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AN INVESTIGATION ON HETEROSIS AND INBREEDING DEPRESSION IN THE SILKWORM (*Bombyx mori* L.)

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ABSTRACT

The aim of this study was to define heterosis and inbreeding depression in the four silkworm (*Bombyx mori* L.) races namely C_{108}, NB_4D_2, Pure Mysore and Nistari for four important characters including larval weight, cocoon weight, shell weight and shell percentage. The traits of larval weight and cocoon weight showed highly significant heterosis in F_1 hybrids ranging from 11 to 23% and 14 to 27 % respectively, while inbreeding depression in the F_2 progeny ranged from -0.366 - 10.814% and 2.682 - 12.312% respectively. Shell weight showed low level of heterosis in F_1 hybrids (14 to 20 %), whereas the effect of inbreeding depression in F_2 progeny was -4.369 to 8.467% for this character. $C_{108} \times NB_4D_2$ hybrids proved to be a good specific combiner by making higher contribution towards heterosis both in F_1 hybrids and inbreeding at F_2 generation.

Keywords: *Bombyx mori*, heterosis, inbreeding depression.

INTRODUCTION

Diversity among breeds of *Bombyx mori* causes the opportunity to increase cocoon production efficiency through crossbreeding. Specific crossbred combinations originate maximum utilization of heterosis and of breed differences in maternal and paternal performance. Heterosis is a phenomenon in which the performance of an F_1, generated by crossing of two genetically different individuals, is superior to that of the better parent. The heterosis is observed when the silkworm of different genetic backgrounds is mated.

Instead, inbreeding has been used in silkworm breeding to "purify" the breed, to "concentrate" the good genes, and to increase uniformity of the offspring. Inbreeding is a possible type of mating between relatives. These related individuals often engender a more or less closed population such as a managed breeding population or a wild population that has become isolated from others with little or no migration (Gjedrem 2005).

Inbreeding depression is only seen in traits with non-additive inheritance, in particular dominance. Typical traits with dominant inheritance are fitness traits intercommunicate with reproductive capacity or physiological efficiency. These traits can be life-history traits, morphological traits and disease resistance (Falconer and Mackay 1996). Inbreeding and finite population size has important effects on gene and genotype frequencies and it is a resultant of the exposure and expression of deleterious recessive alleles due to continuous selfing within populations. The species that are normally self-fertilized exhibit lower levels of inbreeding depression than those that are normal out breeders (Stebbins 1950; Shields 1982).

This investigation was planned with the objective to record the heterotic effects in F_1 hybrids and the inbreeding depression in F_2 population for the better understanding of the four important characters in the silkworm hybrids and selfed conditions.

MATERIALS AND METHODS

This research study was conducted at the Department of Studies in Sericulture Science in University of Mysore, Mysore, India. Two bivoltine races (namely C_{108} and NB_4D_2) and two multivoltine races (namely Pure Mysore and Nistari) were crossed to get F_1 hybrids. All the F_1 hybrids were reared during the pre monsoon of 2008-2009 and 4 hybrids were mated to get F_2 progenies. The parents, F_1 hybrids and F_2 population were reared using RCD design with three replications.

Data was recorded on the important characters including larval weight, cocoon weight, shell weight and shell percentage. The data about parents, F_1 hybrids and F_2 populations were statistically analyzed independently using SAS.

Mid and better parent heterosis for F_1 hybrids were estimated using the following formulae:

$$MPV = [(F_1 - MPV)/MPV] \times 100$$

$$BPV = [(F_1 - BPV)/BPV] \times 100$$

Where

MPV: Mid Parent Value
BPV: Better Parent Value

Significance of heterosis was determined as follow by using t-test (Wynne *et al*., 1970):

$$t_{ij} = (F_{1ij} - MPV_{ij})/\sqrt{(3 \times EMS/8)}$$

The 't' value for overdominance was calculated following the formula:

$$t_{ij} = (F_{1ij} - MPV_{ij})/\sqrt{(EMS/2)}$$

Where

F_{1ij}: the mean of the ij^{th} F_1 cross
MPV_{ij}: the mid parent values for the ij^{th} cross
BPV_{ij}: the better parent values for ij^{th} cross

EMS: error mean square

Inbreeding depression (ID) on F_2 was calculated following the formula:

$ID (\%) = [(F_1 - F_2)/F_1] \times 100$

Where

F_2: mean of F_2 population for a trait.

