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Content

Volume 60 | Number 3 & 4 | 2020

Research Papers

ROBEVA-Bm: A robust multivariate evaluation method for selecting silkworm genetic resources
V. Sivaprasad and G. R. Manjunatha 75

Identification and characterization of a *p53* homologue (*Bmp53-240*) in the silkworm, *Bombyx mori*
Yan Wu, Jiaxin Yuan, Chenchen Wang, Feng Yu and Wenbing Wang 96

Expansion of mulberry sericulture in Meghalaya using geospatial tools and geoportal
P. T. Das, P. S. Singh, J. Goswami, C. Goswami, B. K. Handique, G. Borah, C. M. Bajpeyi and P. L. N. Raju 104

Development of motorized tasar reeling charkha for enhancement of yarn productivity and quality
Debasis Chattopadhyay, Z. M. S. Khan and T. K. Paul 112

Baby corn- an excellent and compatible intercrop for mulberry
R. M. Shivaprakash, S. N. Narayanagowda, P. G. Radhakrishna, P. B. Vijayakumar, N. Siddalingaswamy and H. Thimmareddy 119

Fluorescence disposition of Indian mulberry silk cocoons and its effect on reeling performance and quality of raw silk
G. Hariraj, S. Aravinda and Subhas V. Naik 124

Growth and performance of bivoltine silk production in India
P. Kumaresan 131

Twist optimization of muga silk yarns for development of diversified fabrics by retaining its natural golden colour

S. N. Mishra and H. H. Sambhulingappa 138

India's trade intensity in silk

P. Kumaresan 145

Muga silk moth (*Antheraea assamensis*) laying eggs

Sericologia 60 (3&4): 75-95, 2020
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Research Paper

ROBEVA-Bm: A ROBUST MULTIVARIATE EVALUATION METHOD FOR SELECTING SILKWORM GENETIC RESOURCES

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ABSTRACT

The selection of promising silkworm genetic stocks or breeds or hybrids based on multiple traits of economic importance is always a challenging task. Majority of multivariate data analytic tools usually suffer with econometric issues, such as multi-collinearity, outliers / extreme observations besides the influence of high and low value traits; which could not be addressed in a single statistical tool. Under such circumstances, the present study proposes *ROBEVA-Bm* as the most efficient and robust multivariate statistical tool for selection of silkworm genetic stocks/breeds/hybrids in a more appropriate way as compared to the existing selection indices (multiple trait evaluation index, similarity co-efficient/sub-ordinate function and joint scoring) in silkworm breeding programmes. *ROBEVA-Bm* is an amalgamated technique based on principal components and robust estimators for determining the best performer(s) for mulberry silkworm breeders and also other fields of sericology. *ROBEVA-Bm* is a user-friendly tool for computing and interpretation with the capability to present the results graphically (box-plots, correlation color triangles, cluster heatmaps & bio-plots). R codes for *ROBEVA-Bm* are appended for ready-use of silkworm breeders for the genetic stocks/hybrids' evaluation process.

Key words: Bi-plot, heatmaps, hierarchical clusters, multi trait selection index, principal component analysis, robust estimators, silkworm breeds/ hybrids.

INTRODUCTION

Silkworm breeds/hybrids and mulberry varieties are important components for improving productivity and silk quality in mulberry sericulture. All the major sericultural countries possess unique genetic resources and utilize the appropriate parental stocks depending upon the breeding objectives to develop silkworm breeds/hybrids which are suitable for the specific agro-climatic conditions. At the same time, applying suitable statistical tools is also vital for the experimenter. The researchers in mulberry sericulture especially breeders apply different statistical methods *viz*., multi trait evaluation (Mano *et al*., 1993), sub-ordinate function/co-efficient of similarity (Gower, 1971), joint scoring method (Arunachalam and Bandopadhyay, 1984) *etc*. to evaluate the relative superiority of genetic resources or hybrids.

The performance of silkworm breeds/hybrids is recorded for quantitative economic characteristics including 12 rearing (fecundity, larval duration, pupation rate, cocoon weight, shell weight, cocoon yield *etc*.) and 16 post cocoon traits (filament length, non-breaking filament length, reelability, denier, renditta, raw silk percentage, neatness, cleanness, evenness, elongation, cohesion *etc*.) for evaluation purposes (Datta *et al*., 2014). However, the selection of traits/characters for such evaluations varies from breeder to breeder based on targeted objectives. These characteristics include higher and lower value traits, such as larval duration, denier and renditta. Multi trait evaluation, sub-ordinate function and joint scoring methods are usually employed to identify the best performing silkworm breeds/hybrids (Datta *et al*., 2001; Sudhakara Rao *et al*., 2002; Mal Reddy *et al*., 2002; Ramesh Babu *et al*., 2005; Lakshmi *et al*., 2012; Datta *et al*., 2014; Balachandran and Kamble, 2016; Hemmatabadi *et al*., 2014; Buhroo *et al*., 2017). At the same time, breeders encounter certain issues in dealing with calculating a single index for parameters due to the limitations in the existing statistical methods *viz*., high - value traits (fecundity, pupation rate, cocoon weight, *etc*.) and low - value traits (larval duration, denier, renditta, *etc*.). The other limitations include handling extreme values or outliers in data (abnormal values present in data due to sampling error or breed potentiality), econometric problem of multicollinearity (disturbance in the data, its presence vitiates statistical inferences) and equal weighing for all traits or variables or characters.

Currently, China (68,600 MT) and India (38,820 MT) are the major silk producing countries in the world accounting for 97 % of silk, majority (90 %) of which is mulberry (Anonymous, 2020). Continuous replacement of existing breeds/hybrids with superior breeds/hybrids utilizing different genetic resources for targeted traits, objectives and suitability helps for improving crop sustainability, productivity and quality. Systematic evaluation of superior breeds/hybrids for multiple economic traits and wholesome performance is an important task for assisting breeders. The present study proposes *ROBEVA-Bm*, an efficient statistical method for the evaluation of silkworm genetic resources based on robust estimators and principal component analysis; focussing on major silkworm productivity variables, which could overcome the limitations of existing methods.

METHODOLOGY

Silkworm breeding programmes are initiated by selecting the suitable parental stocks from the available genetic resources based on passport data or by rearing trials in a given location. The best stocks after evaluation would be used for undertaking the breeding plan. Generally, silkworm breeders evolve 10 - 12 superior or inbred lines by following the specified breeding plan with an aim to select the best performing lines based on targeted objectives. The Chinese (oval) and Japanese (dumbbell) type breeding lines need to be sorted out in separate groups as the male and female component of a silkworm hybrid has different priorities for each economic trait. For analyzing the hybrids in complete diallele with 10 breeding lines each, 90 (${}^{10}P_2$) possible crosses or permutation combinations could be made. The hybrid combinations would be short-listed to 20 based on survival and cocoon yield, the most important indicators of productivity. Further, these hybrids need to be assessed for multiple traits under standard rearing conditions (300 larvae out of III moult; 3 replications per combination). The data should be recorded for traits *viz.*, fecundity (No.), pupation rate (%), cocoon yield/10,000 larvae (kg), larval duration (D:H), cocoon weight (g), shell weight (g), filament length (m), non-breakable filament length (m), reelability (%), raw silk (%), neatness (points), cleanness (%), evenness (points), elongation (%), cohesion (strokes), denier (d) and renditta. The data recorded for three seasons/rearings would be analyzed using appropriate statistical methods for identifying the promising breeds/hybrids. The most popular or ruling hybrid in an area is usually maintained as control for determining the superiority of new hybrid combinations. As per the combining ability studies, often complete diallele for bivoltine hybrids and line x tester for crossbreeds are employed separately in the hybrid performance.

Data

Hypothetical data for the study were generated manually based on experience in silkworm breeding and considering the silkworm breeder's priority in evaluating genetic stocks and hybrids (Datta *et al*., 2014). The hypothetical data were presented for economic characters of genetic resources (40 each for bivoltines and polyvoltines/multivoltines); bivoltine (oval & peanut/dumbbell) and multivoltine silkworm breeding lines (10 each); bivoltine × bivoltine and polyvoltine × bivoltine (crossbreed) silkworm hybrids (20 each) including the performances of control breeds/hybrids. The data sets were analyzed for computing indices employing methods *viz*., multiple trait evaluation (Mano *et al*., 1993), joint-scoring (Arunachalam and Bandopadhyay, 1984) and sub-ordinate function or similarity co-efficient (Gower, 1971) and also by the presently proposed approach, *ROBEVA-Bm*. This novel approach was compared with the existing popular systems of evaluation in respect of efficiency, robustness, especially overcoming the known limitations of each system in order to develop a robust evaluation method for assessment of genetic resources/breeds/hybrids by considering the following twelve important silkworm economic traits.

