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Studies on the manifestations of heterosis in new hybrids

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ABSTRACT

Concerted efforts have been made to cross different silkworm varieties to produce the hybrids with an objective to improve the productivity traits. Systematic and planned hybridization together with improved farming in rearing practices in sericulture has helped a great deal to increase the productivity by several folds in sericultural countries including tropical India. In fact, the ultimate results in silkworm breeding are judged by the superiority of commercial characters of the parental strains that appear in the F1 hybrids in the form heterosis or the extra vigor which form paramount criteria in the evaluation of the suitability of hybrids for commercial exploitation. Hence, in the present investigation, an attempt has been made to select superior bivoltine hybrids utilizing the four newly evolved bivoltine races of the authors' *viz.* MG405, MG406, MG408 and MG414 and crossing them with four conventional bivoltine races *viz.* KA, NB4D2, NB7 and NB18, to evaluate the rearing performance of different hybrid combinations for heterosis, over dominance and also determine their extent improvement over the control hybrids. The manifestation of heterosis was observed to be varying with the different economic traits and the hybrids. The extent of heterosis was high for productivity traits than the viability traits. Higher level of heterosis and over dominance was noticed for the traits, cocoon yield by weight, single cocoon weight, shell weight and filament length. Majority of the new hybrid combinations manifested better heterosis and over dominance values than the two control hybrid combinations, NB_{18} x NB_7 and KA x NB_4D_2 for most of the characters studied.

KEYWORDS

Heterosis;
Bombyx mori;
Bivoltines.

INTRODUCTION

Systematic and planned hybridization together with improved farming in rearing practices in sericulture has helped a great deal to increase the productivity of silk attributes by many folds. It is apparent that ultimate results in silkworm breeding are judged by the Excellency of the commercial characters of the parental strains that pronounced in the F_1 hybrids. Since the dawn of Sericulture, efforts have been made to cross different silkworm varieties to produce the hybrids with an improvement in productivity. However, the rearing of F1 hybrids instead of pure lines was introduced for the first time in Japan by Toyama in 1906 in a systematic manner and this commercial exploitation of hybrid vigour heralded a new era in sericulture which contributed substantially to the increased silk production.

In India, cross breeding of silkworm races which differed in voltinism and quantitative characters were initiated even though during 1960's, utilisation of four bivoltine races such as KA, NB_7, NB_{18} and NB_4D_2 evolved during 1970's[13,15] as male parents in the cross-breeding programme with pure Mysore race in the preparation of F_1 hybrids have brought a quantum jump in the cocoon productivity[1]. These hybrids have contributed to the increased unit production of silk, but the quality of the silk filament remains poor since the inherent defects of multivoltine races are passed on to the hybrids. Several attempts made to utilize different F_1 bivoltine hybrid combinations from four bivoltine races for commercial exploitation have not yielded expected results due to less hybrid vigour[10]. Further, these bivoltine hybrids exhibited lesser adaptability of 25-30% than the conventional multi x bi cross breeds and have not gained wider acceptance among the farmers[2].

Keeping in view the importance of rearing F_1 bivoltine hybrids for commercial exploitation, the author has felt the need for evaluating the new bivoltine lines evolved[18] in the production of F_1 hybrids using four bivoltine races that are popular in the field namely KA, NB_7 NB_{18} and NB_4D_2 as male parents through line x tester analysis. The degree of heterosis, over dominance, and the extent improvement over the control hybrids were evaluated for nine economic characters to adjudicate the best hybrids.

MATERIALS AND METHODS

The four evolved bivoltine breeds MG 405, MG 406, MG 408 and MG 414 and four tropical bivoltine races, KA, NB7, NBI8 and NB4D2 formed the material for the present study. Among the four evolved bivoltine breeds used as lines for the present analysis, MG 405, MG 406 and MG 414 are characterized by spinning white dumbbell cocoons and MG 408 spins white oval cocoons. Among the four testers, KA and NB7 spins white oval cocoons while, NB_{18} and NB_4D_2 spins white dumbbell cocoons.