T-test of ID = Estimated value of ID / Standard error of mean

Where

Standard error of mean = $\sqrt{\sigma^2 F_1 + \sigma^2 F_2}$

$\sigma^2 F_1$ = Variance of F_1 mean

$\sigma^2 F_2$ = Variance of F_2 mean

RESULTS

The mean value of parental races and F_1 hybrids for four characters namely larval weight, cocoon weight, shell weight and shell percentage along with the statistical data are presented in Table-1. It is evident that the results that there is differential performance in regard to expression of the economic traits ($p<0.05$). Among the parents, maximum larval weight of 3.45 gm was observed for NB_4D_2, while minimum (1.85 gm) value was recorded for Pure Mysore.

Statistical analysis of the data for cocoon weight revealed significant differences among the parents and F_1 hybrids. Mean data for cocoon weight among the pure races ranged from 0.98 to 1.56 gm. As well as, analysis of variance revealed significant genetic differences for shell weight and shell percentage among pure races and F_1 hybrids (Table-1).

The estimation of heterosis over respective mid parent and better parent revealed significant difference between the four characters (Table-2). Varied heterotic effect was observed for different traits for hybrid combination. Larval weight and cocoon weight showed highly significant heterosis in F_1 hybrids ranging from 11 to 23% and 14 to 27 %, respectively. For the trait of larval weight maximum heterosis over the mid parent and better parent was observed in Nistari × Pure Mysore (23% and 19.9% respectively). On the other hands, $NB_4D_2 \times C_{108}$ showed maximum heterosis over the mid parent and better parent for cocoon weight (27 and 25.7% respectively). The maximum shell weight heterosis and overdominance was recorded by $NB_4D_2 \times C_{108}$ hybrid (20% and 16.8% respectively). The results exhibited that numbers of heterosis and overdominance for the crosses *viz*., $C_{108} \times NB_4D_2$, $NB_4D_2 \times C_{108}$, Nistari × Pure Mysore and Pure Mysore × Nistari were (3,2), (3,3), (1,1) and (1,1), respectively.

Table-3 presents the data related to inbreeding depression of four traits among the F_1 and F_2 hybrids. None of the F_2 population had significant increase or decreases over F_1 hybrids and as a result no negative or positive inbreeding depression was observed except Pure Mysore × Nistari hybrid. Wherein significant inbreeding depression for cocoon weight and shell weight ($p<0.05$) was noticed.

DISCUSSIONS

Heterosis, expressed as the improvement in a character shown by a hybrid over their mid - or better parental value, is a vital measure of the genetic progress made in silkworm selection. It is an already established fact that the amount of heterosis obtained by hybrids depends largely on the genetic divergence of the populations from which the parental lines have been extracted (Moll *et al*., 1962). Based on the results, $C_{108} \times NB_4D_2$ hybrids proved itself to be a good specific combiner by making higher contribution towards heterosis both in F_1 hybrids and F_2 generation. The present finding based on the estimates of heterosis and overdominance in different hybrids of C_{108}, NB_4D_2, Pure Mysore and Nistari for four characters (Table-2) clearly confirms the findings of krishnasawmi *et al*. (1964), Sengupta *et al*. (1974), Satenahalli (1990) and Doddaswamy *et al*. (2009) who demonstrated positive heterosis in F_1. Similar results were noticed by Morohoshi (1957), Yokoyama (1979), Tazima (1988), Murkami (1994) and Ravindra Singh *et al*. (2000).

Inbreeding depression results due to fixation of unfavourable recessive genes in F_2. As well as, the fixation of all favourable dominant genes in one homozygous line is impossible due to linkage between some unfavourable recessive and favourable dominant genes (Nadarajan and Gunasekaran 2008). In this experiment, based on the calculation of inbreeding depression for four characters, it is evident that inbreeding depression was not significant in the three hybrids except Pure Mysore × Nistari for cocoon weight and shell weight out of four traits (Table-3). Inbreeding depression is only seen in traits with non-additive inheritance, in particular dominance (Falconer and Mackay 1996). The present study corroborates the findings of Narasimhanna (1976), Chandrashekaraiah (1992) and Talebi and Subramanya (2009) where in they have demonstrated that non additive gene action are important for many of the cocoon characters. Doddaswamy and Subramanya (2008) reported that inbreeding depression for nine economic traits was not significant in the selected hybrids.

CONCLUSIONS

Based on the present findings of the authors, it is possible to conclude that though the level of inbreeding depression is insignificant for three out of four hybrids at F_2 yet a detailed investigators utilizing different voltinistic races may throw light on the mechanism of heterosis and its relevance to inbreeding depression at F_2 generations.

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Table-1. Mean values of four economic traits in four parental races and their F_1 hybrids.