Computation of economic traits in silkworm (Kee-Wook Sohn, 2003; Datta *et al*., 2004)

Trait	Computation method
Fecundity (No.)	Number of eggs laid by a single moth (often expressed as a measure of reproductive fitness)
Pupation rate (%)	Number of cocoons with live pupae from basic stocks of larvae retained after 3rd moult (uzi/muscardine infestation should be addressed separately).
Cocoon weight (g)	Average weight of 25 male and 25 female cocoons sampled randomly on 6th or 7th day after spinning
Shell weight (g)	Average weight of 25 male and 25 female cocoon shells
Cocoon yield/ 10000 larvae (kg)	Weight of cocoons harvested per 10000 larvae brushed
Non-breakable filament length (m)	Total filament length/1+ number of breaks
Reelability (%)	Number of reeling cocoons/number of feeding ends
Neatness (points)	Comparison of raw silk yarn for minor imperfections, such as loops, split-ends, fuzziness, nibs and hairiness with the standard photograph
Cohesion (strokes)	Number of strokes required to split silk thread for examining the state of cocoon filaments sticking together
Evenness (points)	Comparison of silk samples for the intensity of variation with the standard photographs
Denier (d)	Weight of filament x 9000/length of silk filament
Renditta	Number of kg of cocoons required to yield 1 kg of raw silk

Evaluation Methods

The widely followed methods for evaluation of silkworm genetic resources/breeds/ hybrids are described below:

a) Multiple Trait Evaluation Index (Mano *et al.*, 1993)**:** Evaluation index values were computed for each trait using the formula,

$$EI_{ij} = \frac{A-B}{C} \times 10 + 50$$

$$EI_i = \frac{\sum_{j=1}^{k} EI_{ij}}{k}$$

Where,

Ei_{ij}= Evaluation index of i^{th} breed and j^{th} character (i=1,2, ..., n; j=1,2,...,k)

Ei_i=Average evaluation index of i^{th} breed

k = Total number of traits

A = Value of a j^{th} trait

B = Mean of a j^{th} trait

C = Standard deviation of j^{th} trait

10 = Standard

50 = Constant

The evaluation index values were calculated for each trait and the mean evaluation index values were considered for ranking the breeds/hybrids in the descending order (highest to lowest). The breeds/hybrids scoring >50 were considered as the most promising ones.

b) Sub-ordinate Function or similarity co-efficient (Gower, 1971)**:** Similarity co-efficient values were computed for each trait using the formula,

$$S_{ij} = \frac{\sum_{k=1}^{v} S_{ijk}}{\sum_{k=1}^{v} \delta_{ijk}}$$

Where,

i and j breeds / hybrids compared on particular character 'k'

k = Particular character of breeds

$S_{ijk} = 1 - \frac{|x_i - x_j|}{R_k}$ *i.e.*, co-ordinate function for i^{th} & j^{th} breeds of particular character k.

x_i and x_j = values of character k of i^{th} & j^{th} breeds (x_j as maximum value of character k)

R_k = range of the character 'k'

$\sum_{k=1}^{v} \delta_{ijk} = v$ = Total no. of characters

Similarity co-efficient or sub-ordinate function values for each trait were added per breed/hybrid combination and average cumulative values on the number of traits was considered and the breed/hybrid with the highest cumulative value was ranked first and so on.

c) Joint scoring method (Arunachalam and Bandopadhyay, 1984)**:** Joint scores for each trait were computed using the formula,

$$t = \frac{\bar{x}_i - \bar{x}_j}{\sqrt{e\left[\frac{1}{n_i} + \frac{1}{n_j}\right]}}$$

Where

$\bar{x}_i$ = mean of population i & $\bar{x}_j$ = mean of population j

n_i = number of components (selection) making up population i

n_j = number of components (selection) making up population j

e = error of mean square in the ANOVA

The t would follow a t-distribution with error degrees of freedom

The population means of each trait were arranged in groups based on t-test. The top-most group containing population with the highest mean was given a score of 1, followed by next best with 2 and so on. If k, was the number of groups for a particular character, the population in group was given a score = 1/k, those in group 2, a score = 2/k and so on, to obtain standardized scores across the traits. If, overlapping of groups occur, it is possible that a population could be found in group 1 and also in group 2. The score for that population was considered as the average; which would thus be equal to (1+2)/2k = 3/2k. Populations occurring in more than 2 groups would be treated in the similar manner for allotment of scores. The individual scores for each trait were added to provide a total score for each breed/hybrid and ranked in the descending order of the numerical values of the total scores.

d) Proposed Method (*ROBEVA-Bm*)

To address the limitations of multicollinearity, extreme values, high and low value traits and to allot proper weightages for each trait, they were estimated to propose an efficient and robust method for evaluating silkworm breeds/hybrids *viz*., *ROBEVA-Bm*.

Detection of multicollinearity

Multicollinearity is a situation, wherein two or more explanatory or independent variables/traits in a regression model are highly related linearly. To check multicollinearity, variance inflation factor (VIF) was obtained by regressing one with the rest of the traits (Montgomery *et al*., 2001).

For j^{th} variable (j=1,2,….,k) VIF could be obtained using

$$VIF_j = \frac{1}{1 - R_j^2}$$

Where,

VIF_j = Variance Inflating Factor for j^{th} variable / trait

R_j^2 = Co-efficient of determination (obtained by regressing j^{th} explanatory variable on other explanatory variables)

If the values of VIF are > 2.5, the variables are under the trouble of multicollinearity. Another way to find multicollinearity or singularity is through the determinant of correlation matrix of traits, if 'n' is > 0.00001, the trait does not suffer from singularity or multicollinearity. These issues could be nullified or addressed through the technique of Principal Component Analysis (Rencher, 2002; Anderson, 2003).

Detection of extreme observations

Extreme values are the observations (outliers) usually associated with the traits (due to sampling or non-sampling errors) and are the indicator of skewed distribution. If ratio of the largest value to the smallest value of each trait is 2 or more, it reflects the existence of extreme value in the data (Rangaswamy, 2010). Another way is through calculating Cook's statistic (Cook, 1977) and box plotting, when data of particular trait is > 1.5 of inter-quartile range, it is suspicious that data contain outliers. These extreme values/outliers could be suppressed through the usage of appropriate estimators like standard error in place of standard deviation, and median in place of mean, which are not influenced by the extreme values/outliers. These estimators are usually termed as “robust estimators”.

High & low-value traits

The traits or characters in a silkworm breed/hybrid are governed by the desirable targets of a breeding programme; the preferred choices would be the ones performing above the benchmark values. Among the economically important traits in silkworm, fecundity, pupation rate, cocoon yield/10,000 larvae, single cocoon weight, single shell weight, filament length, non-breaking filament length, reelability, raw silk, neatness, cleanliness, evenness, elongation and cohesion traits should be higher; while, lower values are desirable for the traits *viz*., larval duration, denier and renditta.

Steps for *ROBEVA-Bm*

The computation of *ROBEVA-Bm* is accomplished step-wise, which includes normalization of data values, estimation of correlation matrix, extraction of principal components, construction of weighted values and computation of weighted evaluation index.

Step-1: Normalization

The different units of measurement for various traits are nullified through z-scoring; is termed as normalization/standardization of data and conducted as given below:

$$Z_{ij} = \begin{pmatrix} \dfrac{X_{ij}\text{-min}\left(X_{ij}\right)}{\max\left(X_{ij}\right)-\min\left(X_{ij}\right)}, \text{ if traits are higher values} \\ \dfrac{X_{ij}\text{-max}\left(X_{ij}\right)}{\min\left(X_{ij}\right)-\max\left(X_{ij}\right)}, \text{ if traits are lower values} \end{pmatrix}$$

Where,

X_{ij} = observation of i^{th} breed/ hybrid of j^{th} trait (i=1,2, ..., n; j=1,2,...,k)

Min (X_{ij}) = minimum value of particular indicator/ trait

Max (X_{ij}) = maximum value of particular indicator/ trait

Or

$$Z_{ij} = \begin{pmatrix} \dfrac{X_{ij}\text{-}\bar{X}}{S_e}, \text{ if traits are positive/high value} \\ \dfrac{\bar{X}\text{-}X_{ij}}{S_e}, \text{ if traits are negative/ low value} \end{pmatrix}$$

Where,

X_{ij} = observation of i^{th} GR of j^{th} trait (i=1,2, ..., k; j=1,2,...,m)

$\bar{X}$= overall median of particular indicator/ trait

S_e = overall standard error of particular trait (SD/√n-1)

$$Z_{ij}=\begin{bmatrix} \hat{z}_{11} & \hat{z}_{12} & \cdots & \hat{z}_{1k} \\ \hat{z}_{21} & \hat{z}_{22} & \cdots & \hat{z}_{2k} \\ \vdots & & & \vdots \\ \hat{z}_{n1} & \cdots & \hat{z}_{(n-1)(n-1)} & \hat{z}_{nk} \end{bmatrix}_{n\times k}$$

Step-2: Estimation of Correlation Matrix

The normalized data (Z_{ij}) are used to estimate the correlation matrix.