The heterosis experiment was initiated by crossing evolved female lines with each of the male testers. For each of the lines, testers and their sixteen hybrids, three replicates were maintained. Following standard rearing methods[12], the data has been recorded for the nine economic traits such as hatching percentage, larval duration, cocoon yield by number/ 10,000 larvae brushed, cocoon yield by weight/ 10,000 larvae brushed, single cocoon weight, single shell weight, cocoon shell percentage, pupation rate and filament length were subjected to estimate heterosis and over dominance. The percentages of increment in the sixteen new hybrids were evaluated over the two control hybrids NB_{18} x NB_7 and KA x NB_4D_2.

STATISTICAL METHODS

1. Estimates of heterosis and over dominance for different crosses were calculated by the following formulae:

$$\text{Heterosis \%} = \frac{F1 - MP}{MP} \times 100$$

$$\text{Over dominance \%} = \frac{F1 - BP}{BP} \times 100$$

Where, F_1 = Mean of hybrid; MP = Mean of mid parental value; BP = Mean of better parent

2. The percentage of increment/decrement with regard to the expression of economic traits of the new hybrids over the traditional hybrids were calculated by employing the following formula

$$\frac{X - Y}{Y} X\,100$$

Where, X = the object compared, Y = the compared ones.

RESULTS

The mean values of the nine economic characters of the new isolated lines *viz*. MG 405, MG 406, MG 408 and MG 414 and four testers, KA, NB_7, NB_{18} and NB_4D_2 are given in TABLES 1 and 2 and their hybrids in TABLE 3.The heterosis and over dominance levels expressed by the new bivoltine hybrids as well the two traditional control hybrids is given in TABLE 4. The percentage of improvement/ decrement in the hybrids for nine economic traits over the two control hybrids are presented in TABLES 5 and 6.

From the TABLES 1 and 2, it is clear that among the lines and testers, the lines MG 405, MG 406, MG 408 and MG 414 were found to be superior over the four testers for the traits hatching percentage, larval duration, cocoon yield by number and pupation rate. All the testers, however were found to be superior over the lines for single cocoon weight, shell weight, cocoon shell percentage and filament length. Further, for the trait cocoon yield by weight, the four lines recorded almost similar values when compared to those of three testers *viz.* KA, NB_7 and NB_{18}.

TABLE 1 : Mean values of economic characters of the lines

LINES	Hatching percentage	Larval duration (hrs)	Cocoon yield by No/10,000 larvae	Cocoon yield by weight /10,000 larvae	Single cocoon weight (gms)	Single shell weight (gms)	Shell percentage	Pupation rate	Filament length
MG 405	94.41	573.30	9256.0	15.76	1.723	0.313	18.22	91.43	926.66
MG 406	94.57	575.26	9276.0	15.73	1.730	0.324	18.70	92.18	924.66
MG 408	95.29	572.66	9360.6	15.97	1.723	0.321	18.67	93.21	932.66
MG414	94.69	575.00	9336.6	15.96	1.750	0.325	18.62	92.90	941.66

TABLE 2 : Mean values of economic characters of the testers

TESTERS	Hatching percentage	Larval duration (hrs)	Cocoon yield by No/10,000 larvae	Cocoon yield by weight /10,000 larvae	Single cocoon weight (gms)	Single shell weight (gms)	Shell percentage	Pupation rate	Filament length
KA	92.55	592.00	8748.60	15.71	1.82	0.363	19.90	86.60	960.33
NB7	92.21	586.80	8858.00	15.11	1.78	0.366	20.59	85.63	981.33
NB18	93.22	593.30	8778.60	15.79	1.85	0.376	20.27	85.83	953.33
NB4D2	93.58	605.10	8991.30	16.74	1.90	0.390	20.58	87.28	1014.60

TABLE 3 : Mean values of economic characters in the new bivoltine hybrids and control

