. One - way and three - way crosses were made using the above three breeds. The first single cross comprised KA females and PM males. The second unique cross comprised NB_{18} females and PM males. Selection was performed at the egg, larva, pupal, and cocoon stages over the course to determine the desired traits. The offspring of F from the respective crosses were backcrossed with their respective bivoltine males to improve commercial traits. Heterosis in the F_1 generations of crosses, including NB_{18} and PM, was determined by the mean score of the parents (MPV) and the best score of the parents (BPV). A significant test for heterosis was performed using a standard ANOVA table. Based on the results of our study, it was concluded that the mean performance of characters viz. single cocoon weight, single shell weight and shell ration revealed the appearance of higher heterosis for productivity traits, and it could be due to the fact that the influence of the super dominant or incomplete genes on the expression of cocoon yield by weight.***

Keywords: Bombyx *mori* L, Bivoltine, Cocoon weight, Shell weight

1. Introduction

Among insects, Drosophila and domesticated mulberry silk worm Bombyx mori have been used extensively for various experimental purposes. The silk worm Bombyx *mori* for a long time has been under the patronage of man due to its economic value, and this has been an object of research since medieval times. [1] The sericulture probably was practiced in China since 2255 BC and gradually spread to South Korea, Japan and by the North Eastern route to India in 140 BC via the so called 'Silk Road', a road ultimately leading to world culture. [2] Since the birth of silkworm genetics, extensive investigations have been carried out with reference to improve the economic characters. These results together with silkworm breeding experiments contributed much to the establishment of contemporary silkworm breeds of high economic values.

In India, sericulture is a domestic agriculture industry that mainly provides employment to the weaker sectors of society. Due to its employment potential and profitability, its low investment costs and its high foreign exchange earnings, silkworm farming could become an important factor for the economic development of our country. Therefore, studies of the genetic, reproductive and biochemical aspects of the silkworm will have a direct impact on the development of the silkworm industry.

There are many species of silkworm which produce cocoons of superior filament quality and containing larger quantities of silk. Among them Bombyx mori L. of the family Bombycidae is the only species widely used for commercial rearing. India holds unique position in the world by producing all the four commercially known varieties of silk namely, mulberry, eri, Tasar and muga. India ranks second in raw silk (12, 665 tonnes) production in the world (Statistical Biennial CSB 2017). The mulberry silk production in India accounts for 90.7% (28, 523 tonnes) while non - mulberry silks (eri 5060 tonnes 4.9%, Tasar 2819 tonnes) 3.8% and muga (166 tonnes 0.5%) account for 9.3% of the total raw silk production. The major share of the Indian mulberry silk production is from Karnataka accounting for 54.095% (6214 tonnes) (Statistical Biennial CSB 2017).

Systematic breeding experiments of silkworm evolved during the past few years have enabled the breeders to synthesise desirable genotypes of known genetic constitution with a main objective of increasing the productivity and viability. Application of conventional hybridization methods with appropriate selection have contributed a great deal in increasing quality and quantity of silk. Sericulturally advanced countries such as Japan and China have achieved a remarkable breakthrough in increasing the unit production of high grade silk by evolving silkworm races suitable to their agroclimatic conditions. [3]In India several attempts have been made during the last two decades to synthesise suitable, high productive bivoltine races and also multivoltine races to our tropical climatic conditions but with little success. [4 - 8] Further, in the absence of suitable bivoltine races, the locally available multivoltine and bivoltine races are being used for the production of commercial hybrids. Therefore, the unit production and the quality of silk produced by the commercial hybrids remains poor. Hence, it is essential to synthesise better bivoltine races for commercial exploitation under tropical climatic conditions. Moreover, voltinism, moultinism, viability, productivity, resistance or susceptible to disease and tolerance to unfavourable environmental conditions assume a special importance in the efforts to synthesise suitable silkworm races.

