-African Journal of Basic & Applied Sciences 2 (5-6): 135-143, 2010
ISSN 2079-2034


# Heterosis Studies in Selected Quantitative Traits in Silkworm, *Bombyx mori* L.

[1]S. Nirmal Kumar, [2]P. Murthy and [1]S.M. Moorthy

[1]Central Sericultural Research and Training Institute, Mysore, Karnataka, India
[2]Silkworm Seed Technological Laboratory, Kodathi, Bangalore, Karnataka, India

**Abstract:** The extent of heterosis in certain important characters was studied in silkworm, *Bombyx moriL* in a set of 30 hybrids produced from a two different voltine groups (Three multivoltine breeds and five bivoltine breeds). Appreciable and variable amount of relative heterosis was noticed for all the traits studied indicating genetic diversity among parents used. Irrespective of crosses, negative heterobeltiosis was observed for all the traits except pupation rate. The relative heterosis (%) varied from 8.95 to 37.14 in regular crosses and 8.97 to 36.6 in reciprocal crosses for different characters. In heterobeltiosis, the heterosis (%) ranged from -10.57 to 4.17 in regular crosses and -11.06 to 5.68 in reciprocal crosses for different characters. As far as traits are concerned, maximum relative heterosis was observed in filament length both in regular (37.14%) and in reciprocal crosses (36.6%), whereas pupation rate has shown maximum heterobeltiosis in regular (4.17%) as well as in reciprocal crosses (5.68%). The crosses with CSR17, CSR18 and KA (bivoltine) as one of the parents have shown higher relative heterosis and heterobeltiosis. This result was further confirmed through evaluation index (EI) calculated over heterosis. Five top heterotic crosses were identified based on mid and better parent heterosis and evaluation index calculated over both heterosis for each trait.

**Key words:** Multivoltine x bivoltine cross · Relative heterosis · Heterobeltiosis · Evaluation index

## INTRODUCTION

Heterosis, described in terms of the superiority of F1 hybrid performance over the parental performance, is a phenomenon widely observed in the biological kingdom. Investigations on heterosis provide fundamental information regarding the expression of cross combinations and its potential for commercial exploitation. In silkworm *Bombyx mori* the importance of increased vigour in order to understand the phenotypic expression of the hybrids was realized as early as in 1905 in Japan. In India, nearly 90% of the silk produced are from the multivoltine x bivoltine hybrids called as cross breed and it is successfully exploited commercially as it can withstand the tropical climate [1]. Heterosis breeding has been recognized as the most suitable breeding methodology for augmenting yield in Silkworm. The required goals of increasing productivity in the quickest possible time can be achieved only through heterosis breeding, which is regular practice in this crop. In general heterosis leads to combination of good or most favourable genes through crossing process but this method may be not only and / or not the quickest compared to modern techniques of molecular genetics [2]. The magnitude of heterosis in different cross combination is a basic requisite for identifying crosses that exhibit high amount of exploitable heterosis. Hence, the present study was undertaken with an objective of studying the extent of heterosis in different crosses and then utilization in future crop improvement programmes.

## MATERIALS AND METHODS

Three multivoltine breeds viz., PM, Nistari, C.Nichi and five bivoltine breeds viz., CSR2, CSR3, CSR17, CSR18, KA were utilized in the study to understand the degree of heterosis and heterobeltiosis. A total of thirty hybrid combinations including reciprocals were derived. All the hybrids and their parents were reared in a replication of three for three seasons (summer, rainy and winter) for two years by following the standard rearing techniques. The data on the rearing performance of the hybrids as well the parental races with respect to five important economic characters such as pupation rate (%), cocoon weight (g), shell weight (g), cocoon shell ratio (%) and filament length (m) were evaluated. The data generated

**Corresponding Author:** S.M. Moorthy, Central Sericultural Research and Training Institute, Mysore, India.
E-mail: moorthysm@hotmail.com.

was pooled and subjected to relevant statistical analysis in order to evaluate the performance of the parents as well the degree of manifestation of heterosis and heterobeltiosis in the hybrids with respect to each one of the traits. The heterosis and heterobeltiosis in $F_1$ crosses is calculated by using the following formula

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

$$\text{Heterobeltiosis} = \frac{\text{F1-BPV}}{\text{BPV}} \times 100$$

Where,
F1 = Mean of the hybrid
MPV = Mid Parental Value
BPV = Better Parental Value

To estimate differences among mean heterotic value and evaluation index (EI) was computed for all the traits over heterosis (%) by following formula [3].

$$\text{EI} = [(A-B)\times 10/C]+50$$

Where:
A = Value of particular genotype for a trait
B = Mean value
C = Standard deviation
10 = Standard unit
50 = Fixed value