Hybrid	Hatching percentage	Larval duration (hrs)	Cocoon yield by No/10,000 larvae	Cocoon yield by weight /10,000 larvae	Single cocoon weight (gms)	Single shell weight (gms)	Shell percentage	Pupation rate	Filament length
MG 405xKA	96.80	565.0	9500.3	18.04	1.94	0.398	20.54	94.21	1074
MG 405XNB7	96.35	562.0	9469.3	16.94	1.80	0.338	18.83	93.10	957
MG405XNB18	95.53	564.3	9380.0	17.44	1.91	0.382	20.01	93.78	1001
MG405XNB4D2	96.57	565.3	9420.3	17.17	1.85	0.361	09.53	93.81	982
MG406XKA	96.28	555.3	9554.6	17.89	1.92	0.381	09.82	94.62	1009
MG406XNB7	97.58	562.3	9360.6	17.53	1.94	0.388	20.35	94.67	1006
MG406XNB18	95.19	564.3	9402.0	18.67	2.09	0.407	19.50	93.65	1156
MG406XNB4D2	95.53	565.0	9358.6	18.59	2.05	0.405	19.79	92.81	1159
MG408XKA	97.13	556.0	9433.3	17.73	1.90	0.397	20.93	93.16	1050
MG408XNB7	94.71	554.6	9466.0	16.34	1.78	0.348	19.60	93.20	991
MG408XNB18	97.82	558.0	9490.3	17.74	1.90	0.373	21.04	94.01	1147
MG408XNB4D2	97.02	555.0	9772.0	18.46	1.92	0.390	20.28	95.57	1084
MG414XKA	97.91	553.6	9492.6	19.18	2.05	0.417	20.98	95.50	1192
MG414XNB7	96.27	557.0	9406.6	18.62	2.05	0.401	19.59	93.89	1182
MG414XNB18	97.44	564.6	9502.6	18.10	1.96	0.394	19.95	93.91	1107
MG414XNB4D2	96.63	556.6	9621.3	19.11	2.06	0.406	20.11	94.61	1207
CONTROL									
NB18XNB7	95.10	574.0	9128.6	17.45	1.90	0.374	20.14	87.76	1038
KAXNB4D2	94.46	573.0	9046.0	17.91	1.94	0.393	20.25	89.90	1122

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TABLE 4 : Heterosis and over dominance in new bivoltine hybrids and control

