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# Heterosis and combining ability of larval weight in $F_1$ multivoltine and bivoltine silkworm hybrids under different rearing seasons.

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**Abstract:** Heterosis and combining ability for larval weight of silkworm *Bombyx mori* L were investigated in a six parent diallel crossing programme in four rearing seasons. Cross "Nistari ×BSRI-98", "Nistari (oval)×BSRI-95" and "Nistari (oval)×BSRI-98" exhibited significant positive heterosis over mid-parents in all the seasons. A few numbers of crosses showed significant positive heterosis over better parents in limited of rearing seasons. The varieties BSRI-95, BSRI-98 and BV-High were highly significant (P<0.01) with respect to general combining ability of the parents. The variance due to the specific combing ability ($\sigma^2$ sca) and the general combining ability ($\sigma^2$gca) indicated the preponderance of non-additive gene action in inheritance of this trait for all the seasons. Majority of the crosses showing significant sca effects had either one or both the parents were good general combiners. On basis of magnitude of heterosis, general combining ability and specific combining ability, the crosses "Nistari ×BSRI-98", "Nistari (oval)×BSRI-95" and "Nistari (oval)×BSRI-98" are recommended for the commercial exploitation of heterosis in respest of best larval weight resulting cocoon productioni in majority of the rearing seasons.

**Key words:** Heterosis, Combining ability, Larval weight, *Bombyx mori*.

## Introduction

Heterosis or hybrid vigour can be expounded as the extra vigour, exceeding that of both the parental stocks, which is frequently shown by hybrids from the crossing of species, breeds. strains or inbred lines. It is the genetic expression of the beneficial effects of hybridization. Heterosis for various economic characters has also been studied by a number of silkworm breeders in different countries practicing sericulture. Several studies have demonstrated significant levels of heterosis in the silkworm, *Bombyx mori* L. (Subba Rao and Sahai, 1989; Ashoka and Govindan, 1990; Malik and Krisnamurthy, 1994; Rahman and Jahan, 1997; Rao *et al.,* 2003; Boyko *et al.,* 2004). The choice of parents for the exploitation of hybrid vigour and hybridization programme was one of the crucial tasks for the breeders. Sometimes parents with poor performance produce superior offspring while promising parents produce disappointing results (Allard, 1960). The combining ability of the parents would therefore depend on complex *per se* performance and adaptation of the parents. Methods of evaluating combining ability of parents and other crosses had been devised through line×tester design (Kempthorne, 1957) and utilizing diallel progenies (Griffing, 1956a).

Due to inadequate information concerning heterosiss and combining ability with respect to indigenous, introduced multi and bivoltine varieties of silkworm, very little efforts have been made to explore hybrid vigour in the breeding of silkworm in Bangladesh. The present investigation was, therefore, undertaken to determine heterosis, general and specific combining abilities in a number of crosses among the varieties with genetic diversity, different geographical origin and voltinism for an important larval trait of *B. mori* in four different rearing seasons.

## Materials and methods

Five multivoltine viz. Nistari (**$P_1$**), Nistari oval (G) (**$P_2$**), BSRI-95 (**$P_3$**), NanNung-7B (**$P_4$**), BSRI-98 (**$P_5$**) and one bivoltine viz. BV (High) (**$P_6$**) varieties of silkworm, *B. mori*. were utilized as parents in the present experiments and were crossed following diallel crossing including reciprocals.

Thirty $F_1$ hybrids along with six parents were reared in randomized block design with three replications in four rearing seasons corresponding to commercial rearing seasons as practiced by farmers in Bangladesh. These rearing seasons, average room temperature and relative humidity have shown as follows:

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| Rearing seasons (Local name) | Rearing period | Code name | Average temperature (°C) | Relative humidity (%) |
|---|---|---|---|---|
| Agrahyoni | October - November | S-1 | 23.01±1.02 | 91.36±1.56 |
| Chaita | March - April | S-2 | 29.76±1.21 | 92.02±2.68 |
| Jaistha | May -June | S-3 | 30.24±1.81 | 94.21±1.81 |
| Bhaduri | August- Setember | S-4 | 31.42±1.63 | 96.11±1.12 |

The rearing was conducted in the Sericulture Research Laboratory of the Department of Zoology, Rajshahi University. The weight of mature larva was taken at the end of the 5th instar, i.e., one day before spinning. Twenty five larvae were collected at random from each rearing-bed and used for statistical analysis. The average performance of parents and $F_1$ hybrids (average over reciprocal crosses) over replications were used for calculating the magnitude of heterosis.