## RESULTS

**Relative Heterosis:** The data regarding relative heterosis in regular and reciprocal crosses are presented in Table 1 and 3 respectively. All regular and reciprocal crosses have shown positive heterosis for all the characters. The range of heterosis in different hybrids of regular crosses is from 16.41 to 27.01 with the average of 22.53% (Table 1). The top five regular crosses showing higher heterosis are C.Nichi x KA (27.01%), Nistari x KA (26.99%), Nistari x CSR17 (25.97%), Nistari x CSR18 (25.82%) and C. Nichi x CSR17 (25.69%). Evaluation index calculated over relative heterosis indicated that the same hybrids gets listed in the top five position having scored > 50 index apart from the change in ranking order (Figure 1). Of the five top crosses, Nistari x CSR18 with score of 56.71 followed by C.Nichi x KA (56.14), C.Nichi x CSR17 (55.37), Nistari x KA (55.17) and Nistari x CSR17 (54.38) (Table 2). Similarly top five crosses showing higher heterosis in reciprocals (Table 3) are KA x C.Nichi (28.10) with EI value of 56.19 followed by CSR17 x C.Nichi (27.48) with EI value of 56.12, CSR18 x C.Nichi (26.44) with EI value of 57.28, CSR17 x PM (26.23%) with EI value of 54.97 and CSR18 x PM (25.69%) with EI value of 55.42 (Table 4 & Figure 2).

The heterosis (%) for pupation rate in regular crosses was found to be in the range of 4.07 to 12.71 percent and in reciprocals between 4.63 to 18.01%. For cocoon weight the heterosis (%) varied from 15.73 to 35.53 in regular and

Table 1: Heterosis values in the multivoltine x bivoltine hybrids

| Hybrids | Pupation rate (%) | Cocoon weight (g) | Shell weight (g) | Shell ratio (%) | Filament length (m) | Average heterosis |
|---|---|---|---|---|---|---|
| C.Nichi x CSR2 | 4.63 | 24.36 | 27.43 | 10.57 | 17.78 | 16.96 |
| C.Nichi x CSR3 | 8.12 | 24.27 | 32.12 | 13.85 | 32.43 | 22.16 |
| C.Nichi x CSR17 | 11.08 | 31.61 | 33.68 | 8.94 | 43.12 | 25.69 |
| C.Nichi x CSR18 | 11.28 | 30.90 | 32.50 | 13.08 | 30.06 | 24.96 |
| C.Nichi x KA | 7.78 | 26.87 | 37.47 | 12.60 | 50.34 | 27.01 |
| Nistari x CSR2 | 4.07 | 30.14 | 30.35 | 8.38 | 23.64 | 19.31 |
| Nistari x CSR3 | 6.93 | 28.49 | 31.94 | 8.97 | 38.60 | 22.99 |
| Nistari x CSR17 | 9.23 | 31.19 | 32.60 | 7.69 | 49.16 | 25.97 |
| Nistari x CSR18 | 10.61 | 35.53 | 38.77 | 8.16 | 36.03 | 25.82 |
| Nistari x K.A | 9.67 | 28.64 | 33.48 | 7.25 | 55.90 | 26.99 |
| PM x CSR2 | 6.13 | 20.82 | 24.83 | 9.12 | 21.17 | 16.41 |
| PM x CSR3 | 8.64 | 15.73 | 28.27 | 16.82 | 33.71 | 20.63 |
| PM x CSR17 | 11.74 | 21.81 | 28.81 | 10.94 | 44.83 | 23.63 |
| PM x CSR18 | 12.71 | 26.91 | 29.13 | 5.89 | 33.50 | 21.63 |
| PM x KA | 11.63 | 16.90 | 13.17 | 0.33 | 46.91 | 17.79 |
| Mean | 8.95 | 26.28 | 30.30 | 9.51 | 37.14 | 22.53 |
| Maximum | 12.71 | 35.53 | 38.77 | 16.82 | 55.90 | 27.01 |
| Minimum | 4.07 | 15.73 | 13.17 | 0.33 | 17.78 | 16.41 |
| CD at 5% | 0.47 | 0.02 | 0.04 | 0.32 | 1.02 | - |

Table 2: Evaluation index values in the multivoltine x bivoltine hybrids calculated over relative heterosis

| Hybrids | Pupation rate (%) | Cocoon weight (g) | Shell weight (g) | Shell ratio (%) | Filament length (m) | Average heterosis |
|---|---|---|---|---|---|---|
| C.Nichi x CSR2 | 33.78 | 46.60 | 44.80 | 52.77 | 32.79 | 42.15 |
| C.Nichi x CSR3 | 46.87 | 46.43 | 52.11 | 61.28 | 45.81 | 50.50 |
| C.Nichi x CSR17 | 58.01 | 59.48 | 54.54 | 48.53 | 55.30 | 55.37 |
| C.Nichi x CSR18 | 58.75 | 58.22 | 63.60 | 59.28 | 43.71 | 56.71 |
| C.Nichi x KA | 45.60 | 51.05 | 60.44 | 58.05 | 61.72 | 56.14 |
| Nistari x CSR2 | 31.66 | 56.87 | 49.34 | 47.06 | 38.00 | 44.59 |
| Nistari x CSR3 | 42.42 | 53.94 | 51.83 | 48.61 | 51.29 | 49.62 |
| Nistari x CSR17 | 51.05 | 58.74 | 52.85 | 45.27 | 60.68 | 54.38 |
| Nistari x CSR18 | 56.25 | 66.47 | 62.46 | 46.51 | 49.01 | 56.71 |
| Nistari x K.A | 52.69 | 54.20 | 54.22 | 44.14 | 66.66 | 55.17 |
| PM x CSR2 | 39.39 | 40.29 | 40.75 | 49.00 | 35.81 | 41.05 |
| PM x CSR3 | 48.82 | 31.24 | 46.10 | 69.01 | 46.95 | 48.42 |
| PM x CSR17 | 60.49 | 42.05 | 46.94 | 53.73 | 56.82 | 52.01 |
| PM x CSR18 | 64.14 | 51.13 | 47.44 | 40.60 | 46.77 | 50.02 |
| PM x KA | 60.08 | 33.31 | 22.57 | 26.17 | 58.68 | 40.16 |