Hybrid	Hatching percentage		Larval duration		Cocoon yield by Number		Cocoon yield by weight		Single cocoon weight		shell weight		Shell percentage		Pupation rate		Filament length	
	H	OD	H	OD	H	OD	H	OD	H	OD	H	OD	H	OD	H	OD	H	OD
MG405XKA	3.55	2.53	-3.02	-4.56	5.53	2.63	14.68	14.46	9.60	6.59	12.42	9.64	7.76	3.21	5.84	3.04	12.59	11.84
MG405XNB7	3.25	2.05	-3.11	-4.22	4.54	2.30	9.78	7.48	2.85	1.12	-2.02	-7.65	-3.38	-8.54	5.16	1.82	0.32	-2.47
MG405XNB18	1.83	1.18	-3.25	-4.88	4.02	1.33	10.58	10.44	9.14	3.24	11.04	1.59	2.77	-0.29	5.81	2.57	6.51	5.00
MG405XNB4D2	2.74	2.28	-4.05	-6.57	3.25	1.77	5.66	2.56	2.20	-2.63	2.84	-7.43	0.67	-5.10	4.99	2.60	1.23	-3.15
MG406XKA	2.90	1.80	-5.01	-6.53	6.01	3.00	13.80	13.73	8.47	5.49	11.07	4.95	2.69	-0.40	5.85	2.64	7.06	5.07
MG406XNB7	4.48	3.18	-3.22	-4.17	3.23	0.19	13.68	11.44	10.85	8.98	12.46	6.01	4.41	-1.16	6.49	2.70	5.84	2.78
MG406XNB18	1.38	0.65	-3.41	-4.88	4.15	1.35	18.46	18.27	16.75	12.97	16.28	8.24	0.10	-3.79	5.22	1.59	23.15	21.29
MG406XNB4D2	1.55	1.01	-4.26	-6.62	2.46	0.89	14.54	11.05	13.25	7.89	13.44	3.84	0.76	-3.83	3.43	0.68	19.32	14.63
MG408XKA	3.41	0.02	-4.52	-6.08	4.18	0.77	11.93	11.02	7.34	4.39	16.08	9.36	8.66	5.17	4.12	0.42	10.94	9.34
MG408XNB7	1.02	-0.60	-4.33	-5.48	3.91	1.12	5.14	2.31	1.71	0.00	1.45	-4.91	-0.15	-4.80	4.22	-0.01	3.56	0.98
MG408XNB18	3.78	2.65	-4.27	-5.94	4.63	1.38	11.71	11.08	6.74	2.70	7.18	-0.79	8.06	3.79	5.01	0.85	21.70	20.38
MG408XNB4D2	2.74	1.81	-5.74	-8.27	6.49	4.39	12.60	10.27	6.07	1.05	9.85	0.00	3.36	-1.45	5.90	2.53	11.37	6.86
MG414XKA	4.58	3.40	-5.12	-6.48	7.18	3.81	21.16	20.17	15.16	12.63	21.22	14.87	8.93	5.42	6.40	2.82	25.41	24.19
MG414XNB7	3.01	1.66	-4.11	-5.07	3.39	0.74	19.89	16.66	16.47	15.16	16.23	9.56	-0.05	-4.85	5.18	1.06	22.94	20.45
MG414XNB18	3.71	2.90	-3.33	-4.83	4.91	1.77	14.05	13.40	8.88	5.94	12.57	4.78	2.62	-1.57	5.09	1.08	16.84	16.12
MG414XNB4D2	2.65	2.04	-5.66	-8.01	4.99	3.04	16.88	14.15	13.18	8.42	13.72	4.10	2.60	-2.28	5.01	0.84	23.40	18.97
CONTROL																		
KAXNB4D2	1.50	0.94	-4.26	-5.30	1.98	0.60	10.42	6.99	4.30	2.10	4.52	0.76	0.04	-1.60	3.40	3.00	13.69	14.39
NB18XNB7	2.57	2.01	-2.71	-3.25	3.51	3.05	12.94	10.51	4.97	2.70	0.80	-0.53	-1.41	-2.18	2.36	2.24	7.30	5.77

TABLE 5 : Percentage of improvement/ decrement in the economic traits of new bivoltine hybrids over the control NB18 x NB7

Hybrid	Hatching percentage	Larval Duration	Cocoon yield by Number	Cocoon yield by weight	Single cocoon weight	Shell weight	Shell percentage	Pupation rate	Filament length
MG405XKA	1.787	-1.567	4.072	3.381	2.105	1.272	1.986	4.794	3.468
MG405XNB7	1.314	-2.090	3.732	-2.922	-5.263	-9.625	-6.504	6.084	-7.80
MG405XNB18	0.452	-1.684	2.753	-0.057	0.526	2.139	-0.645	6.859	-3.564
MG405XNB4D2	1.545	-1.515	3.195	-1.604	-2.631	-3.475	-3.028	6.893	-5.331
MG406XKA	1.240	-3.257	4.666	2.521	1.368	1.871	-1.588	7.816	-2.793
MG406XNB7	2.607	-2.038	2.541	0.458	2.105	3.743	1.042	7.873	-2.832
MG406XNB18	0.094	-1.689	2.994	6.991	10.000	8.823	-3.177	6.711	-11.396
MG406XNB4D2	0.452	-1.567	2.516	6.532	7.894	8.288	-1.737	5.754	11.464
MG408XKA	2.134	-3.135	3.344	1.604	0.000	6.149	3.922	6.153	1.156
MG408XNB7	-0.4102	-3.379	3.696	-6.361	-6.315	-6.951	-2.681	6.198	-4.527
MG408XNB18	2.860	-2.787	3.962	1.661	0.000	-0.267	4.468	7.121	10.558
MG408XNB4D2	2.018	-3.310	7.048	5.787	1.052	4.278	0.695	8.899	4.460
MG414XKA	2.954	-3.554	6.178	9.914	7.894	11.497	4.170	8.819	14.894
MG414XNB7	1.230	-2.961	3.045	6.704	7.894	7.219	-2.730	6.984	13.872
MG414XNB18	2.460	-1.637	4.097	3.724	3.157	5.347	-0.943	7.007	6.647
MG414XNB4D2	1.608	-3.031	5.397	9.512	8.421	8.556	-0.148	7.805	16.281