The general and specific combining ability effects and variances were estimated following Griffings (1956b) Method I. In the model II the experimental material is to be regarded as the population about which inference are to be made. The objectives are to compare combining abilities of the parents when the parents themselves are used as tester and to identify the yielding combinations.

## Results and discussion

Fifteen $F_1$ hybrids along with six parental performances for different rearing seasons have been shown in Table 1. The estimates of heterosis over mid and better parents for different rearing seasons have been presented in Table 2. Of the fifteen crosses, four crosses in S-1 (cross no. 4, 5, 6 and 8); three crosses in S-2 and S-3 (cross no. 4, 6 and 8) and six crosses in S-4 (cross no. 4, 5, 6, 8, 9 and 14) exhibited significant positive heterosis over mid-parents. The estimates of heterosis ranged from -14.70 to 29.40% in S-1, -13.30 to 21.34% in S-2, -17.38 to 35.98% in S-3 and -12.63 to 16.43% in S-4. With respect to better parent cross no 12 in S-2; 6 in S-3 and 4, 8, and 9 in S-4 showed significant positive heterosis. Significant negative heterosis was recorded in cross number 2 and 13 in S-1; 2, 5, 9, 10, 13 and 15 in S-2; 12 and 13 in S-3; and 1 and 7 in S-4. The ranges of heterosis were from -2298 to 7.01%, -22.74 to 5.98%, -19.27 to 27.32% and -14.68 to 9.64% in S-1, S-2, S-3 and S-4 respectively (Table 2).

**Table 1.** Mean performance of parents and hybrids ($F_1$) in Agrahyoni (S-1), Chaita (S-2), Jaistha (S-3) and Bhaduri (S-4) rearing seasons for mature larval weight in *B. mori* L.

| Parents | S-1 | S-2 | S-3 | S-4 |
|---|---|---|---|---|
| $P_1$ | 1.847 | 2.200 | 2.130 | 2.103 |
| $P_2$ | 2.227 | 2.290 | 2.193 | 2.270 |
| $P_3$ | 3.127 | 3.067 | 2.513 | 2.550 |
| $P_4$ | 2.560 | 2.420 | 2.320 | 2.163 |
| $P_5$ | 3.177 | 3.093 | 2.750 | 2.420 |
| $P_6$ | 3.280 | 3.240 | 2.627 | 2.420 |
| Crosses | | | | |
| $P_1 \times P_2$ | 2.24 | 2.25 | 2.21 | 1.95 |
| $P_1 \times P_3$ | 2.71 | 2.61 | 2.55 | 2.42 |
| $P_1 \times P_4$ | 2.44 | 2.35 | 2.27 | 2.05 |
| $P_1 \times P_5$ | 3.25 | 3.21 | 2.81 | 2.63 |
| $P_1 \times P_6$ | 3.06 | 2.81 | 2.61 | 2.45 |
| $P_2 \times P_3$ | 3.32 | 3.25 | 3.20 | 2.66 |
| $P_2 \times P_4$ | 2.25 | 2.08 | 2.12 | 1.94 |
| $P_2 \times P_5$ | 3.16 | 3.01 | 2.82 | 2.62 |
| $P_2 \times P_6$ | 3.10 | 2.81 | 2.57 | 2.65 |
| $P_3 \times P_4$ | 2.93 | 2.65 | 2.50 | 2.45 |
| $P_3 \times P_5$ | 3.21 | 2.74 | 2.79 | 2.56 |
| $P_3 \times P_6$ | 3.35 | 3.28 | 2.12 | 2.62 |
| $P_4 \times P_5$ | 2.45 | 2.39 | 2.22 | 2.29 |
| $P_4 \times P_6$ | 3.26 | 2.94 | 2.51 | 2.46 |
| $P_5 \times P_6$ | 3.51 | 3.40 | 2.83 | 2.34 |