Table 3: Heterosis values in the bivoltine x multivoltine hybrids

| Hybrids | Pupation rate (%) | Cocoon weight (g) | Shell weight (g) | Shell ratio (%) | Filament length (m) | Average heterosis |
|---|---|---|---|---|---|---|
| CSR2 x C.Nichi | 4.63 | 29.69 | 32.06 | 10.18 | 20.53 | 19.42 |
| CSR2 x Nistari | 5.43 | 32.45 | 27.63 | 3.28 | 19.28 | 17.61 |
| CSR2 x PM | 9.78 | 24.17 | 29.92 | 10.21 | 22.98 | 19.41 |
| CSR3 x C.Nichi | 6.51 | 28.71 | 33.84 | 11.80 | 34.34 | 23.04 |
| CSR3 x Nistari | 7.80 | 28.82 | 31.08 | 8.73 | 33.14 | 21.91 |
| CSR3 x PM | 11.78 | 22.02 | 30.93 | 12.44 | 37.18 | 22.87 |
| CSR17 x C.Nichi | 9.78 | 31.82 | 37.50 | 12.36 | 45.92 | 27.48 |
| CSR17 x Nistari | 10.50 | 33.78 | 33.02 | 6.02 | 43.87 | 25.44 |
| CSR17 x PM | 16.17 | 26.41 | 31.38 | 9.04 | 48.13 | 26.23 |
| CSR18 x C.Nichi | 10.91 | 35.06 | 42.11 | 12.39 | 31.73 | 26.44 |
| CSR18 x Nistari | 12.58 | 36.95 | 39.28 | 7.69 | 30.81 | 25.46 |
| CSR18 x PM | 18.01 | 30.62 | 36.79 | 8.96 | 34.09 | 25.69 |
| KA x C.Nichi | 7.10 | 28.98 | 43.94 | 12.25 | 48.22 | 28.10 |
| KA x Nistari | 11.05 | 29.03 | 26.27 | 1.76 | 49.03 | 23.43 |
| KA x PM | 12.65 | 22.39 | 27.97 | 7.40 | 49.76 | 24.04 |
| Mean | 10.31 | 29.39 | 33.58 | 8.97 | 36.60 | 23.77 |
| Maximum | 18.01 | 36.95 | 43.94 | 12.44 | 49.76 | 28.10 |
| Minimum | 4.63 | 22.02 | 26.27 | 1.76 | 19.28 | 17.61 |
| CD at 5% | 0.30 | 0.01 | 25.85 | 0.21 | 2.75 | |

22.02 to 36.95 in reciprocal crosses. The heterosis (%) in shell weight and shell% was varied from 13.17 to 38.77 and 0.33 to 16.82 in regular and from 26.27 to 43.94 and 1.76 to 12.44 in reciprocal crosses respectively. The range of heterosis (%) for filament length was from 17.78 to 55.90 and 19.28 to 49.76 in regular and reciprocal crosses respectively (Table 1,2). Among the characters maximum heterosis was obtained in filament length (37.14%) followed by shell weight (30.30%) and cocoon weight (26.28%) and minimum was observed in pupation rate (8.95%) in regular crosses (Table 1). Similar trend was observed in reciprocals too, where filament length has shown maximum heterosis (36.6%) followed by shell weight (33.58%) and cocoon weight (29.39%), but minimum was observed in shell % (8.97%) (Table 3).

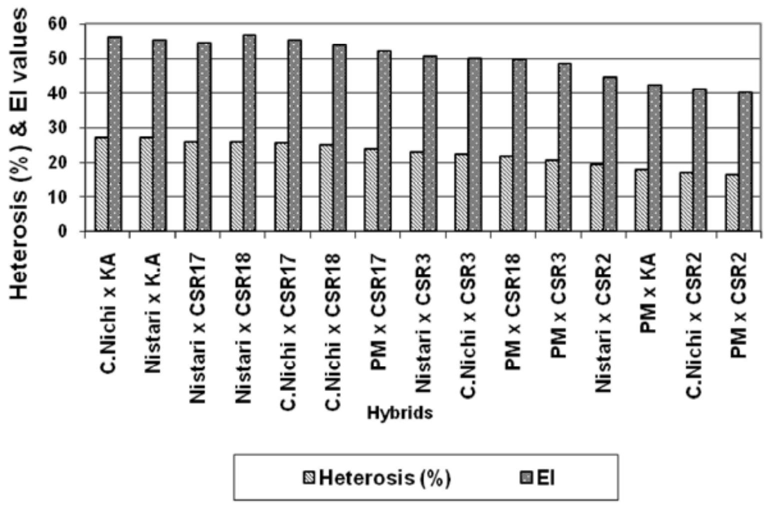


Fig. 1: Mean heterosis and mean evaluation index in the multi x bi hybrids of silkworm, *B. mori* L.