With this viewpoint, the present study was undertaken to evolve bivoltine races for our tropical climatic conditions by utilizing the silkworm races of known genetic background (KA, NB_{18} and PM) in different hybrid combinations and to inbreed them over generations followed by backcrossing and adopting appropriate selection at different generations with an objective of the viability and productivity. The isolated bivoltine lines (R_1 and R_2) were reared in different seasons of the year along with their parental races to evaluate their stability in the expression of commercial characters.

2. Materials and Methods

2.1 Silkworm varieties and rearing

The pure races of bivoltine Kalimpong - A (KA) spinning oval white cocoons, New Bivoltine - 18 (NB_{18}) spinning dumbbell white cocoons and multivoltine Pure Mysore (PM) spinning pointed yellow cocoons of mulberry silkworm Bombyx *mori* L. were selected for the present breeding programme. These races were obtained from their respective seed areas and are reared in cytogenetics laboratory, Jnana Bharathi, Bangalore University.

The disease free layings were prepared as described by Narasimhanna, (1988), [9] and were incubated at 25°C and relative humidity of 60 - 70%. On 8th day composite layings were prepared (10 - 20 layings were prepared 100 - 200 eggs were collected from each laying). The hatched worms were reared according to the method described by Krishnaswamy (1978). [10] MS variety of mulberry leaves were used in rearing. The worms were reared in mass upto III instar, after III moult 300 worms were collected in three replicates in order to evaluate the rearing performance. Standard temperature and humidity were maintained in the rearing house. The quantitative traits such as fecundity and hatching percentage were evaluated to assess the performance breeding lines of Bombyx *mori* L.

2.2 Breeding

Single and three way crosses were made by using the above said three races. The first single cross involved KA females and PM males. The second single cross involved NB_{18} females and PM males. During the course of breeding selection was made at the egg, larva, pupa and cocoon stages to fix the desirable traits. Fs progenies of the respective crosses were back crossed to their respective bivoltine males to improve commercial characters.

2.3 Evolutions of new lines R_1 and R_2

Females of KA and NB_{18} were crossed with males of PM. The composite layings of F_1 hybrid were brushed and reared under standard laboratory conditions. The selection parameters explained earlier were applied to choose the seed cocoons for the preparation of F_2 layings. The replicates showing higher pupation rate were selected for intra family selection of cocoons. Further, segregation with respect to cocoon colour and built was noticed. Only white oval in case of KAxPM and dumbbell white in case of NB_{18}xPM qualifying the parameter of selection were choosen for breeding in subsequent generations. The females of F_5 were backcrossed to the males of KA and NB_{18} respectively in both the lines and reared up to 11 generations. At the end of the 11^{th} generation the lines R_1 and R_2 were extracted with higher ERR than their respective better parents, with shorter larval period and with moderate cocoon productivity character in case of R_1 and R_2.

Breeding Plans I and II													
				I							II		
	KA	O	O	x	PM	Cto		NB18	O	O	x	PM	Cfo
		+	i -						+	+			
				F1							F1		
				F2							F2		
				F3							F3		
				F4							F4		
F5	x	KA	O	→	er'		F5x	NB18	Cta	+			
				F1							F1		
				F2							F2		
				F3							F3		
				F4							F4		
				F5							F5		
				F6	(R1)						F6	(R2)	

Statistical Analysis

Heterosis in F_1 generations of crosses including NB_{18} and PM were determined over Mid - parental value (MPV) andBetter parent value (BPV). Heterosis was determined as follows;

% Heterosis over MP = (F1 – MPV/MPV) X 100
% Heterosis over BP = (F1 – BPV/BPV) X 100
Where;
MP: Mid Parent
BP: Better Parent

Significant test for heterosis was performed using standard ANOVA table. To test the generation effect on the rearing performance standard regressions of different parameters on the generation number were worked out. To compare the generation performance of crosses, the data were transformed into standard normal varieties. This is due to the fact that per second comparison of the absolute value does not show the inherent trend in the data.

