MATERIAL AND METHODS

The popular bivoltine breeds namely CSR2 spinning white oval cocoons and CSR4 spinning white dumb-bell cocoons were utilized to study the effect of different types of selection on the breeds (Plate 1&2). A total of 3 replications were reared by following the standard rearing technology of Basavaraja, et al., 2002. All the cocoons of the base population were subjected to single cocoon assessment for each selection method and the phenotypic selection for cocoon weight, shell weight and cocoon shell percentage for directional, stabilizing, disruptive, cyclical selection and control is presented in Table I to XI. The details of the selection are as follows:

After cocoon assessment, the batches were selected for further continuation in accordance with the four selection methods and selection for a particular trait as detailed below.

1) Directional selection: Based on high values for cocoon weight, cocoon shell weight and cocoon shell percentage, three separate lines were maintained (Fig. A).

2) Stabilizing selection: Based on mean values, selection for cocoon weight, cocoon shell weight and cocoon shell percentage were made (Fig. B).

3) Disruptive selection: Based on extreme low and extreme high values, selection for cocoon weight, cocoon shell weight and cocoon shell percentage were made (Fig. C).

4) Cyclical selection: Selection were made based on extreme high values for cocoon weight, cocoon shell weight and cocoon shell percentage in one cycle and extreme low values in the succeeding generation and same were repeated in every alternate cycles (Fig. D).

5) Control: Selection were made based on the visual observation of cocoon shape, size and uniformity with higher pupation rate (Fig. E).
At every generation, 25 male and 25 female cocoons were assessed individually in each replication and from the assessed cocoons, selection for cocoon weight, shell weight and cocoon shell percentage for each type of selection methods were made from generation 1 to generation 8. At 9th generation, hybrid evaluation for all the selected lines from all the four types of selection method along with control were made. Further selection for each trait for all the selection method was continued upto 12th generation. At every generation from the assessed cocoons, 10 to 12 male and female cocoons (for cocoon weight, shell weight and cocoon shell percentage) were selected for each selection methods.

At every generation three replications are reared, both female and male cocoons were selected in accordance with selection methods as described above and were pooled and subjected for random mating to produce progenies for next cycle. The data generated was subjected to statistical methods ANOVA (One way and Three way Classification) Kempthrone, (1957)

**Hybrid evaluation**

After 8th cycle, hybrid evaluation was conducted by utilizing the individuals separately from the different selection methods (Table I). Based on the expression of hybrid vigour for all the economic characters, the selected batches of CSR2 and CSR4 from each selection method were continued for four more generations. Again at 12th generation, hybrid evaluation of all the selected lines were made. The data were subjected to ‘T’ test, ANOVA and heterosis and over dominance.
Table I: Hybrids evaluated for the estimation of hybrid vigour

CSR2 (DIR-CW) x CSR4 (DIR-CW)
CSR2 (DIR-SW) x CSR4 (DIR-SW)
CSR2 (DIR-SR%) x CSR4 (DIR-SR%)
CSR2 (STA-CW) x CSR4 (STA-CW)
CSR2 (STA-SW) x CSR4 (STA-SW)
CSR2 (STA-SR%) x CSR4 (STA-SR%)
CSR2 (DIS-CW) x CSR4 (DIS-CW)
CSR2 (DIS-SW) x CSR4 (DIS-SW)
CSR2 (DIS-SR%) x CSR4 (DIS-SR%)
CSR2 (CYL-CW) x CSR4 (CYL-CW)
CSR2 (CYL-SW) x CSR4 (CYL-SW)
CSR2 (CYL-SR%) x CSR4 (CYL-SR%)
CSR2 x CSR4 (Control)