**Table 2.** Estimates of heterosis over mid parents (MP) and better parents (BP) for mature larval weight in Agrahyoni (S-1), Chaita (S-2), Jaistha (S-3) and Bhaduri (S-4) rearing seasons

| Crosses | S-1 | | S-2 | | S-3 | | S-4 | |
|---|---|---|---|---|---|---|---|---|
| | MP% | BP% | MP% | BP% | MP% | BP% | MP% | BP% |
| $P_1 \times P_2$ | 10.15 | 0.75 | 0.22 | -1.75 | 2.08 | 0.61 | -10.67** | -13.95** |
| $P_1 \times P_3$ | 8.98 | -13.33* | -0.89 | -14.89* | 9.83 | 1.46 | 3.87 | -5.23 |
| $P_1 \times P_4$ | 10.89 | -4.56 | 1.88 | -2.75 | 2.02 | -2.16 | -3.91 | -5.24 |
| $P_1 \times P_5$ | 29.40** | 2.31 | 21.28** | 3.77 | 15.30* | 2.30 | 16.43** | 8.82* |
| $P_1 \times P_6$ | 19.38** | -6.71 | 3.43 | -13.17* | 9.74 | -0.63 | 8.33* | 1.24 |
| $P_2 \times P_3$ | 23.91** | 6.08 | 21.34** | 5.98 | 35.98** | 27.32** | 10.24** | 4.18 |
| $P_2 \times P_4$ | -5.99 | -12.11 | -11.54 | -13.91 | -5.91 | -8.48 | -12.63** | -14.68** |
| $P_2 \times P_5$ | 17.09** | -0.42 | 11.70* | -2.80 | 14.09* | 2.55 | 11.73** | 8.26* |
| $P_2 \times P_6$ | 12.47 | -5.59 | 1.63 | -13.27* | 6.78 | -2.03 | 13.15** | 9.64** |
| $P_3 \times P_4$ | 3.05 | -6.29 | -3.52 | -13.70* | 3.45 | -0.53 | 3.96 | -3.92 |
| $P_3 \times P_5$ | 1.85 | 1.05 | -11.04* | -11.42* | 5.89 | 1.33 | 2.88 | 0.26 |
| $P_3 \times P_6$ | 4.47 | 2.03 | 4.02 | 1.23* | -17.38** | -19.16** | 5.30 | 2.61 |
| $P_4 \times P_5$ | -14.70* | -22.98** | -13.30* | -22.74** | -12.43* | -19.27** | -0.22 | -5.51 |
| $P_4 \times P_6$ | 11.64 | -0.61 | 3.89 | -9.26 | 1.48 | -4.44 | 7.49* | 1.79 |
| $P_5 \times P_6$ | 8.72 | 7.01 | 7.37 | 4.94 | 5.15 | 2.79 | -3.31 | -3.31 |

*P< 0.05 , **P< 0.01

The results revealed that considerable amount to heterosis was obtained in the crosses where parents BSRI-95, BSRI-98 and BV-High were involved in different seasons. These three breeds showing heterosis in majority of the crosses were picked from diverse genetic origin. These observations are in conformity with the previous findings that greater heterosis is obtained between the crosses of parents of different regions than crosses between closely related parents (Narayanan *et al.,* 1964; Gamo *et al.,* 1985; Tayade, 1987; Govindan *et al*., 1987; Rahman, 1989; Datta *et al.,* 2001; Farooq *et al.,* 2002; Rashid *et al.,* 2011). Falconer (1960) also supported this view and reported that the amount of heterosis of a cross depends on the square of the differences of gene frequencies between the populations or lines and therefore, heterosis is not expected where the parental populations do not differ in gene frequencies.

The mean squares of gca and sca were significant for all the rearing seasons showing a considerable amount of genetic variability in the materials of present study (Table 3). But the reciprocal effects showed non-significant results in all the four seasons. The variance of components of general and specific combining abilities and their ratios were showed in Table 4. Estimates of variance due to the general ($\sigma^2$gca) and specific combining ability ($\sigma^2$sca) indicated that the variance due to the specific combining ability was higher in all the seasons showing the predominant role of non-additive type of gene action. A similar picture has also been shown by the ratio $\sigma^2$gca/$\sigma^2$sca, which were less than unity indicating the predominant of non-additive gene action in the inheritance of this trait. Non-additive gene actions governing the expression of some quantitative traits have been reported by a number of workers in *B. mori* (Narasimhanna and Shelly, 1979; Subba Rao, 1983; Datta and Pershad, 1989; Ravindra *et al.,* 2000).