TABLE 6 : Percentage of improvement/ decrement in the economic traits of new bivoltine hybrids over the control KAXNB4D2

Hybrid	Hatching percentage	Larval Duration	Cocoon yield by Number	Cocoon yield by weight	Single cocoon weight	Shell weight	Shell percentage	Pupation rate	Filament length
MG405XKA	2.477	-1.396	5.022	0.720	0.000	1.272	1.432	4.794	-4.329
MG405XNB7	2.000	-1.919	4.679	-5.421	-7.216	-13.994	-7.012	3.559	-14.751
MG405XNB18	1.132	-1.513	3.692	-2.629	-1.546	-2.798	-1.185	4.315	-10.831
MG405XNB4D2	2.233	-1.343	4.137	-4.137	-4.639	-8.142	-3.555	4.349	-12.465
MG406XKA	1.926	-3.089	5.619	-0.117	-0.721	-3.053	-2.123	5.250	-10.119
MG406XNB7	3.302	-1.867	3.477	-0.021	0.000	-1.272	0.493	5.305	-10.154
MG406XNB18	0.772	-1.518	3.935	4.237	7.731	3.562	-3.703	4.171	3.001
MG406XNB4D2	1.132	-1.396	3.455	3.790	5.670	3.053	-2.271	3.236	3.064
MG408XKA	2.826	-2.966	4.281	-1.010	-2.06	1.017	3.358	3.626	-6.467
MG408XNB7	0.264	-3.211	4.642	-8.771	-8.247	-0.011	-3.209	3.670	-11.722
MG408XNB18	3.557	-2.617	4.911	-2.061	-2.061	-5.089	3.901	4.571	2.226
MG408XNB4D2	2.710	-3.141	8.025	3.065	-1.030	-0.763	0.148	6.307	-3.411
MG414XKA	3.652	-3.385	7.147	7.085	5.670	6.106	3.604	6.229	6.235
MG414XNB7	1.916	-2.792	3.986	3.958	5.670	2.035	-3.259	4.438	5.291
MG414XNB18	3.154	-1.465	5.047	1.055	1.030	0.254	-1.481	4.460	-1.389
MG414XNB4D2	2.297	-2.862	6.359	6.694	6.185	3.307	-0.691	5.239	7.518

Comparison of the mean values of nine economic traits in new bivoltine hybrids and control bivoltine hybrids revealed that, majority of the hybrids recorded higher mean values for most of the economic traits except shell percentage than NB_{18} x NB_7 combination. While comparison to KA x NB_4D_2, the new hybrids registered higher mean values for hatching percentage, shorter larval duration, cocoon yield by number, yield by weight and pupation rate in addition to several of the new hybrids recording superior values for single cocoon weight, shell weight, shell ratio and filament length thus revealing their superior rearing performance over the control hybrid combinations.

Based on the mean values of the hybrids under study, the percentage of increment/decrement calculated for various economic traits over the control bivoltine hybrids revealed superiority of the new hybrids for majority of the character analyzed over NB_{18} x NB_7 combination. Similar comparison to another control KA x NB_4D_2 however, revealed improvement in the new hybrids for hatching percentage, shorter larval duration, cocoon yield by number, yield by weight, shell weight and pupation rate in addition to few of the hybrids excelling for cocoon weight, shell percentage and filament length thus confirming the superiority of the new hybrids over the control hybrids for various economic traits.

The manifestation of heterosis was observed to be varying with the different economic traits and the hybrids. The extent of heterosis was high for productivity traits than the viability traits. Higher level of heterosis and over dominance was noticed for the traits, cocoon yield by weight, single cocoon weight, shell weight and filament length. Majority of the new hybrid combinations manifested better heterosis and over dominance values than the two control hybrid combinations, NB_{18} x NB_7 and KA x NB_4D_2 for most of the characters under study.