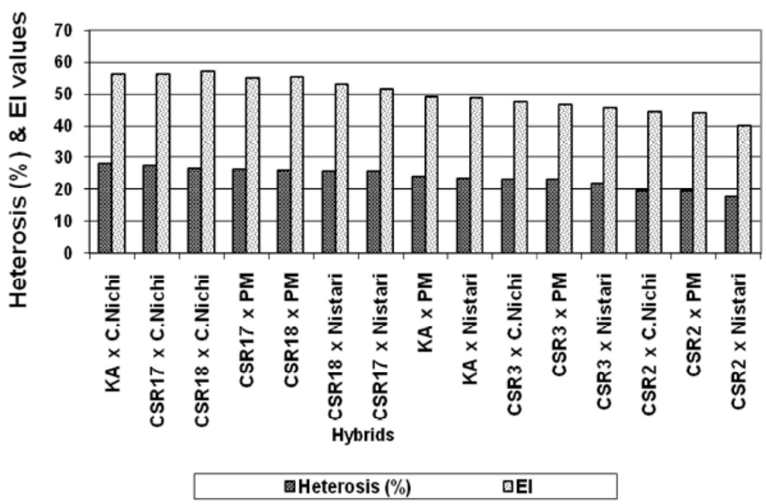


Fig. 2: Mean heterosis and mean evaluation index in the bivoltine x multivoltine hybrids of silkworm, *B. mori* L.

Table 4: Evaluation index values in the bivoltine x multivoltine hybrids calculated over relative heterosis

| Hybrids | Pupation rate (%) | Cocoon weight (g) | Shell weight (g) | Shell ratio (%) | Filament length (m) | Average heterosis |
|---|---|---|---|---|---|---|
| CSR2 x C.Nichi | 34.77 | 50.69 | 47.13 | 53.64 | 34.78 | 44.20 |
| CSR2 x Nistari | 36.93 | 57.01 | 38.76 | 32.87 | 33.59 | 39.83 |
| CSR2 x PM | 48.58 | 38.02 | 43.09 | 53.73 | 37.10 | 44.10 |
| CSR3 x C.Nichi | 39.82 | 48.44 | 50.48 | 58.55 | 47.86 | 49.03 |
| CSR3 x Nistari | 43.26 | 48.68 | 45.27 | 49.29 | 46.72 | 46.65 |
| CSR3 x PM | 53.94 | 33.08 | 44.99 | 60.46 | 50.54 | 48.60 |
| CSR17 x C.Nichi | 48.57 | 55.56 | 57.40 | 60.22 | 58.83 | 56.12 |
| CSR17 x Nistari | 50.51 | 60.06 | 48.93 | 41.12 | 56.88 | 51.50 |
| CSR17 x PM | 65.69 | 43.15 | 45.85 | 50.22 | 60.92 | 54.97 |
| CSR18 x C.Nichi | 51.60 | 63.00 | 66.10 | 60.31 | 45.39 | 57.28 |
| CSR18 x Nistari | 56.07 | 67.34 | 60.76 | 46.14 | 44.52 | 54.97 |
| CSR18 x PM | 70.62 | 52.82 | 56.05 | 49.97 | 47.62 | 55.42 |
| KA x C.Nichi | 41.40 | 49.06 | 69.56 | 59.90 | 61.00 | 56.19 |
| KA x Nistari | 51.97 | 49.16 | 36.20 | 28.29 | 61.78 | 45.48 |
| KA x PM | 56.28 | 33.93 | 39.41 | 45.29 | 62.47 | 47.47 |