**Table 3.** Analysis of variance (ANOVA) of combining ability for mature larval weight in *B. mori* L in Agrahyoni (S-1), Chaita (S-2), Jaistha (S-3) and Bhaduri (S-4) rearing seasons

| Source | d. f. | Mean sum of squares for different seasons | | | |
|---|---|---|---|---|---|
| | | S-1 | S-2 | S-3 | S-4 |
| gca | 5 | 0.9956** | 0.7681** | 0.2319** | 0.1532** |
| sca | 15 | 0.1517** | 0.1427** | 0.1396** | 0.0408** |
| Reciprocal | 15 | 0.0033 | 0.0065 | 0.0045 | 0.0089** |
| Error | 70 | 0.0199 | 0.0155 | 0.0139 | 0.0038 |

*P< 0.05 , **P< 0.01

**Table 4.** Estimates of components of variance due to gca and sca and their ratio for mature larval weight in *B. mori* L. in Agrahyoni (S-1), Chaita (S-2), Jaistha (S-3) and Bhaduri (S-4) rearing seasons

| Components | S-1 | S-2 | S-3 | S-4 |
|---|---|---|---|---|
| $\sigma^2$gca | 0.071 | 0.052 | 0.008 | 0.009 |
| $\sigma^2$sca | 0.077 | 0.074 | 0.073 | 0.022 |
| Reciprocal | -0.008 | -0.005 | -0.005 | 0.003 |
| $\sigma^2$gca / $\sigma^2$sca | 0.924 | 0.711 | 0.111 | 0.441 |

The general combining ability effect of individual parents with their corresponding standard error have been shown in Table 5. Among the six varieties, BSRI-95, BSRI-98 and BV-High were found good general combiners showing highly significant (P<0.01) result in all the rearing seasons (except BV-High in S-3). The varieties Nistari, Nistari -oval (G) and Nan Nung7B exhibited gca effect in the negative direction in all the four rearing seasons. These good general combiners could effectively be utilized in the future hybridization programmes for developing high yielding varieties but it would be difficult to develop pure line with yielding ability equal to $F_1$ hybrid, because much of the yielding ability of $F_1$ appear to be due to the non-additive type of genetic variance.

**Table 5.** Estimates of general combining ability effects of the parents for mature larval weight in *B. mori* L. in Agrahyoni (S-1), Chaita (S-2), Jaistha (S-3) and Bhaduri (S-4) rearing seasons

| Parents | Seasons | | | |
|---|---|---|---|---|
| | S-1 | S-2 | S-3 | S-4 |
| Nistari | -0.3105** | -0.2094** | -0.0914** | -0.1361** |
| Nistari Oval (G) | -0.1913** | -0.1352** | -0.0128 | -0.0322 |
| BSRI-95 | 0.2012** | 0.1584** | 0.0858** | 0.1233** |
| Nan Nung 7B | -0.2652** | -0.3157** | -0.2103** | -0.1222** |
| BSRI-98 | 0.2087** | 0.1909** | 0.1864** | 0.0750** |
| BV-High | 0.3570** | 0.3109** | 0.0422 | 0.0922** |
| SE ( $\hat{g}i$ ) | 0.037 | 0.033 | 0.031 | 0.016 |

*P< 0.05 , **P< 0.01

Estimates of sca effects indicated that out of 15 crosses tested, four crosses in S-1 (crosses 4, 6, 8 and 14) and S-2 (cross 4, 6, 8 and 15); and six crosses in S-3 (cross 4, 5, 6, 8 14 and 15) and seven crosses in S-4 (cross 4, 5, 6, 8, 9, 10 and 14) showed significant positive sca effect (Table 6). Most of these crosses were the resultant of at least one good combining parent except the cross 14 in S-3 season. High sca effects of those crosses might be the result of the complementary type of genetic interactions. Thus the combining ability of parents may be considered as a reliable guide in the prediction of the yield potential of these crosses. A good number of crosses also showed significant negative sca effect which might be due to the presence of epistasis.

Cross 5 ($P_1 \times P_6$) in S-1 and. cross 12 ($P_3 \times P_6$) in S-2 exhibited significant heterosis as well as they were the product of one or both good general combining parents. But they did not show significant specific combing ability (Table 2 and 6). High sca denotes, a high heterotic response but this may be due to the very poor performance of the parents in comparison to their hybrids. With the same amount of heterotic effect the sca effect may be less where the mean performances of the parents were higher (Ahmed *et al*., 1979). This suggests that the selection of cross combinations based on the heterotic response would be more realistic.

Considering magnitude of heterosis, estimates of gca and sca the $F_1$ hybrids “Nistari ×BSRI-98”, “Nistari (oval)×BSRI-95” and “Nistari (oval)×BSRI-98” exhibited the best larval weight resulting cocoon productioni in majority of the rearing seasons. The performance of a cross in a season did not necessarily give good performance in other seasons, i.e., the expressions of these quantitative traits were season specific. Here cross 5, “Nistari× BV-High” in S-1, S-4 and cross 12, “BSRI-95 ×BV-High” in S-2 exhibited a promising performance. Therefore, it is suggested that $F_1$ hybrids should to be identified for their commercial exploitation specific to deferent rearing seasons. Heterosis over better parents are very limited in this study which is always desirable for maximum gains and for this, there is need for searching genetically diverse materials.