3. Results

Single Cocoon Weight

The F_1 hybrids of the cross KAxPM revealed mean single cocoon weight (SCW) of 1.623±0.126 gm. which decreased in succeeding generations up to F_5 (1.445±0.062). The F_5 females were backcrossed to the KA males (1.627±0.084 gm), in F_1 the SCW was found to be 1.594±0.038. In succeeding generations, it was found to be the same marginal change (Tables 1 and 2). It was further shown by Table 3 and Fig.1 which is expressed in standard deviation units. The line shows declining trend in two - way cross whereas in three way cross the degree of declining is less but in F_6 generation it is showing declining trend.

Table 1: Mean±S. D of important characters of silkworm hybrid KAxPM in 5 generations

Generations	Single Cocoon Weight (g)	Single Shell weight (g)	Shell Ratio (%)
F1	1.623±0.126	0.351±0.012	20.732±0.984
F2	1.506±0.076	0.334±0.010	21.207±1.049
F3	1.495±0.051	0.335±0.007	21.743±0.896
F4	1.503±0.044	0.318±0.003	20.615±0.277
F5	1.445±0.062	0.303±0.008	20.132±0.948

Table 2: Mean±S. D of important characters of silkworm hybrid F (KAxPM) x KA in 6 generations

Generations	Single Cocoon Weight (g)	Single Shell weight (g)	Shell Ratio (%)
F1	1.594±0.038	0.357±0.009	21.632±0.780
F2	1.567±0.066	0.350±0.003	21.987±0.260
F3	1.503±0.048	0.335±0.005	21.812±0.844
F4	1.470±0.050	0.310±0.003	20.702±0.110
F5	1.505±0.048	0.334±0.012	21.225±0.409
F6	1.573±0.49	0.326±0.018	20.815±0.579

Table 3: Performance of important silkworm characters in two - way and three - way hybrids KAxPM

	Generations	Single Cocoon Weight (g)	Single Shell weight (g)	Shell Ratio (%)
KA x PM	1	1.1196	1.2282	- 0.1489
	2	- 0.0835	0.3107	0.3103
	3	- 0.1989	0.3743	0.8291
	4	- 0.1195	- 0.5432	- 0.2617
	5	0.7168	- 1.3699	- 0.7289
F5 (KAxPM) x KA	1	0.5101	1.1908	0.3624
	2	0.3769	0.8014	0.8394
	3	0.0628	- 0.0226	0.6043
	4	- 0.1000	- 1.3809	- 0.8872
	5	0.0702	- 0.0951	- 0.1840
	6	- 0.9199	- 0.4935	- 0.7349

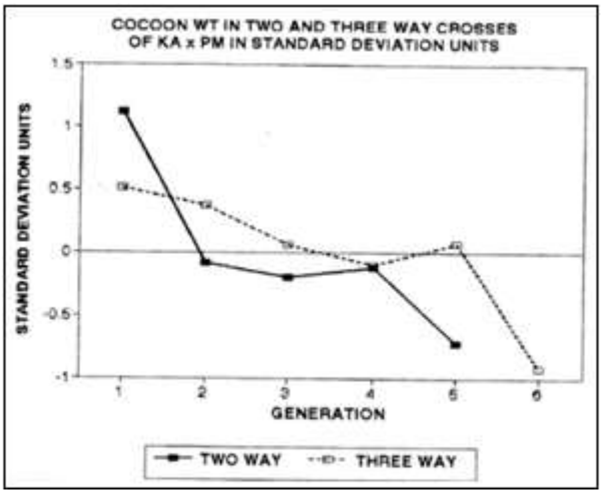

Figure 1

The F_1 hybrids of the cross NB_{18}xPM revealed a mean single cocoon weight of 1.564±0.029 which remained same in F_2 and decreased in succeeding generations up to F_5 (1.519±0.034). The F_5 females were backcrossed to NB_{18} males with a mean cocoon weight of 1.465±0.076. In F1 the cocoon weight increased to 1.645±0.178 gm, it later decreased 1n succeeding generations showing the fixation of the trait leading to the isolation of the race R_2 (Tables 4 and 5). It may be seen from Table 6 and Fig.2 expressed in terms of standard deviation units, that the curve shows similar trend like that of the KAxPM but in two way cross the curve takes upward trend in F_5 generation. Regression of single cocoon weight on generation number is non - significant for KA, NB_{18} and also PM.