$$r_{k\times k}=\begin{bmatrix} \hat{r}_{11} & \hat{r}_{12} & \cdots & \hat{r}_{1k} \\ \hat{r}_{21} & \hat{r}_{22} & \cdots & \vdots \\ \vdots & & & \\ \hat{r}_{k1} & \cdots & \hat{r}_{(k-1)(k-1)} & \hat{r}_{kk} \end{bmatrix}, \text{ where}$$

$$\hat{r}_{ij}=\frac{\sum_{i\neq i'=1, j\neq j'=1}^{n,k}(x_{ij}-\bar{x}_{ij})(x_{i'j'}-\bar{x}_{i'j'})}{\sqrt{\sum_{i=1,j=1}^{n,k}(x_{ij}-\bar{x}_{ij})^2\sum_{i'=1,j'=1}^{n,k}(x_{i'j'}-\bar{x}_{i'j'})^2}}$$

Step-3: Extraction of Principal Components

Eigen values (weights *i.e.*, λ_j) and Eigen vectors (loadings *i.e.*, a_{mm}) are estimated from correlation matrix (using R program/online calculators). Principal components are extracted by matrix multiplication of Eigen vectors and standardized variables (Z_{ij}). The principal components are:

$$\lambda_j=\begin{pmatrix} \lambda_1 \\ \lambda_2 \\ \vdots \\ \lambda_k \end{pmatrix}_{k\times 1}; \quad a_j=\begin{pmatrix} |a_{11}| & |a_{21}| & \cdots & |a_{k1}| \\ |a_{12}| & |a_{22}| & \cdots & |a_{k2}| \\ \vdots & \vdots & & \vdots \\ |a_{1k}| & |a_{2k}| & \cdots & |a_{kk}| \end{pmatrix}_{k\times k}$$

$$P_{ij}=\begin{pmatrix} a_{11}Z_{11}+a_{12}Z_{12}+...+a_{1k}Z_{1k} & a_{21}Z_{11}+a_{22}Z_{12}+...+a_{2k}Z_{1k} & \cdots & a_{k1}Z_{11}+a_{k2}Z_{12}+...+a_{kk}Z_{1k} \\ a_{11}Z_{21}+a_{22}Z_{22}+...+a_{2k}Z_{2k} & a_{21}Z_{21}+a_{22}Z_{22}+...+a_{2k}Z_{2k} & \cdots & a_{k1}Z_{21}+a_{k2}Z_{22}+...+a_{kk}Z_{2k} \\ \vdots & \vdots & & \vdots \\ a_{11}Z_{n1}+a_{12}Z_{n2}+...+a_{1k}Z_{nk} & a_{21}Z_{n1}+a_{22}Z_{n2}+...+a_{2k}Z_{nk} & \cdots & a_{k1}Z_{n1}+a_{k2}Z_{n2}+...+a_{kk}Z_{nk} \end{pmatrix}_{n\times k}$$

$$P_{ij}=\begin{pmatrix} P_{11} & P_{12} & \cdots & P_{1k} \\ P_{21} & P_{22} & \cdots & P_{2k} \\ \vdots & & & \vdots \\ P_{n1} & P_{n2} & \cdots & P_{nk} \end{pmatrix}_{n\times k}$$

Where,

P_{ij}s = principal components of order n×k (i=1,2,...,n; j=1,2,...,k)

λ_j= Eigen values of k traits

a_j= scores or Eigen vector of order k×k

Step-4: Construction of weighted values

Weighted values are constructed using Eigen values and principal components of variables (Gupta and Kapoor, 1997; Kumar *et al.*, 2013, 2015).

$$\bar{W}_i=\frac{1}{\sum_{j=1}^{k}\lambda_j}\begin{pmatrix} \lambda_1 P_{11}+\lambda_2 P_{12}+....\lambda_k P_{1k} \\ \lambda_1 P_{21}+\lambda_2 P_{22}+....\lambda_k P_{2k} \\ \\ \lambda_1 P_{n1}+\lambda_2 P_{n2}+....\lambda_k P_{nk} \end{pmatrix}_{n\times 1}$$

Where,

$\bar{W}_i$ = weighted value for i^{th} breed (i=1,2,…,n)

λ_j's = eigen value or weights of j^{th} trait (j = 1, 2 , . . . , k)

P_k's = k^{th} principal components (i = 1, 2, . . . , n; j = 1, 2 , . . . , k)

Step-5: Computation of ROBEVA-Bm

ROBEVA-Bm of each breed/hybrid was computed using the formula,

$$ROBEVA\text{-}Bm_i=\frac{\bar{W}_i-\min(\bar{W}_i)}{\max(\bar{W}_i)-\min(\bar{W}_i)}$$

Where,
$ROBEVA\text{-}Bm_i$ = index of i[th] breed (lies between 0 to 1)
min (W) = minimum value of weighted values
max (W) = maximum value of weighted values

After the construction of *ROBEVA-Bm* as per the above methodology, ranks were assigned to different breeds/hybrids based on the magnitude of values in the descending order. The breeds/hybrids were further classified into high and medium performing groups. Breeds/hybrids with >80th percentile (*ROBEVA-Bm*) were grouped as high performers and those between 80th to 50th percentile as medium performers and the rest as low performers.

PCA bi-plot

PCA biplot was constructed to group or classify the genetic stocks/breeds/hybrids as high and low performers along with traits (characters) associated, graphically based on loadings of principal components.

Cluster Heatmaps

Cluster heat maps were constructed to divulge hierarchical clusters (Anderson, 2003; Rencher, 2002) based on principal component (PC) values of *ROBEVA-Bm*. A heatmap is a data visualization technique that shows magnitude of a phenomenon as color in two dimensions (rows: breeds/hybrids; columns: traits). The variation in color may be by hue or intensity, giving obvious visual cues to the researcher about how the phenomenon is clustered or varies over space.

The *ROBEVA-Bm* being proposed could easily be computed with the help of R program as given in Appendix-I; provided i > j (number of hybrids/genetic stocks should be greater than number of characters under consideration). Otherwise, repeat the set of hybrids data to meet the prerequisite of i > j.

RESULTS AND DISCUSSION

The evaluation of forty each of bivoltine oval (Table 1a), peanut (Table 1b) and multivoltine (Table 3) silkworm genetic stocks are presented based on twelve important economic traits (fecundity, pupation rate, cocoon weight, shell weight, cocoon yield /10000 larvae, non-breakable filament length, reelability, neatness, evenness, cohesion, denier and renditta). Similarly, data on 20 each of bivoltine hybrids and crossbreeds along with the control are shown in Tables 4 and 5. The characteristics *viz*., larval duration, cleanliness, elongation, raw silk and filament length were not considered for the evaluation as they do not influence the process in a variety/breed/hybrid selection; twelve other major/direct indices including the low-value traits were considered (Datta *et al*., 2014). It is evident that all the characters measured are free from extreme observations/outliers, as the ratio of maximum to minimum value of each trait was < 2 (Tables 1a, 1b, 2, 4 and 5); which was also confirmed with box-plot presentation (Figure 1) depicting various positional measures of dispersion of each trait graphically.

The correlation among all the traits of silkworm stocks/breeds/hybrids is presented in Figure 2. Each trait pattern/distribution *vis-à-vis* the rest of the traits is highlighted with colour shading (0 to 1) in triangular graphs. It reveals that the majority of economic traits were significantly correlated (near to ±1), addressing the problem of multicollinearity/singularity. The same was also confirmed with the determinant value of correlation matrix (*i.e.*, zero). The basic assumption in a multivariate analysis is that variables should be independent or free from multi-collinearity.

Selection of suitable breeding resource material helps the breeder to successfully amalgamate desired traits in a hybrid, improving cocoon yields from the breeding programme. Appropriate strategies and selection criteria plays a major role in the fixation of major traits in silkworm. Most of the economic traits in silkworm are complex and are under polygenic control; more so with higher Genotype × Environment interaction. Silkworm

Table 1a: Evaluation of bivoltine silkworm genetic stocks (Oval)