Genotypes	Larval weight	Cocoon weight	Shell weight	Shell %
C_{108}	3.40 ± 0.11 ^{b}	1.52 ± 0.07 ^{c}	0.24 ± 0.01 ^{b}	15.55 ± 0.39 ^{ab}
NB_4D_2	3.45 ± 0.08 ^{ab}	1.56 ± 0.03 ^{c}	0.26 ± 0.01 ^{ab}	16.61 ± 0.29 ^{a}
Pure Mysore	1.85 ± 0.05 ^{d}	1.17 ± 0.06 ^{de}	0.17 ± 0.01 ^{c}	14.68 ± 0.90 ^{ab}
Nistari	1.96 ± 0.04 ^{d}	0.98 ± 0.06 ^{e}	0.13 ± 0.01 ^{c}	13.44 ± 1.06 ^{b}
$C_{108} \times NB_4D_2$	3.78 ± 0.04 ^{a}	1.74 ± 0.02 ^{b}	0.28 ± 0.01 ^{ab}	15.89 ± 0.31 ^{ab}
$NB_4D_2 \times C_{108}$	3.94 ± 0.18 ^{a}	1.94 ± 0.04 ^{a}	0.29 ± 0.02 ^{a}	14.98 ± 0.97 ^{ab}
Pure Mysore × Nistari	2.09 ± 0.04 ^{cd}	1.33 ± 0.02 ^{d}	0.14 ± 0.01 ^{c}	10.36 ± 0.55 ^{c}
Nistari × Pure Mysore	2.35 ± 0.08 ^{c}	1.16 ± 0.06 ^{de}	0.15 ± 0.01 ^{c}	12.95 ± 0.18 ^{b}
F - value	94.99	46.80	33.75	9.06

The values are derived from three replicates ± SE. Means having the same superscript letters do not differ significantly at 0.05 level of probability.

Table-2. Estimation of heterosis and overdominance for different economic traits in the four hybrids.

Hybrids	Larval weight		Cocoon weight		Shell weight		Shell %	
	Ht	OD	Ht	OD	Ht	OD	Ht	OD
Pure Mysore × Nistari	0.10	0.068	0.26**	0.175*	-0.06	-0.142	-0.13	-0.198*
Nistari × Pure Mysore	0.23**	0.199**	0.10	0.027	0.03	-0.062	0.09	0.003
$C_{108} \times NB_4D_2$	0.11**	0.097*	0.14**	0.126*	0.14*	0.110	0.00	-0.010
$NB_4D_2 \times C_{108}$	0.15**	0.143**	0.27**	0.257**	0.20**	0.168*	-0.06	-0.066

Ht: Relative heterosis, OD: Overdominance; Tabulated't' value at 5 and 1% for $d.f._{16}$ is 2.042 and 2.750, respectively; *: Significant, **: Highly significant.

Table-3. Estimation of inbreeding depression for different economic traits in the four hybrids.

Hybrids	Generation	Larval weight		Cocoon weight		Shell weight		Shell %	
		Mean ± SE	ID	Mean ± SE	ID	Mean ± SE	ID	Mean ± SE	ID
$C_{108} \times NB_4D_2$	F_1	3.78 ± 0.04	6.225 (0.182)	1.74 ± 0.02	2.682 (0.297)	0.28 ± 0.01	3.614 (1.888)	15.89 ± 0.31	0.745 (0.006)
$C_{108} \times NB_4D_2$	F_2	3.55 ± 0.19		1.69 ± 0.05		0.27 ± 0.01		15.77 ± 0.61	
$NB_4D_2 \times C_{108}$	F_1	3.94 ± 0.18	10.814 (0.284)	1.94 ± 0.04	11.321 (1.545)	0.29 ± 0.02	8.467 (2.248)	14.98 ± 0.97	-3.257 (-0.019)
$NB_4D_2 \times C_{108}$	F_2	3.52 ± 0.13		1.72 ± 0.02		0.27 ± 0.01		15.47 ± 0.28	
Nistari × Pure Mysore	F_1	2.35 ± 0.09	0.468 (0.028)	1.16 ± 0.06	-5.747 (-0.398)	0.15 ± 0.01	2.222 (1.455)	12.95 ± 0.18	7.602 (0.176)
Nistari × Pure Mysore	F_2	2.34 ± 0.05		1.23 ± 0.06		0.15 ± 0.01		11.96 ± 0.18	
Pure Mysore × Nistari	F_1	2.09 ± 0.04	-0.366 (-0.019)	1.33 ± 0.02	12.312 * (3.959)	0.14 ± 0.01	-4.369 * (-3.513)	10.36 ± 0.55	-18.920 (-0.180)
Pure Mysore × Nistari	F2	2.10 ± 0.10		1.16 ± 0.01		0.14 ± 0.00		12.32 ± 0.26	

ID: Inbreeding depression; t = 2.78 (at 5% level) for d.f. = 4; *: Significant at 5% level.