Table 4: Mean±S. D of important characters of silkworm hybrid NB1axPM in 5 generations

Generations	Single Cocoon Weight (g)	Single Shell weight (g)	Shell Ratio (%)
1	1.564±0.029	0.331±0.010	21.160±0.399
2	1.573±0.025	0.322±0.013	20.470±0.634
3	1.493±0.109	0.314±0.003	20.438±0.068
4	1.454±0.063	0.316±0.006	20.970±1.055
5	1.519±0.034	0.309±0.005	21.663±2.040

Table 5: Mean±SD of important characters of silkworm hybrid F (NBxPM) x NB in 6 generations

Generations	Single Cocoon Weight (g)	Single Shell weight (g)	Shell Ratio (%)
1	1.645±0.178	0.365±0.023	21.495±1.275
2	1.588±0.178	0.353±0.014	21.328±0.649
3	1.544±0.075	0.350±0.011	22.127±1.074
4	1.581±0.147	0.331±0.010	20.647±0.761
5	1.509±0.107	0.341±0.008	22.010±1.057
6	1.514±0.457	0.345±0.006	23.025±1.176

Table 6: Performance of important silkworm character in two and three - way hybrid of NB18xPM

	Generations	Single Cocoon Weight (g)	Single Shell weight (g)	Shell Ratio (%)
NB$_{18}$xPM	1	0.6562	1.2587	0.2210
	2	0.7888	0.3433	- 0.4732
	3	- 0.4142	- 0.4087	- 0.5051
	4	- 1.0019	- 0.2452	0.0298
	5	- 0.0290	- 0.9481	0.7275
F 5 (NB$_{18}$xPM) x NB$_{18}$	1	0.5573	1.1699	- 0.2481
	2	0.3064	0.3712	- 0.3974
	3	0.1114	0.1462	0.3177
	4	0.2762	- 1.1136	- 1.0080
	5	- 0.0432	, - 0.4162	0.2132
	6	- 1.2081	- 0.1575	1.1224

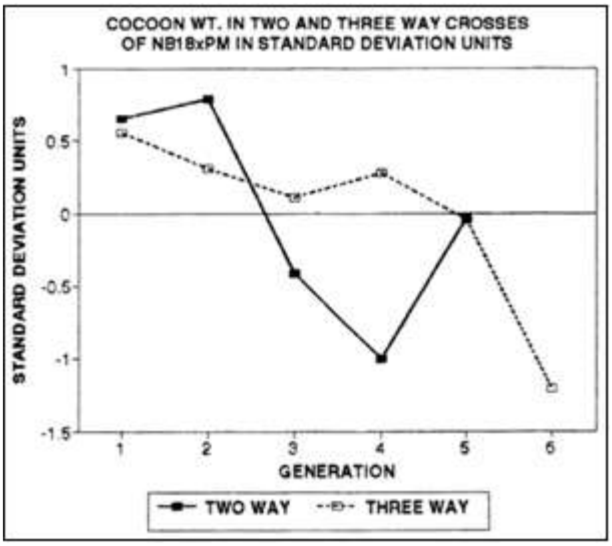

Figure 2

When the mean performance of KA (1.647±0.036) with F$_5$ (KA x PM) x KA (1.573±0.049) was compared. The parent has high magnitude (Tables 7 and 2). When the mean performance of NB$_{18}$ (1.412±0.178) with F$_5$ (NB$_{18}$ x PM) x NB$_{18}$ (1.514) was compared, the magnitude was marginally higher in hybrid (Tables 8 and 6). It may be seen from the Table 9 the degree of heterosis over MP (20.12) and over BP (- 7.061) is significant for the cross KAxPM. In the cross F$_5$ (KAxPM) x KA the degree of heterosis is found to be negative over BP (- 5.16) and positive over MP (2.15) which is non - significant in both the cases (Table 10). For the cross NB$_{18}$xPM the degree of heterosis is found to be significant over MP (13.654) and also significant over BP (- 13.661) (Table 11). In the cross F5 (NB$_{18}$xPM) x PM the degree of heterosis is significant over MP (10.29) and also over BP (8.30) (Table 12).