Genetic stock	Fecundity (No.)	Pupation rate (%)	Cocoon weight (g)	Shell weight (g)	Cocoon yield/10000 larvae (kg)	NBFL (m)	Reelability (%)	Neatness (points)	Cohesion (strokes)	Evenness (points)	Denier (d)	Renditta (kg)	Index		
													Robeva-Bm	MTE	SF
BO1	538	84.16	2.040	0.430	17.17	663	82.62	94.86	133	87.72	3.06	7.55	0.55	52.65	0.65
BO2	605	94.06	1.730	0.460	16.31	681	95.88	90.78	95	85.68	2.65	7.14	0.66	52.24	0.59
BO3	489	93.07	1.430	0.290	13.29	615	94.86	88.74	120	91.80	2.96	6.53	0.38	48.10	0.45
BO4	640	86.14	1.430	0.430	12.30	893	79.56	93.84	94	94.86	2.75	6.43	0.64	51.07	0.53
BO5	634	74.26	1.630	0.410	12.12	946	72.42	81.60	92	86.70	2.86	7.85	0.05	45.89	0.43
BO6	512	92.08	1.430	0.280	13.15	761	90.78	81.60	97	82.62	2.35	8.16	0.07	44.79	0.36
BO7	639	78.22	1.730	0.290	13.56	831	94.86	84.66	87	90.78	2.96	7.24	0.31	48.30	0.49
BO8	657	94.06	2.140	0.260	20.15	888	84.66	84.66	101	89.76	2.55	7.14	0.72	53.38	0.60
BO9	589	97.03	1.940	0.410	18.81	728	77.52	89.76	81	90.78	2.14	6.12	0.79	51.71	0.48
BO10	465	84.16	2.040	0.270	17.17	883	90.78	94.86	132	94.86	2.04	8.16	0.78	53.74	0.62
BO11	540	96.04	2.140	0.460	20.57	870	90.78	82.62	115	95.88	2.75	6.32	1.00	56.59	0.70
BO12	599	84.16	1.530	0.410	12.88	740	73.44	93.84	129	85.68	2.45	6.73	0.47	48.92	0.45
BO13	498	90.10	1.630	0.320	14.71	807	72.42	90.78	132	88.74	2.75	6.63	0.41	48.87	0.46
BO14	615	87.13	2.140	0.420	18.66	896	85.68	90.78	79	85.68	2.04	6.43	0.87	53.02	0.53
BO15	476	76.24	1.730	0.460	13.22	746	82.62	92.82	85	82.62	2.45	7.55	0.21	46.18	0.40
BO16	573	79.21	2.040	0.460	16.16	830	95.88	91.80	131	96.90	2.65	7.65	0.89	56.11	0.73
BO17	469	79.21	2.140	0.400	16.97	842	92.82	93.84	103	95.88	2.35	7.55	0.77	53.48	0.62
BO18	447	92.08	1.430	0.390	13.15	716	90.78	91.80	118	96.90	2.24	6.73	0.66	50.33	0.48
BO19	483	75.25	1.430	0.270	10.75	787	83.64	95.88	138	86.70	2.14	7.45	0.30	46.41	0.37
BO20	442	89.11	2.040	0.290	18.18	939	77.52	95.88	103	89.76	2.86	7.75	0.49	51.60	0.60
BO21	547	86.14	1.530	0.270	13.18	664	90.78	81.60	90	94.86	2.35	6.43	0.32	45.67	0.32
BO22	545	87.13	1.840	0.290	16.00	789	81.60	88.74	107	86.70	2.55	8.06	0.31	48.75	0.50
BO23	605	95.05	1.630	0.430	15.51	937	93.84	93.84	106	93.84	2.55	8.16	0.85	55.71	0.73
BO24	509	80.20	1.940	0.440	15.54	618	95.88	87.72	135	84.66	2.45	7.24	0.54	50.43	0.52
BO25	466	84.16	1.940	0.390	16.31	629	74.46	92.82	119	96.90	2.75	6.22	0.56	50.15	0.49
BO26	503	93.07	2.140	0.270	19.94	749	94.86	92.82	81	97.92	2.55	7.14	0.78	53.48	0.61
BO27	450	75.25	2.140	0.370	16.12	859	71.40	89.76	121	82.62	2.55	6.22	0.39	47.91	0.40
BO28	597	95.05	1.430	0.410	13.57	685	88.74	93.84	87	84.66	2.65	6.63	0.49	49.08	0.47
BO29	464	89.11	1.630	0.430	14.54	716	82.62	93.84	115	90.78	2.96	6.94	0.46	50.09	0.54
BO30	606	96.04	1.940	0.350	18.61	672	94.86	89.76	102	91.80	2.96	6.32	0.78	53.64	0.62
BO31	409	95.05	1.530	0.370	14.54	645	94.86	81.60	95	96.90	2.24	6.53	0.47	47.62	0.39
BO32	662	88.12	1.730	0.430	15.28	643	88.74	90.78	91	83.64	2.24	6.94	0.58	49.90	0.47
BO33	550	83.17	1.630	0.420	13.57	705	94.86	83.64	106	94.86	2.35	7.96	0.44	49.49	0.51
BO34	631	97.03	1.530	0.270	14.85	616	74.46	93.84	97	88.74	2.45	8.06	0.29	47.92	0.46
BO35	505	74.26	1.630	0.280	12.12	881	88.74	85.68	92	90.78	2.96	6.83	0.15	45.60	0.39
BO36	445	85.15	2.040	0.350	17.37	785	89.76	90.78	113	82.62	2.65	7.55	0.43	50.03	0.53
BO37	566	85.15	1.940	0.260	16.50	835	83.64	86.70	103	86.70	2.14	7.04	0.49	48.91	0.43
BO38	427	93.07	1.530	0.410	14.24	672	95.88	93.84	135	91.80	2.04	7.85	0.68	51.65	0.55
BO39	482	77.23	1.940	0.260	14.97	678	83.64	85.68	97	82.62	2.35	8.16	0.00	44.13	0.35
BO40	425	76.24	1.430	0.410	10.89	958	86.70	92.82	103	83.64	2.65	6.32	0.32	46.45	0.38
Max	662	97.03	2.140	0.460	20.57	958	95.88	95.88	138	97.92	3.06	8.16	1.00	56.59	0.73
Min	409	74.26	1.430	0.260	10.75	615	71.40	81.60	79	82.62	2.04	6.12	0.00	44.13	0.32
Mean	533	86.54	1.772	0.363	15.32	770	86.50	89.89	106	89.68	2.53	7.14	0.51	50.00	0.50
80th Percentile	606	94.06	2.040	0.430	17.33	883	94.86	93.84	127	94.86	2.84	7.85	0.77	53.31	0.61
50th Percentile	525	86.64	1.730	0.390	15.12	755	88.74	90.78	103	89.76	2.55	7.14	0.49	49.96	0.49
SD	72.85	7.18	0.25	0.07	2.47	103.85	7.70	4.38	17.05	4.89	0.29	0.65			
^{Ca}Outlier	1.62	1.31	1.50	1.77	1.91	1.56	1.34	1.18	1.75	1.19	1.50	1.33			

NBFL - Non-breakable filament length; MTE - Multiple trait evaluation; SF - Sub-ordinate function.

Table 1b: Evaluation of bivoltine silkworm genetic stocks (Peanut)