Data on various traits such as fecundity, larval duration, pupation rate, cocoon yield, cocoon weight, shell weight, shell percentage, raw silk percentage, filament length, reelability, filament size (denier) and neatness were recorded to assess the effect of different selection methods on qualitative and quantitative characters of the hybrid and manifestation of hybrid vigour under different selection pressure. Hybrid vigour was calculated in terms of heterosis over Mid Parent Value (MPV) and Better Parent Value (BPV) as follows,

\[
\text{Heterosis over MPV} = \frac{\text{Hybrid value – Mid Parental Value}}{\text{Mid Parental Value}} \times 100
\]

\[
\text{Heterosis over BPV} = \frac{\text{Hybrid value – Better Parental Value}}{\text{Better Parental Value}} \times 100
\]
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Parentage</strong></td>
<td>Shunrei x Shogestsu</td>
</tr>
<tr>
<td><strong>Fecundity</strong></td>
<td>500-550</td>
</tr>
<tr>
<td><strong>Larval marking and color</strong></td>
<td>Plain –Bluish White</td>
</tr>
<tr>
<td><strong>Larval duration</strong></td>
<td>23-24 days</td>
</tr>
<tr>
<td><strong>Cocoon colour and shape cocoon grains</strong></td>
<td>White, oval Fine to medium</td>
</tr>
<tr>
<td><strong>Pupation rate (%)</strong></td>
<td>85-90</td>
</tr>
<tr>
<td><strong>Cocoon weight (g)</strong></td>
<td>1.80 - 1.95</td>
</tr>
<tr>
<td><strong>Cocoon shell weight (g)</strong></td>
<td>0.45 – 0.50</td>
</tr>
<tr>
<td><strong>Cocoon shell percentage</strong></td>
<td>24 - 26</td>
</tr>
<tr>
<td><strong>Raw silk percentage</strong></td>
<td>19 - 20</td>
</tr>
<tr>
<td><strong>Filament length (m)</strong></td>
<td>1000 - 1100</td>
</tr>
<tr>
<td><strong>Neatness (points)</strong></td>
<td>85 - 90</td>
</tr>
<tr>
<td><strong>Denier (d)</strong></td>
<td>3.00 -3.15</td>
</tr>
<tr>
<td><strong>Reelability (%)</strong></td>
<td>80 -85</td>
</tr>
</tbody>
</table>

Plate 1: Characteristics of **CSR2**
<table>
<thead>
<tr>
<th>Parentage</th>
<th>BN18 xBCS25 out crossed with NB4D2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fecundity</td>
<td>470-500</td>
</tr>
<tr>
<td>Larval marking and color</td>
<td>Plain – Bluish White</td>
</tr>
<tr>
<td>Larval duration</td>
<td>24 - 25</td>
</tr>
<tr>
<td>Cocoon colour and shape</td>
<td>White, constricted Fine to medium</td>
</tr>
<tr>
<td>Cocoon weight (g)</td>
<td>1.80 – 1.90</td>
</tr>
<tr>
<td>Cocoon shell weight (g)</td>
<td>0.38 – 0.43</td>
</tr>
<tr>
<td>Cocoon shell percentage</td>
<td>21 – 22</td>
</tr>
<tr>
<td>Raw silk percentage</td>
<td>17 - 18</td>
</tr>
<tr>
<td>Filament length (m)</td>
<td>900 – 95</td>
</tr>
<tr>
<td>Neatness (points)</td>
<td>90 - 92</td>
</tr>
<tr>
<td>Denier (d)</td>
<td>3.00 – 3.19</td>
</tr>
<tr>
<td>Reelability (%)</td>
<td>75 - 80</td>
</tr>
</tbody>
</table>