Table 5: Heterobeltiosis values in the multivoltine x bivoltine hybrids

| Hybrids | Pupation rate (%) | Cocoon weight (g) | Shell weight (g) | Shell ratio (%) | Filament length (m) | Average heterosis |
|---|---|---|---|---|---|---|
| C.Nichi x CSR2 | 2.98 | -4.41 | -16.55 | -12.89 | -22.53 | -10.68 |
| C.Nichi x CSR3 | 3.67 | -4.30 | -12.25 | -8.59 | -9.03 | -6.10 |
| C.Nichi x CSR17 | 4.57 | 2.71 | -11.25 | -13.58 | 0.85 | -3.34 |
| C.Nichi x CSR18 | 3.14 | 4.25 | -6.11 | -9.94 | -11.63 | -4.06 |
| C.Nichi x KA | 0.46 | 0.67 | -4.14 | -4.76 | 8.95 | 0.24 |
| Nistari x CSR2 | 2.50 | -0.01 | -13.72 | -13.10 | -17.76 | -8.42 |
| Nistari x CSR3 | 3.35 | -1.17 | -11.46 | -10.83 | -3.62 | -4.74 |
| Nistari x CSR17 | 3.64 | 2.24 | -11.14 | -13.24 | 6.53 | -2.39 |
| Nistari x CSR18 | 3.32 | 7.81 | -5.14 | -12.26 | -6.39 | -2.53 |
| Nistari x K.A | 2.06 | 1.88 | -5.11 | -7.40 | 14.59 | 1.20 |
| PM x CSR2 | 1.65 | -1.97 | -13.74 | -11.83 | -17.87 | -8.75 |
| PM x CSR3 | 5.05 | -6.06 | -9.95 | -3.77 | -4.94 | -3.93 |
| PM x CSR17 | 9.11 | 0.30 | -9.69 | -10.08 | 5.82 | -0.91 |
| PM x CSR18 | 8.93 | 6.89 | -7.46 | -13.57 | -6.27 | -2.30 |
| PM x KA | 8.17 | -2.04 | -15.37 | -12.83 | 10.67 | -2.28 |
| Mean | 4.17 | 0.45 | -10.20 | -10.58 | -3.51 | -3.93 |
| Maximum | 9.11 | 7.81 | -4.14 | -3.77 | 14.59 | 1.20 |
| Minimum | 0.46 | -6.06 | -16.55 | -13.58 | -22.53 | -10.68 |
| CD at 5% | 0.54 | 0.48 | 0.02 | 0.04 | 0.36 | - |

Table 6: Evaluation index values in the multivoltine x bivoltine hybrids calculated over heterobeltiosis

| Hybrids | Pupation rate (%) | Cocoon weight (g) | Shell weight (g) | Shell ratio (%) | Filament length (m) | Average heterosis |
|---|---|---|---|---|---|---|
| C.Nichi x CSR2 | 45.84 | 37.85 | 33.72 | 42.73 | 33.11 | 38.65 |
| C.Nichi x CSR3 | 48.38 | 38.13 | 44.76 | 56.25 | 45.10 | 46.52 |
| C.Nichi x CSR17 | 51.67 | 55.63 | 47.32 | 40.54 | 53.87 | 49.81 |
| C.Nichi x CSR18 | 46.41 | 59.48 | 60.51 | 52.02 | 42.79 | 52.24 |
| C.Nichi x KA | 33.18 | 50.55 | 65.57 | 68.32 | 61.06 | 55.74 |
| Nistari x CSR2 | 44.08 | 48.85 | 40.98 | 42.05 | 37.35 | 42.66 |
| Nistari x CSR3 | 47.21 | 45.94 | 46.79 | 49.22 | 49.90 | 47.81 |
| Nistari x CSR17 | 48.27 | 54.48 | 47.61 | 41.61 | 58.91 | 50.18 |
| Nistari x CSR18 | 47.07 | 68.40 | 62.99 | 44.72 | 47.44 | 54.12 |
| Nistari x K.A | 42.44 | 53.56 | 63.08 | 60.00 | 66.07 | 57.03 |
| PM x CSR2 | 40.93 | 43.95 | 40.93 | 46.06 | 37.25 | 41.82 |
| PM x CSR3 | 53.45 | 33.71 | 50.66 | 71.44 | 48.73 | 51.60 |
| PM x CSR17 | 68.39 | 49.61 | 51.31 | 51.57 | 58.28 | 55.83 |
| PM x CSR18 | 67.73 | 66.10 | 57.03 | 40.57 | 47.55 | 55.80 |
| PM x KA | 64.93 | 49.12 | 44.25 | 47.85 | 63.59 | 54.12 |

**Heterobeltiosis:** All characters have shown negative heterobeltiosis for regular and reciprocal crosses except pupation rate (Table, 5-7). Heterobeltiosis was recorded for 15 regular crosses ranging from -10.68 to 1.20 (Table 5) and in reciprocal crosses from -9.44 to 2.53% (Table 7). The top five crosses with higher heterobeltiosis values in regular crosses are Nistari × KA (1.2%), C.Nichi × KA (0.24%), PM×CSR17 (-0.91%), PM×KA (-2.28%) and PM×CSR18 (-2.30%) and their corresponding EI values are 57.03, 55.74, 55.83, 54.12 and 55.80 respectively (Table 6 and Figure 3). The top five crosses with higher heterobeltiosis values in reciprocal crosses are KA×PM (2.53%), CSR17×PM (1.15%), CSR18×PM (0.94%), KA x C.Nichi (0.64) and KA× Nistari (-1.33%) and their corresponding EI values are 59.52, 56.81, 61.12, 55.60 and 53.08 respectively (Table 8 and Figure 4).

The heterobeltiosis for pupation rate in regular crosses varied from 0.46 to 9.11 percent and in reciprocals between 0.55 to 13.53 %. In cocoon weight the heterobeltiosis ranged between -6.06 and 7.81 in regular

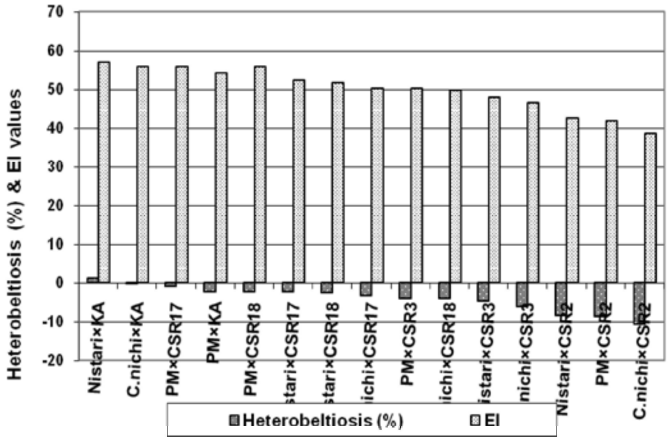


Fig. 3: Mean heterobeltiosis and mean evaluation index in the multi x bi hybrids of silkworm, *B. mori* L.