Genetic stock	Fecundity (No.)	Pupation rate (%)	Cocoon weight (g)	Shell weight (g)	Cocoon yield/10000 larvae (kg)	NBFL (m)	Reelability (%)	Neatness (points)	Cohesion (strokes)	Evenness (points)	Denier (d)	Renditta (kg)	Index		
													Robeva-Bm	MTE	SF
BP1	568	91.09	1.428	0.449	13.01	914	83.64	81.60	128	94.86	2.96	6.63	0.75	53.71	0.59
BP2	423	97.03	1.428	0.459	13.86	799	76.50	92.82	89	96.90	2.24	7.45	0.75	52.12	0.52
BP3	426	75.25	1.530	0.347	11.51	725	79.56	95.88	91	92.82	2.24	7.96	0.37	47.13	0.40
BP4	582	83.17	1.326	0.449	11.03	693	95.88	83.64	80	96.90	2.35	8.06	0.51	49.83	0.48
BP5	408	84.16	1.632	0.337	13.73	687	79.56	95.88	125	87.72	2.45	7.45	0.52	49.73	0.47
BP6	525	91.09	1.734	0.357	15.79	786	75.48	85.68	83	91.80	2.96	6.32	0.58	51.00	0.50
BP7	487	88.12	1.530	0.388	13.48	900	71.40	82.62	107	92.82	2.35	7.85	0.47	49.69	0.47
BP8	461	79.21	1.632	0.428	12.93	909	74.46	82.62	108	88.74	2.14	7.55	0.49	48.76	0.41
BP9	421	85.15	1.530	0.255	13.03	743	71.40	85.68	118	85.68	2.55	7.85	0.13	45.27	0.35
BP10	491	85.15	1.734	0.367	14.76	814	85.68	95.88	91	90.78	2.35	6.73	0.83	52.82	0.53
BP11	470	76.24	1.326	0.286	10.11	877	84.66	93.84	132	82.62	2.35	6.32	0.46	46.85	0.32
BP12	599	86.14	1.326	0.388	11.42	869	71.40	88.74	106	89.76	2.55	7.65	0.42	49.13	0.46
BP13	615	76.24	1.836	0.357	14.00	956	80.58	95.88	101	87.72	2.14	6.94	0.88	53.58	0.54
BP14	661	91.09	1.734	0.326	15.79	704	95.88	82.62	141	95.88	2.35	7.14	1.00	56.69	0.64
BP15	533	78.22	1.530	0.306	11.97	873	77.52	90.78	96	92.82	2.55	7.85	0.39	48.69	0.46
BP16	619	78.22	1.326	0.296	10.37	691	93.84	84.66	125	94.86	3.06	6.32	0.46	49.00	0.44
BP17	569	94.06	1.632	0.357	15.35	635	73.44	88.74	138	92.82	2.55	6.22	0.80	53.00	0.51
BP18	452	83.17	1.428	0.449	11.88	767	73.44	83.64	117	95.88	2.65	7.34	0.42	48.61	0.45
BP19	471	92.08	1.632	0.296	15.03	619	79.56	87.72	100	91.80	2.45	7.75	0.44	49.22	0.46
BP20	494	87.13	1.734	0.418	15.11	845	89.76	85.68	81	85.68	2.86	7.85	0.50	51.53	0.57
BP21	533	74.26	1.326	0.255	9.85	807	90.78	91.80	108	92.82	2.65	7.65	0.33	47.37	0.42
BP22	553	80.20	1.734	0.418	13.91	951	88.74	92.82	119	82.62	2.86	6.22	0.81	53.87	0.58
BP23	646	92.08	1.836	0.347	16.91	962	79.56	82.62	131	96.90	2.86	8.06	0.86	57.68	0.76
BP24	561	87.13	1.428	0.265	12.44	645	88.74	91.80	115	94.86	2.55	6.83	0.61	50.30	0.46
BP25	471	78.22	1.632	0.449	12.77	851	85.68	85.68	116	83.64	2.14	7.34	0.58	49.78	0.43
BP26	639	84.16	1.530	0.367	12.88	747	71.40	89.76	95	92.82	2.35	7.45	0.53	50.00	0.46
BP27	510	92.08	1.734	0.286	15.97	887	78.54	95.88	84	85.68	3.06	8.16	0.45	51.97	0.62
BP28	456	77.23	1.734	0.449	13.39	643	79.56	92.82	139	93.84	2.55	6.12	0.79	51.99	0.50
BP29	555	79.21	1.326	0.388	10.50	673	86.70	91.80	92	96.90	2.45	7.65	0.47	48.74	0.45
BP30	411	83.17	1.734	0.286	14.42	905	86.70	94.86	138	83.64	2.24	6.73	0.77	51.93	0.48
BP31	470	81.19	1.734	0.296	14.08	706	80.58	82.62	112	92.82	2.24	6.73	0.53	48.51	0.38
BP32	511	90.10	1.428	0.255	12.87	635	75.48	82.62	107	95.88	3.06	6.22	0.30	46.81	0.37
BP33	487	78.22	1.734	0.398	13.56	902	78.54	90.78	77	95.88	3.06	6.43	0.60	50.99	0.53
BP34	443	88.12	1.326	0.296	11.68	644	87.72	81.60	112	94.86	3.06	6.94	0.24	46.60	0.40
BP35	550	76.24	1.326	0.428	10.11	912	77.52	89.76	88	82.62	2.45	7.34	0.30	46.38	0.36
BP36	522	90.10	1.428	0.326	12.87	862	75.48	90.78	113	83.64	2.24	7.85	0.45	49.08	0.44
BP37	477	75.25	1.326	0.265	9.98	617	92.82	84.66	133	91.80	2.24	7.04	0.33	45.54	0.29
BP38	618	92.08	1.734	0.357	15.97	669	86.70	83.64	111	83.64	2.14	6.53	0.77	52.19	0.46
BP39	573	75.25	1.530	0.255	11.51	834	72.42	83.64	108	84.66	2.96	7.96	0.00	44.97	0.38
BP40	436	75.25	1.326	0.418	9.98	929	90.78	83.64	142	89.76	3.06	6.43	0.46	48.95	0.46
Max	661	97.03	1.836	0.459	16.91	962	95.88	95.88	142	96.90	3.06	8.16	1.00	57.68	0.76
Min	408	74.26	1.326	0.255	9.85	617	71.40	81.60	77	82.62	2.14	6.12	0.00	44.97	0.29
Mean	517	83.79	1.548	0.353	13.00	790	81.70	88.20	110	90.70	2.56	7.17	0.53	50.00	0.47
80^{th} Percentile	580	91.09	1.734	0.426	14.98	904	88.74	92.82	130	95.68	2.96	7.85	0.77	52.18	0.53
50^{th} Percentile	511	83.67	1.530	0.357	12.97	803	79.56	88.23	110	92.31	2.50	7.34	0.49	49.71	0.46
SD	69.66	6.42	0.17	0.07	1.91	109.79	7.21	4.82	18.54	4.76	0.31	0.64			
^{Ca}Outlier	1.62	1.31	1.38	1.80	1.72	1.56	1.34	1.18	1.84	1.17	1.43	1.33			

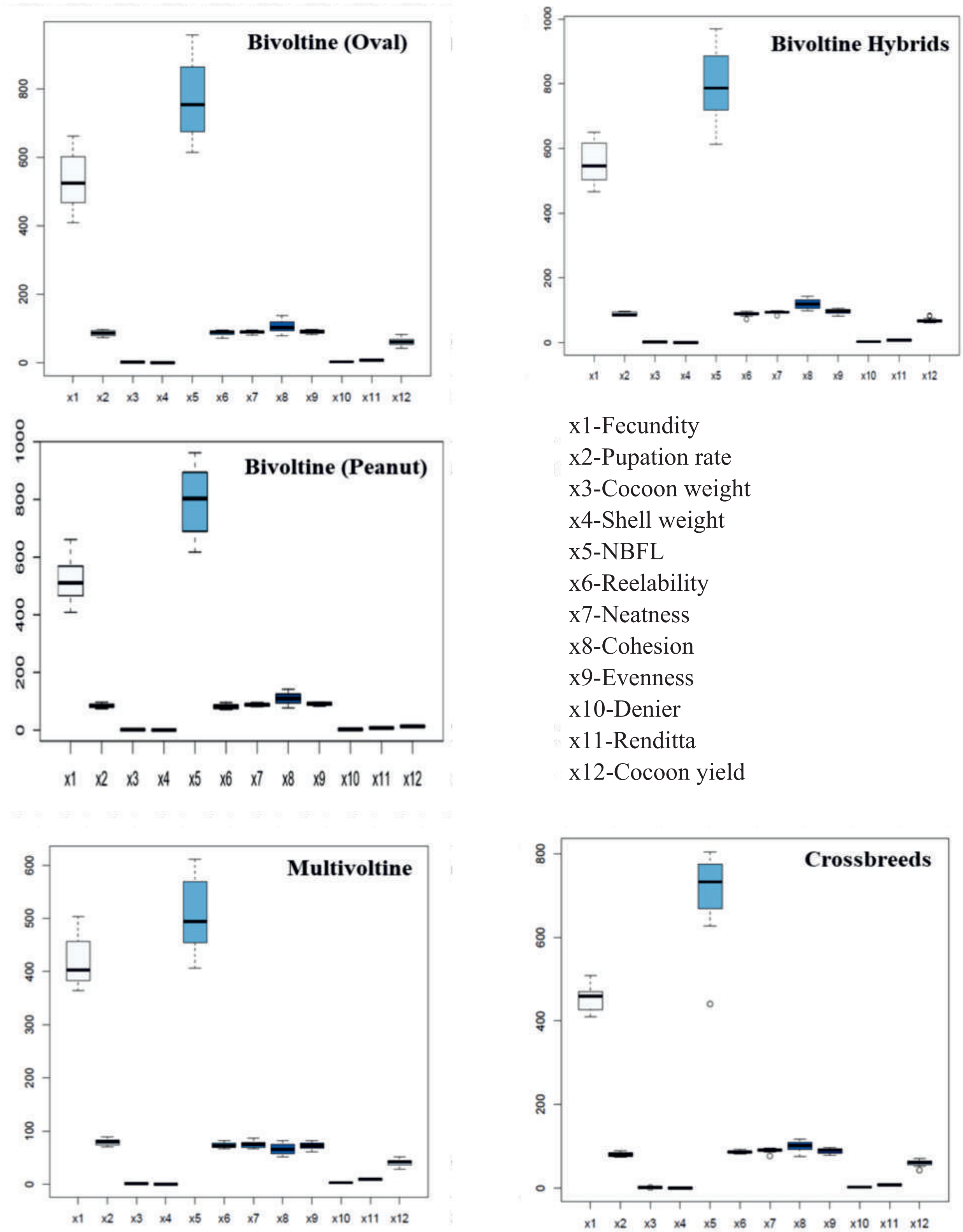


Figure 1: Box-plot of breeds/hybrids for silkworm trait pattern

breeders usually give much attention towards productivity traits rather than survival in adverse seasons which becomes more important for determining the overall performance of the hybrid; however, a few low-value traits also influence the utility of the hybrid. The commonly employed evaluation indices *viz*., multiple trait evaluation (Mano *et al*., 1993), sub-ordinate function (Gower, 1971) and joint scoring (Arunachalam and Bandopadhyay, 1984) cannot include low-trait (negative) along with high-trait (positive) characteristics of silkworm. These methods utilize ANOVA, t-statistic and estimators, mean and standard deviation which could be influenced significantly by the outliers. The proposed *ROBEVA-Bm* method employs the robust estimators, principal component weights and clustering measures; while multiple trait evaluation index employs only normalization scores, SF (similarity coefficients) whereas, joint scoring method uses ANOVA. The silkworm genetic stocks or hybrids are usually ranked in the descending order based on scores with all the indices. In addition to it, *ROBEVA-Bm* provides a scope for classifying the high and low performers through percentile values at >80 and <50. Furthermore, high performing and efficient responder breeds/hybrids along with associated traits could easily be identified through PCA biplot (Figure 4). As the hypothetical data do not contain any outliers, all the indices are reflecting more or less similar pattern (Tables 2 and 4); however, *ROBEVA-Bm* could addresses the issue of outliers or extreme observations in the data sets.