Plate 2: Characteristics of CSR4
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parentage</td>
<td>CSR2 and CSR4</td>
</tr>
<tr>
<td>Fecundity</td>
<td>500 ~ 550</td>
</tr>
<tr>
<td>Larval marking and color</td>
<td>Plain – Bluish White</td>
</tr>
<tr>
<td>Larval duration</td>
<td>22 ~ 23 days</td>
</tr>
<tr>
<td>Cocoon colour and shape cocoon grains</td>
<td>Bright white, with intermediate shape and medium grains.</td>
</tr>
<tr>
<td>Pupation rate (%)</td>
<td>90 ~ 95</td>
</tr>
<tr>
<td>Cocoon weight (g)</td>
<td>2.0 ~ 2.2</td>
</tr>
<tr>
<td>Cocoon shell Weight (g)</td>
<td>0.45 ~ 0.48</td>
</tr>
<tr>
<td>Cocoon shell ratio</td>
<td>22 ~ 24</td>
</tr>
<tr>
<td>Raw silk percentage</td>
<td>19 ~ 20</td>
</tr>
<tr>
<td>Filament length (m)</td>
<td>1000 ~ 1050</td>
</tr>
<tr>
<td>Neatness (points)</td>
<td>90 ~ 93</td>
</tr>
<tr>
<td>Denier (d)</td>
<td>2.9 ~ 3.1</td>
</tr>
<tr>
<td>Reelability (%)</td>
<td>85 ~ 88</td>
</tr>
</tbody>
</table>

**Plate 3: Characteristics of hybrid CSR2XCSR4**
25 females and male cocoons were selected randomly, assessed & high cocoon weight was selected at every generation.

25 females and male cocoons were selected randomly, assessed & high shell weight was selected at every generation.

25 females and male cocoons were selected randomly, assessed & high shell percentage was selected at every generation.

Fig. A: Schematic representation of directional selection
Fig. B: Schematic representation of stabilizing selection
25 females and male cocoons were selected randomly, assessed & extreme cocoon weight was selected at every generation.

25 females and male cocoons were selected randomly, assessed & extreme shell weight was selected at every generation.

25 females and male cocoons were selected randomly, assessed & extreme shell percentage was selected at every generation.

Fig. C: Schematic representation of disruptive selection
25 females and male cocoons were selected randomly, assessed, high & low cocoon weight was selected at alternate generation.

25 females and male cocoons were selected randomly, assessed, high & low shell weight was selected at alternate generation.

25 females and male cocoons were selected randomly, assessed, high & low shell percentage was selected at alternate generation.

Fig. D: Schematic representation of cyclical selection
Depending on cocoon uniformity (Shape, size & grains), cocoons were selected at every generation.

Fig. E: Schematic representation of selection in control.
The details of the quantitative traits studied are as follows

1. Fecundity

   The character is measured as the number of eggs laid by an individual moth. It is obtained by counting all the eggs in a laying.

2. Total larval duration

   It depicts the larval period from hatching up to the onset of spinning. The larval duration of each instar was obtained by adding feeding and moulting duration. The total larval duration was obtained by adding the duration of each instar.

3. Yield / 10000 larvae by number

   This is expressed as the number of live cocoons recorded out of a unit number of larvae retained after 3\textsuperscript{rd} moult or for the total larvae brushed. It is expressed in percentage.

   \[
   \text{Yield/number} = \frac{\text{No. of live cocoons}}{(\text{Basic no. of larvae taken} - \text{uzi infested larvae})} \times 10000
   \]

4. Cocoon yield / 10,000 larvae by weight

   The total quantity of good cocoons in kilogram obtained per unit of 10,000 larvae brushed is the cocoon yield for 10,000 larvae by weight. The following formula is employed for the calculations of cocoon yield

   \[
   \text{Cocoon yield by weight} = \frac{\text{Live cocoon weight (kg)}}{\text{Total larvae brushed} - \text{uzi infested larvae}} \times 10000
   \]
5. **Single cocoon weight**

This is the average weight in gram of a cocoon weighing random sample of 50 cocoons. The cocoon weight of 25 male and 25 female was taken separately and then averages were calculated.