**Table 6.** Estimates of specific combining ability and reciprocal effects for mature larval weight in *B. mori* L in Agrahyoni (S-1), Chaita (S-2), Jaistha (S-3) and Bhaduri (S-4) rearing seasons

| | Cross No. | Crosses | Seasons | | | |
|---|---|---|---|---|---|---|
| | | | **S-1** | **S-2** | **S-3** | **S-4** |
| Specific combining ability | 1 | $P_1 \times P_2$ | -0.1459 | -0.1920* | -0.2647** | -0.2108** |
| | 2 | $P_1 \times P_3$ | -0.1401 | -0.0906 | 0.0917 | -0.0847* |
| | 3 | $P_1 \times P_4$ | 0.1430 | 0.1402 | 0.0378 | -0.0025 |
| | 4 | $P_1 \times P_5$ | 0.4624** | 0.4219** | 0.2128** | 0.2186** |
| | 5 | $P_1 \times P_6$ | 0.1424 | -0.1081 | 0.1569* | 0.0981** |
| | 6 | $P_2 \times P_3$ | 0.3924** | 0.4669** | 0.5697** | 0.0814* |
| | 7 | $P_2 \times P_4$ | -0.1979* | -0.2173** | -0.1625* | -0.1647** |
| | 8 | $P_2 \times P_5$ | 0.2399** | 0.2527** | 0.1625* | 0.2114** |
| | 9 | $P_2 \times P_6$ | 0.0316 | -0.0806 | 0.0233 | 0.1425** |
| | 10 | $P_3 \times P_4$ | 0.0996 | 0.0607 | 0.0806 | 0.1014** |
| | 11 | $P_3 \times P_5$ | -0.0626 | -0.4693** | -0.0528 | -0.0458 |
| | 12 | $P_3 \times P_6$ | -0.0843 | 0.0724 | -0.4836** | 0.0386 |
| | 13 | $P_4 \times P_5$ | -0.4745** | -0.3301** | -0.3050** | -0.0436 |
| | 14 | $P_4 \times P_6$ | 0.2688** | 0.0849 | 0.1558* | 0.0958* |
| | 15 | $P_5 \times P_6$ | 0.0049 | 0.2032** | 0.1525* | -0.2164** |
| Reciprocal effect | 1 | $P_1 \times P_2$ | -0.0383 | 0.0033 | 0.0283 | -0.0617 |
| | 2 | $P_1 \times P_3$ | 0.0300 | -0.0383 | -0.0833 | 0.1200** |
| | 3 | $P_1 \times P_4$ | -0.0533 | -0.0517 | -0.0133 | -0.0833 |
| | 4 | $P_1 \times P_5$ | -0.0400 | 0.0167 | -0.0417 | 0.0817 |
| | 5 | $P_1 \times P_6$ | -0.0583 | 0.0300 | -0.0450 | 0.0017 |
| | 6 | $P_2 \times P_3$ | -0.0150 | -0.0300 | 0.0100 | 0.0900* |
| | 7 | $P_2 \times P_4$ | -0.0250 | -0.0383 | -0.0383 | -0.1383** |
| | 8 | $P_2 \times P_5$ | -0.0233 | -0.0917 | -0.0633 | -0.0283 |
| | 9 | $P_2 \times P_6$ | -0.0300 | -0.0750 | -0.0267 | 0.0567 |
| | 10 | $P_3 \times P_4$ | -0.0350 | -0.0467 | -0.0033 | -0.0467 |
| | 11 | $P_3 \times P_5$ | -0.0667 | 0.0700 | 0.0200 | 0.0100 |
| | 12 | $P_3 \times P_6$ | -0.0567 | -0.0517 | -0.0683 | -0.0317 |
| | 13 | $P_4 \times P_5$ | 0.0483 | 0.0550 | 0.0017 | -0.0167 |
| | 14 | $P_4 \times P_6$ | -0.0300 | 0.0700 | -0.0250 | 0.0033 |
| | 15 | $P_5 \times P_6$ | 0.0100 | -0.0950 | -0.1017 | -0.0050 |
| | SE $(\hat{s}ij)$ | | 0.085 | 0.075 | 0.071 | 0.037 |
| | SE $(\hat{r}ij)$ | | 0.100 | 0.088 | 0.083 | 0.043 |

*P < 0.05 , **P < 0.01

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