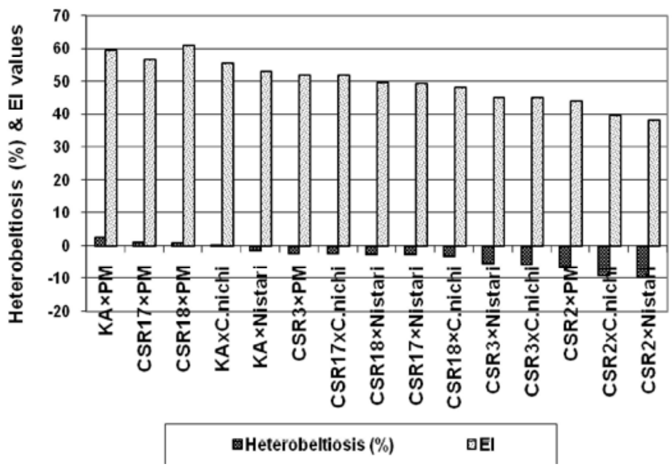


Fig. 4: Mean heterobeltiosis and mean evaluation index in the bivoltine x multivoltine hybrids of silkworm, *B. mori* L.

Table 7: Heterobeltiosis values in the bivoltine x multivoltine hybrids

| Hybrids | Pupation rate (%) | Cocoon weight (g) | Shell weight (g) | Shell ratio (%) | Filament length (m) | Average heterosis |
|---|---|---|---|---|---|---|
| CSR2 x C.Nichi | 3.54 | 0.19 | -14.05 | -14.40 | -20.68 | -9.08 |
| CSR2 x Nistari | 4.15 | 1.90 | -15.52 | -17.31 | -20.42 | -9.44 |
| CSR2 x PM | 4.64 | 1.12 | -10.22 | -11.31 | -16.68 | -6.49 |
| CSR3 x C.Nichi | 2.71 | -0.49 | -11.75 | -11.46 | -7.67 | -5.73 |
| CSR3 x Nistari | 4.49 | -0.79 | -12.04 | -11.15 | -7.14 | -5.33 |
| CSR3 x PM | 7.60 | -0.57 | -8.08 | -7.73 | -2.51 | -2.26 |
| CSR17 x C.Nichi | 3.91 | 3.25 | -9.43 | -12.34 | 2.88 | -2.35 |
| CSR17 x Nistari | 5.15 | 4.37 | -10.87 | -14.71 | 3.12 | -2.59 |
| CSR17 x PM | 12.91 | 4.46 | -7.86 | -11.94 | 8.17 | 1.15 |
| CSR18 x C.Nichi | 3.36 | 8.01 | -4.62 | -11.74 | -10.43 | -3.08 |
| CSR18 x Nistari | 5.46 | 9.06 | -4.83 | -12.76 | -9.68 | -2.55 |
| CSR18 x PM | 13.53 | 10.41 | -1.92 | -11.39 | -5.91 | 0.94 |
| KA x C.Nichi | 0.55 | 2.69 | -1.04 | -6.51 | 7.50 | 0.64 |
| KA x Nistari | 3.64 | 2.25 | -10.30 | -12.26 | 10.03 | -1.33 |
| KA x PM | 9.50 | 2.94 | -5.44 | -7.08 | 12.73 | 2.53 |
| Mean | 5.68 | 3.25 | -8.53 | -11.61 | -3.78 | -3.00 |
| Maximum | 13.53 | 10.41 | -1.04 | -6.51 | 12.73 | 2.53 |
| Minimum | 0.55 | -0.79 | -15.52 | -17.31 | -20.68 | -9.44 |
| CD at 5% | 0.35 | 0.01 | 29.85 | 0.24 | 3.17 | - |

Table 8: Evaluation index values in the bivoltine x multivoltine hybrids calculated over heterobeltiosis