DISCUSSION

The manifestation of heterosis and its evaluation in hybrids derived by lines with testers is an important criterion in understanding the expression of heterosis with respect to each of the economic character. Utilization of heterosis is important in order to obtain favorable economic benefits. It is well established that heterosis is usually more in the hybrids derived from genetically diverse or unrelated lines than those from genetically related[8,9,4].

In the present studies, positive heterosis and over dominance was obtained for the trait hatching percentage in most of the hybrid combinations studied. The heterosis expressed by different hybrids can be partly ascribed to the genetic variability for this trait in addition to the influence of environmental conditions especially incubation conditions and physiological status of embryonic development. With regard to larval duration, all the new hybrids have shown negative heterosis contributing to the reduced larval duration and this could be attributed to the negative heterosis as well as the heterozygocity of alleles governing this character. With regard to cocoon yield by number, all the new hybrids manifested positive heterosis and over dominance indicating the contribution of increased viability in the new hybrids. Even though, all the new hybrids manifested heterotic values for this trait, the extent when compared to other productivity trait was found to be less. Similarly, Mousseau and Roff[14] have pointed out that the characters related to viability traits are less heritable than the characters of productivity which show moderate to high heritability. Cocoon yield by weight is an important trait contributing to cocoon production and most of the new hybrid combinations manifested high level of heterosis and over dominance. Further, Petkov and Nacheva[16] have reported the influence of over dominant or incompletely dominant genes on the expression of cocoon yield by weight and single cocoon weight.

As far as single cocoon weight is concerned, most of the new hybrids were found to excel over the controls for this trait in terms of heterotic values in addition, to the over dominance levels. Shell weight in an important index to forecast the silk protein content in a breed. Most of the new hybrid combinations registered superior heterotic values than the control. With regard to cocoon shell percentage, most of the new hybrids have shown positive heterosis excepting three hybrids, MG 405 x NB_7, MG 408 x NB_7 and MG 414 x NB_7 which recorded negative values. Majority of the new hybrids expressed higher heterotic values than the control.

The pupation rate is an important economic trait which reflects the viability of a breed. It is interesting to note that all the new hybrids expressed positive heterosis for this trait contributing to viability in the new hybrids. All the new hybrids were found to excel over the control in terms of heterotic effects. The magnitude of heterosis observed in the new hybrids for this trait when compared to productivity traits was low and the same can be ascribed to the lower heritability of this trait as pointed by Gamo and Hirabayashi[5] and the results are in conformity with the findings of Kobayashi *et al*.[11].

For the trait filament length, all the new hybrids and most of the new hybrids combinations expressed superior values than the control combinations, NB_{18} x NB_7 and KA x NB_4 D_2 for heterosis and over dominance respectively.

The present study also corroborates that the heterosis for various economic traits in the F_1 hybrids depends on the mid parental value irrespective of the parents involved and greater the mid parental value, lesser is the heterosis manifested and is in conformity with the view of Harada[6,7] and Petkov and Yolov[17]. Further, the degree of heterosis expressed has considerably varied with different hybrid combinations and economic characters studied, It was observed that productivity traits such as cocoon yield by weight, single cocoon weight, shell weight and filament length due to their moderate to higher heritability, manifested higher level of heterosis than the viability traits *viz.* cocoon yield by number and pupation rate which are known for lower heritability as pointed out by Gamo and Hirabayashi[5] and the results are in conformity with the findings of Kobayashi *et al.*[11] and Doddaswamy and Subramanya[3].

Keeping in view, on the basis of foregoing discussion on the performance of new hybrids over the control hybrids, degree of manifestation of heterosis, over dominance, percentage of increment/decrement observed with respect to each one of the economic traits, in the sixteen new hybrids under study, the author felt necessary to suggest five new hybrids MG 414 x KA, MG 408 x NB_4D_2, MG 414 x NB_4 D_2, MG 406 x KA and MG 405 x KA for commercial exploitation.

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