6. **Single shell weight**

This determines the quantity of the silk available from the cocoon shell after the removal of the pupae from the cocoons. The shell weight (g) was calculated as the average weight of 50 shells taken at random from each replication of parents and their hybrids. The shell weight of 25 male and 25 female was taken separately and average was calculated

\[
\text{Cocoon shell weight} = \frac{\text{Weight of shell}}{\text{Total number of cocoon shells (25)}}
\]

7. **Cocoon shell percentage**

The cocoon shell percentage was determined by dividing the cocoon shell weight by cocoon weight. It is expressed in percentage.

\[
\text{Cocoon shell percentage} = \frac{\text{Weight of cocoon shell (g)}}{\text{Weight of cocoon (g)}} \times 100
\]

8. **Filament length**

Filament length: Length of unwound silk filament from the cocoons and represented in meters (Sonwalker, 1987).

\[
\text{Filament length} = \frac{\text{Length of raw silk x average no. of reeling}}{\text{Number of reeling cocoons}}
\]
9. **Denier**

This denotes the thickness of the filament. 9000 meters of the silk filament weighing 1 gram is considered as 1 denier. The silk extracted for the filament length was dried at 60°C for 16 hours and dried weight was taken for calculations.

\[
\text{Denier} = \frac{\text{Weight of reeled silk (g)}}{\text{Length of reeled silk (m)}} \times 9000
\]

10. **Reelability percentage**

It is the efficiency of the experimental cocoon lot and is the ratio of cocoon reeled to the total number of cocoons casted. It is expressed in percentage.

\[
\text{Reelability percentage} = \frac{\text{Total No. of cocoons} - \text{Converted no. of cocoons} - \text{Converted no. of reeled out cocoons}}{\text{Total casting} - \text{Total no. of reeled out cocoons}} \times 100
\]

11. **Raw silk percentage**

It is calculated as the quantity of silk produced from a unit weight of cocoons.

\[
\text{Raw silk percentage} = \frac{\text{Silk weight}}{\text{Green cocoon weight}} \times 100
\]

12. **Neatness (P)**

It is expressed in percentage by directly comparing the panels prepared out of raw silk with the standard boards. The test panel nearing to standard panel (with grade 100, 90, 80, 70 and 60) was considered as the neatness of the raw silk.

1. **Filament length**: Length of unwound silk filament from the cocoons and represented in meters (Sonwalker, 1989).

\[
\text{Filament length} = \frac{\text{Length of raw silk \times average no. of reeling}}{\text{Number of reeling cocoons}}
\]
**Statistical Methods**

The statistical method employed to know the economic character among different races/hybrids during different seasons were analyzed by ANOVA (one and Three way classification) is as follows.

**One way Classification**

\[ Y_{ij} + \mu + R_i + S_i + (SR)_{ij} + e_{ij} \]

Where as \( Y_{ij} \) = effect of \( i^{th} \) value race in the \( j^{th} \) season

\( \mu \) = constant effect

\( R_i \) = effect of \( i^{th} \) race

\( S_i \) = interaction effect of \( i^{th} \) race and \( j^{th} \) seasons

\( C_{ij} \) = Random component effect

**Three way Classification**

\[ Y_{ijkt} = \left[ + a_i + %j + (\alpha%)ij + (a&)ik + (% &)jk + (\alpha%&)ijk + \alpha ijkt \right] . \]

The \( ijkt \) are independent random variables.

Each \( ijkt \) ~ \( N(0, 1, 2) \)

**Selection Differential** = The selection difference is symbolized by capital S. This is the difference between the selected animal’s mean value and the population mean value

**Selection Intensity** = The selection intensity is given by the selection difference divided by sigma-p. Sigma-p symbolizes the standard error of the given trait.

\[
\text{Intensity (i)} = \frac{\text{Selection differential (SD)}}{\text{Phenotypic standard deviation (\( \sigma_p \))}}
\]
Selection Response

\[ R = \Delta G = h^2 S \]

\[ = h^2 \sigma_P \quad \text{OR} \quad \Delta G = (I_s - A) \]

\[ = h^2 \sigma_A \]

R is the difference between the parent population mean value and the mean value of the offspring population.

Heritability

The common formula for heritability estimation of a selection experiment, is

\[ R = h^2 S, \]

and it is a standardized normal distribution, where capital S is equal to i.

Student T test

\[ T = \frac{Z}{s}, \]

Where, Z and s are functions of the data