| Hybrids | Pupation rate (%) | Cocoon weight (g) | Shell weight (g) | Shell ratio (%) | Filament length (m) | Average heterosis |
|---|---|---|---|---|---|---|
| CSR2 x C.Nichi | 44.56 | 41.28 | 37.02 | 40.23 | 34.51 | 39.52 |
| CSR2 x Nistari | 46.18 | 46.14 | 33.57 | 30.02 | 34.74 | 38.13 |
| CSR2 x PM | 47.47 | 43.92 | 46.02 | 51.05 | 38.17 | 45.33 |
| CSR3 x C.Nichi | 42.39 | 39.34 | 42.44 | 50.50 | 46.43 | 44.22 |
| CSR3 x Nistari | 47.08 | 38.47 | 41.76 | 51.58 | 46.92 | 45.16 |
| CSR3 x PM | 55.26 | 39.11 | 51.06 | 63.58 | 51.17 | 52.03 |
| CSR17 x C.Nichi | 45.54 | 49.99 | 47.89 | 47.43 | 56.11 | 49.39 |
| CSR17 x Nistari | 48.80 | 53.18 | 44.50 | 39.13 | 56.32 | 48.39 |
| CSR17 x PM | 69.23 | 53.44 | 51.58 | 48.84 | 60.96 | 56.81 |
| CSR18 x C.Nichi | 44.10 | 63.57 | 59.20 | 49.54 | 43.90 | 52.06 |
| CSR18 x Nistari | 49.62 | 59.25 | 48.69 | 45.97 | 44.59 | 49.64 |
| CSR18 x PM | 70.86 | 70.39 | 65.54 | 50.77 | 48.04 | 61.12 |
| KA x C.Nichi | 33.80 | 48.39 | 67.62 | 67.83 | 60.34 | 55.60 |
| KA x Nistari | 44.84 | 47.15 | 45.84 | 47.70 | 62.66 | 53.08 |
| KA x PM | 60.26 | 49.10 | 57.27 | 65.84 | 65.13 | 59.52 |

and -0.79 and 10.41 in reciprocal crosses. The heterobeltiosis in shell weight and shell% was ranged from -16.55 to -4.14 and -13.58 to -3.77 in regular and from -15.52 to -1.04 and -17.31 to -6.51 in reciprocal crosses respectively. The range of heterobeltiosis (%) for filament length was from -22.53 to 14.59 and -20.68 to 12.73 in regular and reciprocal crosses respectively (Table 5,7). Of the five characters analyzed, maximum heterobeltiosis was observed in pupation rate (4.17%) followed by cocoon weight (0.45%) and minimum was observed in shell% (-10.58%) in regular crosses (Table 5). Trend was same in reciprocals also (Table 7) where pupation rate has shown maximum heterosis (5.68%) followed by cocoon weight (3.25%) and minimum was observed in shell% (-11.61%).

## DISCUSSION

Hybrid vigour is very important in silkworm breeding [4, 5] and it has been successfully utilized at commercial level all over the world. The data obtained in this experiment indicate that the certain hybrids are clearly superior in terms of heterotic expression in certain cocoon traits, although average heterosis exhibited by the hybrids may vary with combination, which was between 16.0 and 28.0%. Among five important characters in silk yield, the multi x bi hybrids seems to have advantage of producing higher filament length, shell weight and cocoon weight, but there was no pronounced effect on pupation rate, since the expression of heterosis was higher in filament length, shell weight and cocoon weight than pupation rate. The lesser heterosis in multi x bi hybrid for pupation rate indicates that parental breeds also performing equally well and higher heterosis for other characters is a merit for commercial exploitation.

The average level of heterosis was low, mainly because of high and low expression of heterosis in these traits, which balanced each other, though the parent populations differed widely in their architecture and origin. Therefore, insufficient genetic diversity could not explain the low average heterosis and the occurrence of negative heterobeltiosis. Further heterosis is the function of various gene frequencies, heterobeltiosis observed to be highly variable and basically it depends on the characters as well as parental strains utilized in the hybridization programme [6]. The high degree of heterosis in specific crosses for some traits in this study can be due to additive gene effects [7,8], especially higher heterosis obtained for filament length and shell weight reveals the magnitude of genetic diversity of the parental material and the predominance of the complimentary type of the gene action in the parents are in conformity with the observations of earlier workers [9-12]. The study also revealed cocoon weight, shell weight, shell % and filament length showing negative heterobeltiosis irrespective of the type of combinations except for pupation rate. It should be noted that when high parental values are considered for heterobeltiosis, incidentally one of the parent of this study i.e., bivoltine has more value for cocoon weight, shell weight, shell% and filament length. This is the inherent potential of the bivoltine silkworm and their cocoon traits are superior as compared to multivoltine resulting in negative heterobeltiosis for these characters. However they are poor survivor when conditions are unfavourable and therefore the pupation rate shows positive relative heterosis and heterobeltiosis. The maximum heterosis obtained over better parent for this character can be due to the accumulated action of favourable dominant or semi-dominant genes dispersed among two parents, i.e. dominance; or by the complementary interaction of additive dominance [13].

It may be noted that among different characters, only pupation rate did not show much variation in heterotic expression (4 -10%) in both forms of heterosis and irrespective crosses, which shows heterosis due to non additive genes and also confirming this low heritability in this character. However, optimum level of genetic distance is necessary to obtain heterosis (14) and it may not be logical to advocate the use of extremely divergent parents to obtain heterotic combinations (15, 16).