ROBEVA-Bm method of evaluation selects the appropriate panel of silkworm genetic stocks/breeds/hybrids by overcoming the limitation in the commonly used evaluation methods, which could be effectively exploited further for research/commercial purposes. The index-wise top ranked silkworm genetic resources, bivoltine (BO and BP series) and multivoltine (M series) are sorted along with the indices values (Table 3); and the best performing hybrid combinations (CB: Crossbreed and BH: Bivoltine hybrid series) are listed in Table 6.

For example, the position of top three crossbreeds was CB6 followed by CB4 and CB13 in the *ROBEVA-Bm* evaluation method (Table 6); while the same were ranked in reverse order (CB13 followed by CB4 and CB6) in MTE and CB13 followed by CB4 in sub-ordinate function method. *ROBEVA-Bm* selection seems to be more appropriate as the cocoon yield (high value trait) of CB6 & CB13 was 17.78 & 16.89 kg/10000 larvae and the low - value trait (renditta) was 6.73 & 7.96 kg, respectively (Table 5). This clearly indicates goodness of *ROBEVA-Bm* for the importance in assigning weights for high & low - value traits; as a result, a new combination (CB18) was one among the top-six, which was not noticed in the other methods. Similarly, BH1 & BH5 entered into the class of high performers as cocoon yield/10000 larvae (17.6-18.6kg) was higher & renditta (5.7-7.0) was lower in *ROBEVA-Bm* method, in place of BH4 (15.09 kg & 7.85) and BH19 (16.77 kg & 7.45) as ranked by the existing methods (Table 4). *ROBEVA-Bm's* soundness could be seen in the evaluation of genetic stocks also (Table 3); for instance, BO9 secured a place in the top-performers by replacing BO1 (Table 1a), BP30 in place of BP2 (Table 1b), and M20 in place of M38 (Table 2). These results highlight that *ROBEVA-Bm* offers much scope for enhancing the genetic base of the silkworm breeds by assigning proper weightage for essential traits. As a result, suitable breeds could be explored in a better way for silkworm hybrid development programme as compared to the existing methods, MTE & SF. These best-performing breeds were also graphically represented (Figures 3 and 4) appropriately along with associated traits. The silkworm genetic stocks/hybrids and the traits are sequenced in cluster heatmaps (Figure 3) with different shades of color from low performer/responder (red) to high performer/responder (blue). Similarly, the bi-plots of first quadrant focuses the efficient/high performing breeds/hybrids with its influential traits, while the 3rd quadrant (opposite of left-down corner of 1st quadrant) highlights the low performing breeds/hybrids and its associated traits and 2nd and 4th quadrants exhibit the medium performers (Figure 4).

Table 2: Evaluation of multivoltine silkworm genetic stocks

Genetic stock	Fecundity (No.)	Pupation rate (%)	Cocoon weight (g)	Shell weight (g)	Cocoon yield/10000 larvae (kg)	NBFL (m)	Reelability (%)	Neatness (points)	Cohesion (strokes)	Evenness (points)	Denier (d)	Renditta (kg)	Index		
													Robeva-Bm	MTE	SF
M1	384	78.22	1.020	0.230	7.98	611	69.36	70.38	78	80.58	3.06	9.38	0.31	48.32	0.48
M2	364	85.15	1.530	0.200	13.03	479	81.60	73.44	72	78.54	2.65	9.49	0.71	53.66	0.60
M3	398	80.20	1.220	0.220	9.82	549	71.40	74.46	77	62.22	3.06	9.18	0.30	48.22	0.47
M4	456	80.20	1.430	0.300	11.45	408	71.40	71.40	82	79.56	2.65	8.57	0.83	53.68	0.56
M5	387	87.13	1.020	0.260	8.89	464	69.36	75.48	61	69.36	2.96	8.67	0.28	46.82	0.39
M6	451	83.17	1.330	0.290	11.03	610	66.30	79.56	59	73.44	2.55	8.98	0.78	53.10	0.55
M7	459	71.29	1.430	0.210	10.18	443	67.32	75.48	64	75.48	2.75	9.59	0.31	47.86	0.44
M8	420	70.30	1.530	0.280	10.76	525	76.50	79.56	60	76.50	2.35	9.28	0.74	52.39	0.52
M9	452	78.22	1.530	0.270	11.97	592	81.60	77.52	66	73.44	2.65	8.36	1.00	56.15	0.63
M10	397	79.21	1.330	0.210	10.50	480	74.46	66.30	74	75.48	2.35	8.98	0.54	48.78	0.40
M11	481	78.22	1.220	0.200	9.58	605	66.30	67.32	69	74.46	2.55	9.89	0.41	48.70	0.46
M12	461	70.30	1.020	0.210	7.17	555	78.54	68.34	55	70.38	3.06	10.10	0.00	44.93	0.42
M13	385	82.18	1.430	0.240	11.74	552	80.58	78.54	71	70.38	2.65	9.18	0.75	53.66	0.59
M14	380	75.25	1.020	0.310	7.68	489	80.58	68.34	65	80.58	3.06	8.16	0.44	48.53	0.44
M15	497	81.19	1.120	0.230	9.11	406	74.46	85.68	68	65.28	2.86	9.18	0.45	49.77	0.49
M16	488	75.25	1.220	0.280	9.21	429	80.58	69.36	77	69.36	2.35	9.49	0.62	50.59	0.48
M17	376	70.30	1.430	0.220	10.04	417	73.44	70.38	70	68.34	2.86	10.10	0.09	45.83	0.42
M18	443	88.12	1.020	0.310	8.99	492	73.44	78.54	51	61.20	2.75	8.26	0.51	48.76	0.41
M19	401	79.21	1.120	0.300	8.89	409	77.52	69.36	54	76.50	2.65	8.36	0.44	47.47	0.37
M20	368	82.18	1.430	0.300	11.74	598	76.50	82.62	51	61.20	2.75	8.67	0.67	52.14	0.53
M21	393	84.16	1.530	0.280	12.88	569	66.30	75.48	57	79.56	2.45	9.18	0.79	53.37	0.55
M22	383	89.11	1.120	0.230	10.00	429	75.48	71.40	64	70.38	2.75	8.26	0.44	47.85	0.38
M23	427	71.29	1.530	0.300	10.91	473	70.38	76.50	66	78.54	2.75	9.49	0.59	51.88	0.56
M24	412	70.30	1.330	0.280	9.32	579	72.42	74.46	81	67.32	2.45	9.69	0.56	50.30	0.49
M25	500	83.17	1.430	0.220	11.88	557	70.38	66.30	60	71.40	2.86	8.67	0.59	51.22	0.52
M26	369	86.14	1.220	0.260	10.54	426	71.40	76.50	57	69.36	2.55	9.28	0.39	47.87	0.40
M27	420	83.17	1.220	0.260	10.18	587	67.32	79.56	74	81.60	2.86	9.49	0.66	53.20	0.61
M28	402	72.28	1.020	0.230	7.37	426	66.30	76.50	77	65.28	2.35	8.98	0.20	43.39	0.23
M29	366	78.22	1.330	0.210	10.37	552	71.40	75.48	54	72.42	2.55	9.59	0.33	47.46	0.40
M30	461	87.13	1.430	0.260	12.44	537	69.36	67.32	77	68.34	3.06	8.36	0.69	53.07	0.58
M31	383	84.16	1.220	0.280	10.30	592	69.36	69.36	78	81.60	2.96	9.38	0.59	52.30	0.59
M32	404	73.27	1.530	0.290	11.21	455	79.56	70.38	52	81.60	2.86	8.87	0.56	51.22	0.53
M33	383	70.30	1.530	0.240	10.76	593	69.36	73.44	72	64.26	2.65	9.18	0.44	48.85	0.45
M34	428	83.17	1.220	0.240	10.18	454	76.50	83.64	64	67.32	2.55	9.59	0.54	50.59	0.49
M35	370	77.23	1.430	0.210	11.03	497	78.54	81.60	55	65.28	2.75	9.28	0.38	48.83	0.45
M36	467	76.24	1.120	0.270	8.56	569	73.44	86.70	52	72.42	2.55	9.89	0.52	50.61	0.51
M37	370	88.12	1.220	0.200	10.79	470	67.32	77.52	58	76.50	3.06	8.36	0.34	47.98	0.42
M38	457	81.19	1.430	0.300	11.59	475	78.54	69.36	74	72.42	2.86	10.10	0.64	54.09	0.67
M39	504	80.20	1.020	0.240	8.18	499	72.42	69.36	72	77.52	2.96	9.49	0.39	49.38	0.51
M40	372	73.27	1.530	0.210	11.21	473	70.38	81.60	60	62.22	2.45	8.26	0.45	47.18	0.32
Max	504	89.11	1.530	0.310	13.03	611	81.60	86.70	82	81.60	3.06	10.10	1.00	56.15	0.67
Min	364	70.30	1.020	0.200	7.17	406	66.30	66.30	51	61.20	2.35	8.16	0.00	43.39	0.23
Mean	418	79.19	1.295	0.252	10.24	508	73.19	74.61	66	72.19	2.72	9.13	0.51	50.00	0.48
80^{th} Percentile	461	84.16	1.510	0.290	11.56	585	78.54	79.56	76	78.54	2.96	9.59	0.69	53.10	0.56
50^{th} Percentile	403	79.71	1.330	0.250	10.34	494	72.42	74.97	66	72.42	2.75	9.18	0.52	49.58	0.48
SD	42.58	5.69	0.18	0.04	1.44	4.73	5.44	9.12	6.06	0.22	0.56	5.77			
[Ca]Outlier	1.38	1.27	1.50	1.55	1.82	1.51	1.23	1.31	1.60	1.33	1.30	1.24			