Table 7: Mean ± SD of important characters in Bivoltine silkworm race of KA over 12 generations

Generations	Single Cocoon Weight (g)	Single Shell weight (g)	Shell Ratio (%)
1	1.747±0.117	0.366±0.010	20.283±0.724
2	1.721±0.067	0.373±0.008	21.275±0.931
3	1.747±0.129	0.360±0.014	19.755±0.887
4	1.557±0.043	0.369±0.016	22.620±0.566
5	1.681±0.084	0.340±0.017	19.295±0.674
6	1.627±0.073	0.336±0.008	20.208±0.873
7	1.693±0.142	1.693±0.142	1.693±0.142
8	1.672±0.103	0.346±0.005	19.700±0.365
9	1.520±0.041	0.352±0.015	22.883±0.324
10	1.564±0.017	0.343±0.014	21.468±1.079
11	1.621±0.114	0.377±0.010	22.392±0.452
12	1.412±0.178	0.352±0.003	22.987±0.615

Table 8: Mean ± SD of important characters in Bivoltine silkworm race of NB$_{18}$ over 12 generations

Generations	Single Cocoon Weight (g)	Single Shell weight (g)	Shell Ratio (%)
1	1.812±0.109	0.432±0.007	22.985±0.191
2	1.743±0.118	0.405±0.004	22.352±0.422
3	1.523±0.014	0.335±0.008	22.155±0.908
4	1.656±0.075	0.355±0.017	21.370±0.579
5	1.464±0.075	0.337±0.002	22.372±0.070
6	1.442±0.062	0.353±0.014	23.822±0.661
7	1.485±0.020	0.348±0.014	23.122±1.134
8	1.673±0.128	0.375±0.012	21.358±0.755
9	1.520±0.041	0.352±0.015	22.883±0.324
10	1.564±0.017	0.343±0.014	21.468±1.079
11	1.621±0.114	0.377±0.010	22.392±0.452
12	1.412±0.178	0.352±0.003	22.987±0.615

Table 9: Heterotic effects in different economic characters of silkworm hybrids KAxPM

KAXPM	Single Cocoon Weight (g)	Single Shell weight (g)	Shell Ratio (%)
MP	20.128*	32.849*	13.072*
BP	- 7.061*	- 4.279*	12.210*

*Significance at 5%;

Table 10: Heterotic effects in different economic characters of silkworm hybrids F5 (KAXPM) X KA

(KAXPM) X KA	Single Cocoon Weight (g)	Single Shell weight (g)	Shell Ratio (%)
MP	2.15	+11.09*	9.73
BP	- 5.16	4.96	7.451

*Significance at 5%;

Table 11: Heterotic effects in different economic characters of silkworm hybrids NB18 XPM

Bt>	Single Cocoon Weight (g)	Single Shell weight (g)	Shell Ratio (%)
MP	13.654ft	10.333*	5.313*
BP	- 13.661*	- 23.291	- 7.940

*Significance at 5%;

Table 12: Heterotic effects in different economic characters of silkworm hybrids F5 (NB18XPM) X NB18

(NB$_{18}$XPM) X NB$_{18}$	Single Cocoon Weight (g)	Single Shell weight (g)	Shell Ratio (%)
MP	10.29*	13.08*	- 2.36
BP	8.30*	8.34*	- 3.92

*Significance at 5%;

Single Shell Weight

The F$_1$ of the cross KAxPM revealed a mean single shell weight of 0.351±0.012 gm. which decreased in succeeding generation upto F$_5$ (0.303±0.008). The F$_5$ females were backcrossed to KA males with a cocoon shell weight of

0.340±0.017, in F_1 the shell weight was found to be 0.357±0.009. It was decreased in succeeding generations and in F_5 and F_6 generations it was found to be 0.334 and 0.326 respectively showing the fixation of the character leading to the isolation of the line R_1 (Tables 1 and 2). Further it may be seen from the Fig.3, the curve shows declining trend in two - way cross, however, taking upward trend in three - way cross after 4thgeneration.