In this study, an attempt was also made to compute evaluation index [3] over heterosis values and pool the heterotic values of all the traits of a particular combination and derive the combined evaluation index for heterosis. The evaluation index method was found to be very useful in selecting potential parents and hybrids for silkworm breeding programme [17-20]. In this method the EI value fixed for the selection of breed / hybrid is 50 or > 50. The breed / hybrid which scored above the limit is considered to possess greater economic value. The EI obtained over heterosis in the present study confirmed the higher or lower heterotic expression of hybrids and characters in particular. The hybrids viz., C.Nichi x KA, C.Nichi x CSR17, PM x CSR17, PM x CSR18 and Nistari x KA were adjudicated as the most promising multi x bi-hybrids based on heterotic expression and EI values. The reciprocals of the same hybrids also behaved in the same manner as regular crosses. The identified hybrids can be used for commercial exploitation and also they are excellent sources for transgressive segregants in future breeding programmes.

## REFERENCES


1. Datta, R.K., D.R. Rao, K.P. Jayaswal, V. Premlatha, R. Singh and B.K. Kariappa, 2001. Heterosis in relation to combining ability in multi x bi strain of silkworm, *Bombyx mori* L. Indian J. Seric., 40: 1-6.
2. Thangavelu, K., 2002. Future research strategy for non-mulberry sericulture with particular reference to tasarculture: Advances in Indian sericulture research. Proceedings of the National Conference on Strategies for Sericulture Research and Development, Nov. 16-18, Central Sericultural Research and Training Institute, Central Silk Board, Mysore, India, pp: 365-368.
3. Mano,Y., S. Nirmal Kumar, H.K. Basavaraja, N. Mal Reddy and R.K. Datta, 1993. A new method to select promising silkworm breeds/combinations. Indian Silk, 3: 53.
4. Harada, C., 1961. On the heterosis of quantitative characters in the silkworm. Bull. Seric. Exp. Station, 17: 50-52.
5. Nagaraju, J., 2002. Application of genetic principles for improving silk production. Current Sci., 83: 409-414.
6. Falconer, D.S., 1981. Introduction to Quantitative Genetics, Ed. 2. Longman, London/New York.
7. Rao, P.R.T., B. Ghosh, S.M. Moorthy, S.K. Das, G.C. Roy, A.K. Sengupta and S.K. Sen, 1998. Combining ability, Gene action and Heterosis through introgressive hybridization in *Bombyx mori* L. In Proceedings of Perspectives in Cytology & Genetics, 9: 461-47.
8. Udupa, S. and V. Gowda, 1988. Heterosis expression in silk productivity of different crosses of silkworm, *Bombyx mori L.,* Sericologia*,* 28: 395-399.
9. Nacheva, I., 1980. Heterosis effect on some technological qualities of cocoons and silkfibres in the silkworm *Bombyx mori*. Zhivotnov'D Nauki, 17: 88-94.
10. Nanjundaswamy, L., 1997. Studies on the combining ability in silkworm *Bombyx mori* L. Ph.D Thesis University of Mysore, Mysore, India.
11. Satenahalli, S.B., R. Govindan and J.V. Goud, 1990. Analysis of heterosis for some quantitative traits in silkworm, *Bombyx mori* L. Mysore J. Agric. Sci., 24: 214-221.
12. Sengupta, K., R.K. Datta, S.N. Biswas and B.D. Singh, 1972. Heterosis in multivoltine silkworm (*Bombyx mori* L.) 1.Yield performance of F1 hybrids of Nistari and four evolved multivoltine breeds. Ind. J. Seric., 10: 6-13.
13. Mackey, I., 1976. Genetics and evolutionary principles of heterosis. In proceedings of the 8th Congress of Eucarpia on Heterosis of Plant Breeding. A. Janossy and F.G.H. Lupton, (ed.), Elsevier Scientific Pub. Co., Amsterdom, Netherlands, pp; 17-33.
14. Arunachalam, V., A. Bandyopadhyay, S.N. Nigam and R.W. Gibbons, 1984. Heterosis in relation to genetic divergence and specific combining ability in ground nut (*Arachis hypogaea* L.) Euphytica, 33: 33-39.
15. Talebi, E. and G. Subramanya, 2009. Genetic distance and Heterosis through evaluation index in the Silkworm, *Bombyx mori* L. J. Agric. Biol. Sci., 5: 52-55.
16. Talebi, E., G. Subramanya and S. Bakappa, 2010. An investigation on heterosis and inbreeding depression in the Silkworm, *Bombyx mori* L. World Appli. Sci. J., 7: 1131-1137.

17. Bhargava, S.K., E. Rajalakahmi and V. Thiagarajan, 1994. An evaluation index for silk yield contributing traits in *Bombyx mori* L. Indian Textile J., 105: 83-84.
18. Moorthy, S.M., S.K. Das, N.B. Kar, K. Mandal and A.K. Bajpai, 2007. Breeding of bivoltine silkworm breeds suitable for tropics and identification of multi x bi silkworm hybrid for commercial exploitation in Eastern India. In perspectives of Cytology and Genetics, 13: 215-222.
19. Ramesh Babu, M., Chandrashekaraiah, H. Lakshmi and J. Prasad, 2001. Silkworm (*Bombyx mori* L.) genetic stocks-an evolutionary analysis. Bull. Ind. Acad. of Seric., 5: 9-1.
20. Rayar, S.G., 2007. Use of Evaluation index for selecting potential parents for silkworm breeding. Karnataka J. Agric. Sci., 20: 420-421.