Table 3: Selection of silkworm genetic stocks based on multivariate analysis

Bivoltine stock (Oval)			Bivoltine stock (Peanut)			Multivoltine stock		
ROBEVA-Bm	MTE	SF	ROBEVA-Bm	MTE	SF	*ROBEVA-Bm*	MTE	SF
BO11 (1.00)	BO11 (56.59)	BO16 (0.73)	BP14 (1.00)	BP23 (57.68)	BP23 (0.76)	M9 (1.00)	M9 (56.15)	M38 (0.67)
BO16 (0.89)	BO16 (56.11)	BO23 (0.73)	BP13 (0.88)	BP14 (56.69)	BP14 (0.64)	M4 (0.83)	M38 (54.09)	M9 (0.63)
BO14 (0.87)	BO23 (55.71)	BO11 (0.70)	BP23 (0.86)	BP22 (53.87)	BP27 (0.62)	M21 (0.79)	M4 (53.68)	M27 (0.61)
BO23 (0.85)	BO10 (53.74)	BO1 (0.65)	BP10 (0.83)	BP1 (53.71)	BP1 (0.59)	M6 (0.78)	M13 (53.66)	M2 (0.60)
BO9 (0.79)	BO30 (53.64)	BO17 (0.62)	BP22 (0.81)	BP13 (53.58)	BP22 (0.58)	M13 (0.75)	M2 (53.66)	M31 (0.59)
BO30 (0.78)	BO17 (53.48)	BO10 (0.62)	BP17 (0.80)	BP17 (53.00)	BP20 (0.57)	M8 (0.74)	M21 (53.37)	M13 (0.59)
BO26 (0.78)	BO26 (53.48)	BO30 (0.62)	BP28 (0.79)	BP10 (52.82)	BP13 (0.54)	M2 (0.71)	M27 (53.20)	M30 (0.59)
BO10 (0.78)	BO8 (53.38)	BO26 (0.61)	BP38 (0.77)	BP38 (52.19)	BP33 (0.53)	M30 (0.69)	M6 (53.10)	M4 (0.58)
BO17 (0.77)	BO14 (53.02)	BO20 (0.60)	BP30 (0.77)	BP2 (52.12)	BP10 (0.53)	M20 (0.67)	M30 (53.07)	M23 (0.56)
BO8 (0.72)	BO1 (52.65)	BO8 (0.60)	BP1 (0.75)	BP28 (51.99)	BP2 (0.52)	M27 (0.66)	M8 (52.39)	M21 (0.56)

Values in parentheses indicate indices

Table 4: Evaluation of bivoltine silkworm hybrids

Hybrid	Fecund-ity (No.)	Pupation rate (%)	Cocoon weight (g)	Shell weight (g)	Cocoon yield/10000 larvae (kg)	NBFL (m)	Reelab-ility (%)	Neatness (points)	Cohesion (strokes)	Evenness (points)	Denier (d)	Renditta (kg)	Index		
													Robeva-Bm	MTE	SF
BH1	581	86.14	2.040	0.450	17.57	819	88.74	92.82	133	83.64	2.65	5.71	0.82	51.18	0.55
BH2	473	85.15	2.040	0.310	17.37	678	87.72	92.82	132	103.02	2.96	6.53	0.58	48.34	0.52
BH3	532	96.04	2.140	0.350	20.57	786	92.82	94.86	110	99.96	2.65	7.75	0.85	54.25	0.69
BH4	651	82.18	1.840	0.380	15.09	961	92.82	93.84	137	105.06	2.75	7.85	0.76	52.46	0.66
BH5	645	82.18	2.040	0.360	16.77	945	95.88	96.90	143	96.90	2.55	5.51	1.00	54.57	0.62
BH6	522	90.10	1.940	0.320	17.46	757	87.72	97.92	103	98.94	2.35	7.65	0.65	49.12	0.50
BH7	501	85.15	1.940	0.320	16.50	861	95.88	91.80	115	95.88	2.96	6.43	0.58	48.37	0.51
BH8	487	86.14	1.840	0.390	15.82	810	93.84	95.88	110	86.70	2.65	7.24	0.54	47.41	0.47
BH9	504	84.16	2.140	0.340	18.03	715	90.78	97.92	104	100.98	3.06	7.75	0.56	50.14	0.60
BH10	631	83.17	1.940	0.340	16.12	629	88.74	97.92	143	97.92	3.06	6.12	0.69	50.27	0.58
BH11	567	87.13	1.840	0.420	16.00	885	86.70	91.80	140	86.70	2.96	7.34	0.62	49.39	0.59
BH12	643	94.06	2.140	0.430	20.15	718	84.66	93.84	130	90.78	2.86	5.20	0.98	54.44	0.66
BH13	605	82.18	2.140	0.400	17.60	885	86.70	96.90	131	100.98	2.35	7.85	0.87	53.75	0.64
BH14	651	85.15	1.840	0.450	15.63	718	84.66	96.90	126	91.80	2.55	6.32	0.75	49.92	0.52
BH15	546	83.17	1.840	0.460	15.27	929	95.88	93.84	103	87.72	2.75	5.20	0.69	48.92	0.46
BH16	508	94.06	1.730	0.420	16.31	668	83.64	93.84	107	92.82	2.65	7.65	0.51	46.55	0.47
BH17	505	97.03	1.730	0.360	16.83	757	93.84	94.86	103	99.96	3.06	6.73	0.60	49.30	0.57
BH18	466	97.03	1.840	0.430	17.82	784	82.62	97.92	119	100.98	2.55	7.04	0.78	51.42	0.58
BH19	617	82.18	2.040	0.330	16.77	969	92.82	92.82	128	103.02	2.86	7.45	0.77	52.40	0.65
BH20	615	96.04	1.940	0.330	18.61	889	86.70	93.84	98	104.04	2.45	7.04	0.82	52.23	0.61
BH21 (Control)	498	82.89	1.590	0.270	17.03	612	71.00	82.00	105	81.00	2.52	8.08	0.00	35.58	0.16
Max	651	97.03	2.140	0.460	20.57	969	95.88	97.92	143	105.06	3.06	8.08	1.00	54.57	0.69
Min	466	82.18	1.590	0.270	15.09	612	71.00	82.00	98	81.00	2.35	5.20	0.00	35.58	0.16
Mean	559	87.68	1.932	0.374	17.11	799	88.77	94.34	120	95.66	2.72	6.88	0.69	50.00	0.55
80^{th} Percentile	638	95.25	2.100	0.430	17.94	913	93.84	97.51	135	102.20	2.96	7.75	0.84	53.23	0.64
50^{th} Percentile	546	85.15	1.940	0.360	16.83	786	88.74	93.84	119	97.92	2.65	7.04	0.69	50.14	0.58
SD	63.52	5.45	0.15	0.05	1.39	106.95	5.71	3.43	14.66	7.02	0.22	0.90			
[Ca]Outlier	1.40	1.18	1.35	1.70	1.36	1.58	1.35	1.19	1.46	1.30	1.30	1.55			

A comprehensive evaluation index covering the high and low-value traits with appropriate weightage to primary traits is therefore highly essential for silkworm breeds/hybrids. Ten characters were considered for authorization of silkworm varieties in China; in which cocoon shell weight, non-breakable filament length and

Table 5: Evaluation of multivoltine x bivoltine silkworm hybrids (crossbreeds)