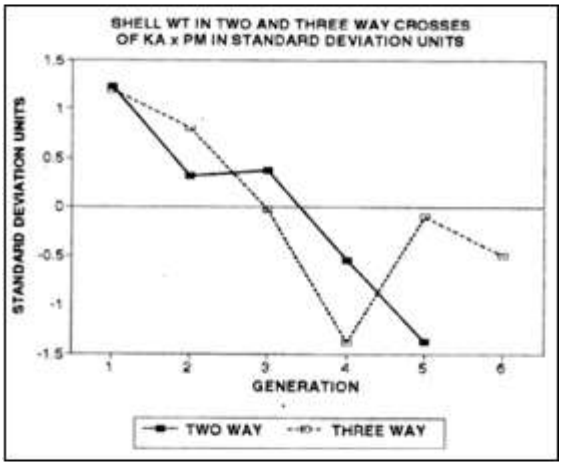

Figure 3

The F_1 hybrids of the cross NB_{18}xPM revealed a mean shell weight of 0.331±0.010 g. which decreased in succeeding generations upto F_5 (0.309±0.005). The F_5 females were backcrossed weight of to the NB_{18} males with a 0.337±0.002. In F_1, the mean single shell weight was0.365±0.023 which decreased and was found to be constant inF_5 and F_6 generations showing the fixation of the trait leading to the isolation of the line R_2 (Tables 4 and 5). Further it was shown by the table 6 and Fig.4, which is expressed in terms of standard deviation units in two - way cross. The curve takes declining trend whereas it takes upward trend in three - way cross.

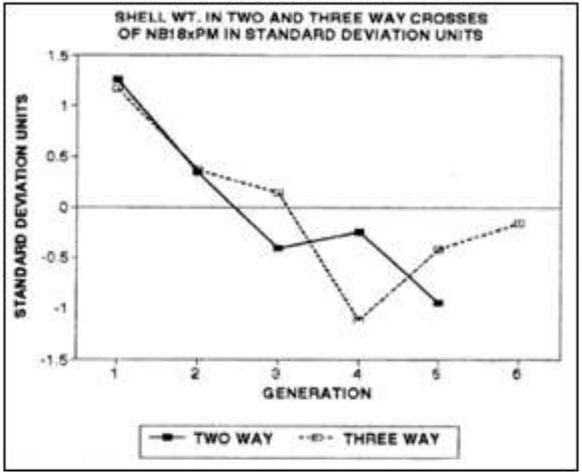

Figure 4

Regression of shell weight on generation number was significant in KA implying that environment has a significant role in expression of their trait in KA. Whereas the role of environment is not significant in NB_{18} and PM. When the mean performance of KA (0.325 0.09) with F_5 (KA x PM) x KA (0.326±0.01) was compared. The performance remains same in both hybrid and the parent (Tables 7 and 2). When the mean performance of NB_{18} (0.352 0.003) with F5 (NB_{18} x PM) x NB_{18} (0.345±0.006) was compared, the magnitude was marginally higher in the parent (Tables 8 and 5). It may be seen from Table 9, the degree of heterosis for the cross KAxPM is significant over MP (32.849) and negative and significant over BP (- 4.279). For the three way cross F_5 (KAxPM) x KA it was significant over MP (11.09) and was not significant over BP (4.96) (Table 10). The degree of heterosis for the cross NB_{18}xPM was found to be significant over MP (10.333) and also over BP (- 23.291). For the cross F_5 (NB_{18}xPM) x NB_{18} the degree of heterosis was found to be significant over MP (13.08) and also over BP (8.34) (tables 11 and 12).

Shell Ratio

The F_1 hybrids of the cross KAxPM revealed a mean shell ratio of 20.73±0.984. It increased to 21% in F_2 and gradually decreased in succeeding generations. The F_5 females with a shell ratio of 20.132±948 were backcrossed to the males of the KA. In F_1 generation the shell ratio was found to be 21.632±0.780. It remained same with marginal change showing the fixation of the trait leading to the isolation of the race R_1 which spins oval white cocoons (Tables 1 and 2). From table 3 and Fig.5 which is expressed in terms of standard deviation units, the curve shows declining trend after F3 generations in two - way cross and the same trend is seen in the three way cross.

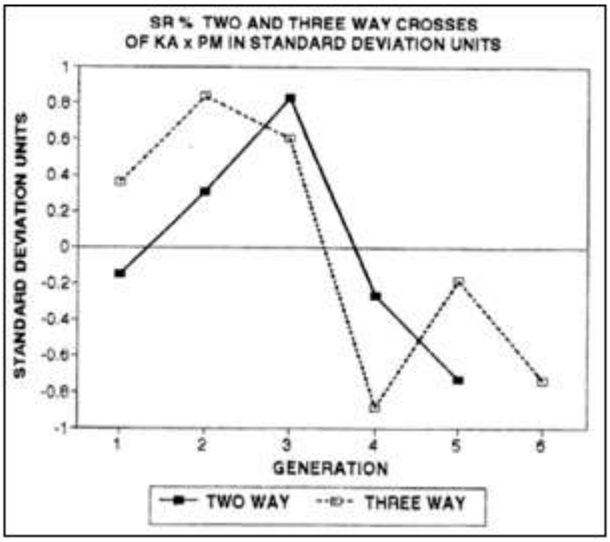

Figure 5

The F_1 hybrids of the cross NB_{18}xPM revealed a mean shell ratio of 21.160±0.399 which decreased in succeeding generations. However, it increased to 21.66±2.0 in F_5 generation. The F_5 females were back crossed to NB_{18} males with a mean shell ratio of 22.3±0.09. In F_1 the shell ratio was 21.49±1.27 and it increased in succeeding generations upto F_6 showing the fixation of the trait leading to the isolation of the line R_2 (Tables 4 and 5). From Fig.6 it was seen that the curve shows increasing trend after F_3 and do not show much variation in two - way cross and in the three - way cross also. Regression of shell ratio on generation number was not significant in all the races.

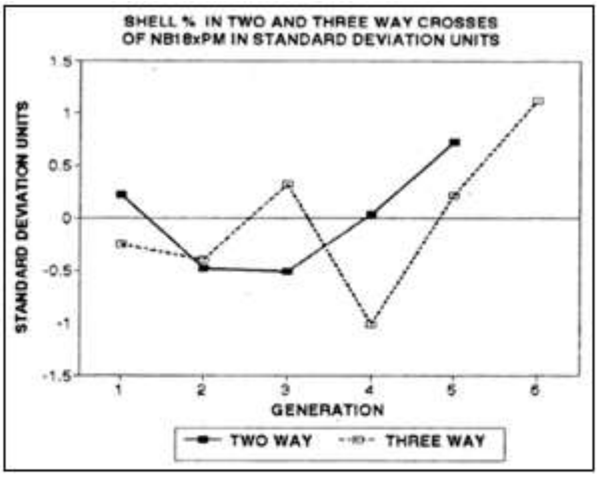

Figure 6

When the mean performance of KA (19.615±0.613) with F_5 (KA x PM) x KA (20.815±8, 57) was compared. The magnitude is marginally higher in the hybrid (Tables 7 and 8). When the mean performance of NB_{18} (22.98±0.615) with F_5 (NB_{18} x PM) x NB (23.025±1.176) was compared, the magnitude was marginally higher in the hybrid (Tables 8 and 5). It may be seen from Table 9 the degree of heterosis calculated for the hybrids KAxPM over MP value (13.072) and over BP (12.210) were significant. The hybrids of the cross F_5 (KAxPM) x KA did not show significant heterosis (Table 9). The hybrids of the cross NB_{18}xPM showed significant heterosis over MP (5.313) and over BP (- 7.940) but it was not significant in the cross F_5 (NB_{18}xPM) x NB_{18} (Table 12 and 11).

4. Discussion

Hybridization as a process has been practiced since the dawn of civilization to improve any breed of animal or plant for better performance than pure breeds. It offers genetic manipulation options to choose new and better combinations of genes. The use of known genotypes, the choice of mating systems and the careful selection method are of decisive importance in conventional breeding methods, such as line breeding and crossbreeding. Crossbreeding is more reliable than online breeding for the evolution of silkworm breeds. Some races are good for some characters and some are bad for some characters. Mestizaje involves two or more races to obtain desirable characters. Three inbred lines of known genotype were used to obtain promising new lines. The multivoltine breed Spinning Pure Mysore yellow tip cocoon shows disease resistance and is known for its lower silk yield. [11] Tropical Bivoltine Kalimpong - A (KA) Spinning Oval White Cocoon and NB_{18} Spinning Dumbell White Cocoon are known for their higher silk yields. and are comparatively less resistant to diseases and adverse environmental conditions. [12]

In the present study the we used bivoltine females and multivoltine males. The crosses were made initially and backcrossed to F_5 generations. Analysis of the metric traits *viz.* single cocoon weight, single shell weight and shell ration revealed the manifestation of varied degrees of heterosis over mid parent and better parent. Owing to the simultaneous segregation of a large number of genes in conjugation with the influence of environmental effects. For instance, the higher heterosis of all the F_1 hybrids of the experimental batches in productivity characters such as single cocoon weight, shell weight, shell ration percentage, support the findings of Kobayashi et al. (1968) who have reported an appearance of higher heterosis for productivity traits compared to viability traits. [13] Similarly, Mousseau and Roff (1987) have pointed out that the characters associated with viability are less heretable than the character associated with productivity which shows moderate to high heritability. [14] Petkov (1980) has reported the influence of the super dominant or incomplete genes on the expression of cocoon yield by weight, single cocoon weight, and pupation rate. [15] Therefore, the lower heterosis recorded for viability character and higher/moderate heterosis recorded for productivity characters can be attributed to lower/moderate/higher heritability for the respective characters.

Furthermore, perusal of heterosis on the importance and value of heterosis has undoubtedly established the fact that inbreeding, which results in increasing homozygosis provides a means for fixation of genetic characters, while out breeding emphasizes the practical value of heterozygosis, wherein the possibility superiority is established for fixation of genetic traits. It with is least obvious that heterosis in terms of specific phenotypic consequences therein would depend, on which loci are involved in the interaction of different alleles of the parents. Selection is made to choose intermediate sized cocoons from the batches of high ERR as these individuals are expected to possess maximum fitness value. [16] Accordingly in breeding and selection over generations resulted in favorable combinations of desired alleles in the progenies leading to the expression of statistically non – significant differences for the metric traits understudies at later generation indicating their fixation in the isolated lines.

The results of the present investigation with regard to the manifestation of heterosis are in agreement with the findings of Osawa and Harada (1944). [17]Harada (1956, 1961) who have pointed that greater the mid parent value, lesser will be the effect of heterosis. Overall performance of back cross hybrids are observed to be better than biparental hybrids (KAxPM or NB18xPM) due to the fact that backcross hybrids have 75% of the genetic structure resembles that of either KA or NB18 as the case may be. While the biparental hybrid contains only50%ofNB18or KA. [18, 19] However, degree of heterosisis more prominent in Biparental cross than backcross hybrids. [20]

5. Conclusion

The results of our study delineated that the mean performance of characters *viz.* single cocoon weight, single shell weight and shell ration delineated that appearance of higher heterosis for productivity traits, and it could be due to the fact that the influence of the super dominant or incomplete genes on the expression of cocoon yield by weight.

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