Cross breed	Fecundity (No.)	Pupation rate (%)	Cocoon weight (g)	Shell weight (g)	Cocoon yield/10000 larvae (kg)	NBFL (m)	Reelability (%)	Neatness (points)	Cohesion (strokes)	Evenness (points)	Denier (d)	Renditta (kg)	Index		
													Robeva-Bm	MTE	SF
CB1	498	77.23	1.730	0.390	13.39	732	88.74	91.80	109	94.86	2.24	7.96	0.91	52.38	0.63
CB2	410	76.24	1.940	0.310	14.78	626	88.74	88.74	109	96.90	2.35	7.04	0.80	48.57	0.50
CB3	456	85.15	1.840	0.350	15.63	725	81.60	86.70	84	91.80	2.35	7.14	0.77	48.44	0.50
CB4	488	78.22	2.040	0.390	15.96	697	89.76	91.80	108	92.82	2.65	7.45	0.94	54.57	0.73
CB5	417	75.25	1.840	0.360	13.82	775	82.62	92.82	102	92.82	2.45	6.83	0.75	48.19	0.49
CB6	481	87.13	2.040	0.410	17.78	781	85.68	94.86	85	81.60	2.35	6.73	1.00	54.27	0.63
CB7	424	89.11	1.940	0.360	17.27	635	86.70	88.74	99	85.68	2.75	7.85	0.74	50.54	0.65
CB8	489	75.25	1.730	0.380	13.05	769	83.64	91.80	85	90.78	2.55	6.73	0.74	48.24	0.51
CB9	466	89.11	1.730	0.320	15.45	631	88.74	86.70	92	83.64	2.75	7.96	0.65	48.33	0.61
CB10	442	80.20	1.730	0.380	13.91	754	82.62	94.86	116	95.88	2.65	7.34	0.81	51.22	0.63
CB11	439	85.15	2.040	0.330	17.37	794	81.60	95.88	96	91.80	2.65	7.04	0.86	52.57	0.64
CB12	429	82.18	1.840	0.410	15.09	784	90.78	86.70	96	87.72	2.65	8.06	0.78	51.13	0.65
CB13	508	87.13	1.940	0.350	16.89	732	88.74	88.74	106	89.76	2.55	7.96	0.94	54.80	0.74
CB14	460	79.21	1.940	0.390	15.35	719	85.68	91.80	102	91.80	2.55	7.34	0.85	51.79	0.63
CB15	426	84.16	1.730	0.310	14.59	804	88.74	95.88	111	94.86	2.65	7.45	0.85	52.14	0.66
CB16	413	83.17	1.940	0.310	16.12	668	89.76	88.74	110	82.62	2.35	7.55	0.77	49.03	0.53
CB17	460	76.24	1.730	0.380	13.22	788	83.64	89.76	82	93.84	2.24	6.63	0.79	47.75	0.44
CB18	459	74.26	1.940	0.400	14.39	742	85.68	95.88	108	83.64	2.24	7.14	0.86	50.76	0.53
CB19	463	75.25	2.040	0.310	15.35	666	91.80	86.70	111	91.80	2.65	7.14	0.82	50.84	0.62
CB20	469	79.21	1.940	0.380	15.35	762	88.74	90.78	117	81.60	2.65	7.85	0.81	52.32	0.67
CB21 (Control)	427	80.00	1.321	0.242	10.57	440	81.00	76.00	75	79.00	2.45	9.00	0.00	32.10	0.16
Max	508	89.11	2.040	0.410	17.78	804	91.80	95.88	117	96.90	2.75	9.00	1.00	54.80	0.74
Min	410	74.26	1.321	0.242	10.57	440	81.00	76.00	75	79.00	2.24	6.63	0.00	32.10	0.16
Mean	454	80.90	1.855	0.355	15.01	716	86.43	90.27	100	89.30	2.51	7.44	0.78	50.00	0.58
80^{th} Percentile	485	86.34	2.000	0.390	16.58	783	89.35	94.86	111	94.45	2.65	7.96	0.89	52.50	0.66
50^{th} Percentile	459	80.00	1.940	0.360	15.35	732	86.70	90.78	102	91.80	2.55	7.34	0.81	50.84	0.63
SD	28.27	4.77	0.16	0.04	1.66	82.25	3.27	4.46	12.08	5.28	0.17	0.56			
[Ca]Outlier	1.24	1.20	1.54	1.69	1.68	1.83	1.13	1.26	1.56	1.23	1.23	1.36			

Table 6: Selection of silkworm hybrids based on multivariate analysis

Crossbreed			Bivoltine Hybrid		
ROBEVA-Bm	MTE	SF	*ROBEVA-Bm*	MTE	SF
CB6 (1.00)	CB13 (54.80)	CB13 (0.74)	BH5 (1.00)	BH5 (54.57)	BH3 (0.69)
CB4 (0.94)	CB4 (54.57)	CB4 (0.73)	BH12 (0.98)	BH12 (54.44)	BH4 (0.66)
CB13 (0.94)	CB6 (54.27)	CB20 (0.67)	BH13 (0.87)	BH3 (54.25)	BH12 (0.66)
CB1 (0.91)	CB11 (52.57)	CB15 (0.66)	BH3 (0.85)	BH13 (53.75)	BH19 (0.65)
CB11 (0.86)	CB1 (52.38)	CB12 (0.65)	BH20 (0.82)	BH4 (52.46)	BH13 (0.64)
CB18 (0.86)	CB20 (52.32)	CB7 (0.65)	BH1 (0.82)	BH19 (52.40)	BH5 (0.62)

Values in parentheses indicate indices

neatness were very important. If a variety under test fails in any one of the above characters in comparison to control, the variety is not considered further. The test-variety should score over the control for at least four traits among the rest *viz*., hatching percentage, larval duration, pupation rate, cocoon yield/10000 larvae, average shell weight/day during fifth instar, raw silk percentage for fresh cocoons and filament size (Jin *et al*., 2000). Evaluation of silkworm genetic resources is conducted with nine characteristics in Japan, except for larval duration and shell weight/day in fifth instar as compared to the Chinese system that includes additionally the cocoon

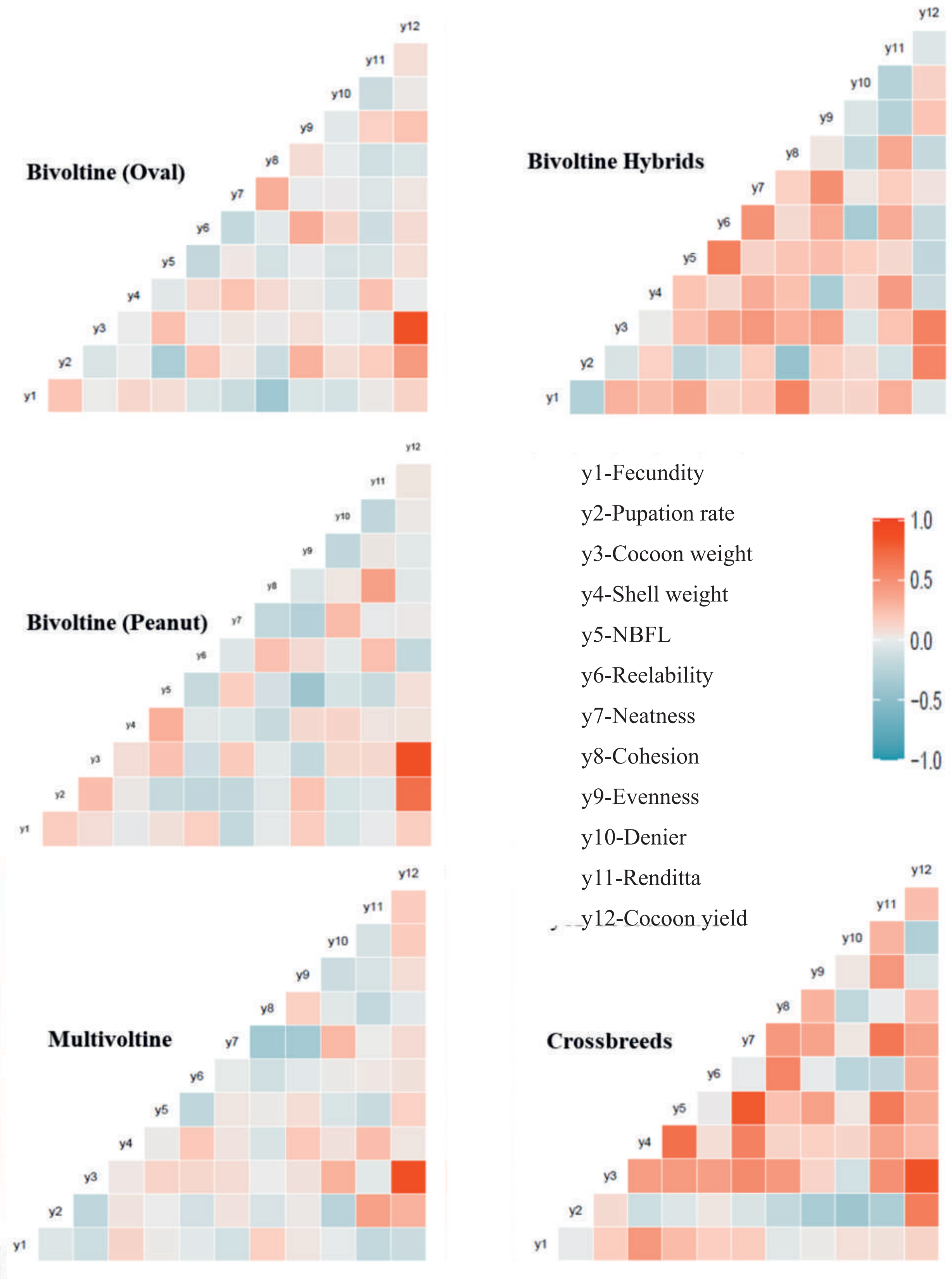


Figure 2: Trait correlation pattern of silkworm breeds and hybrids

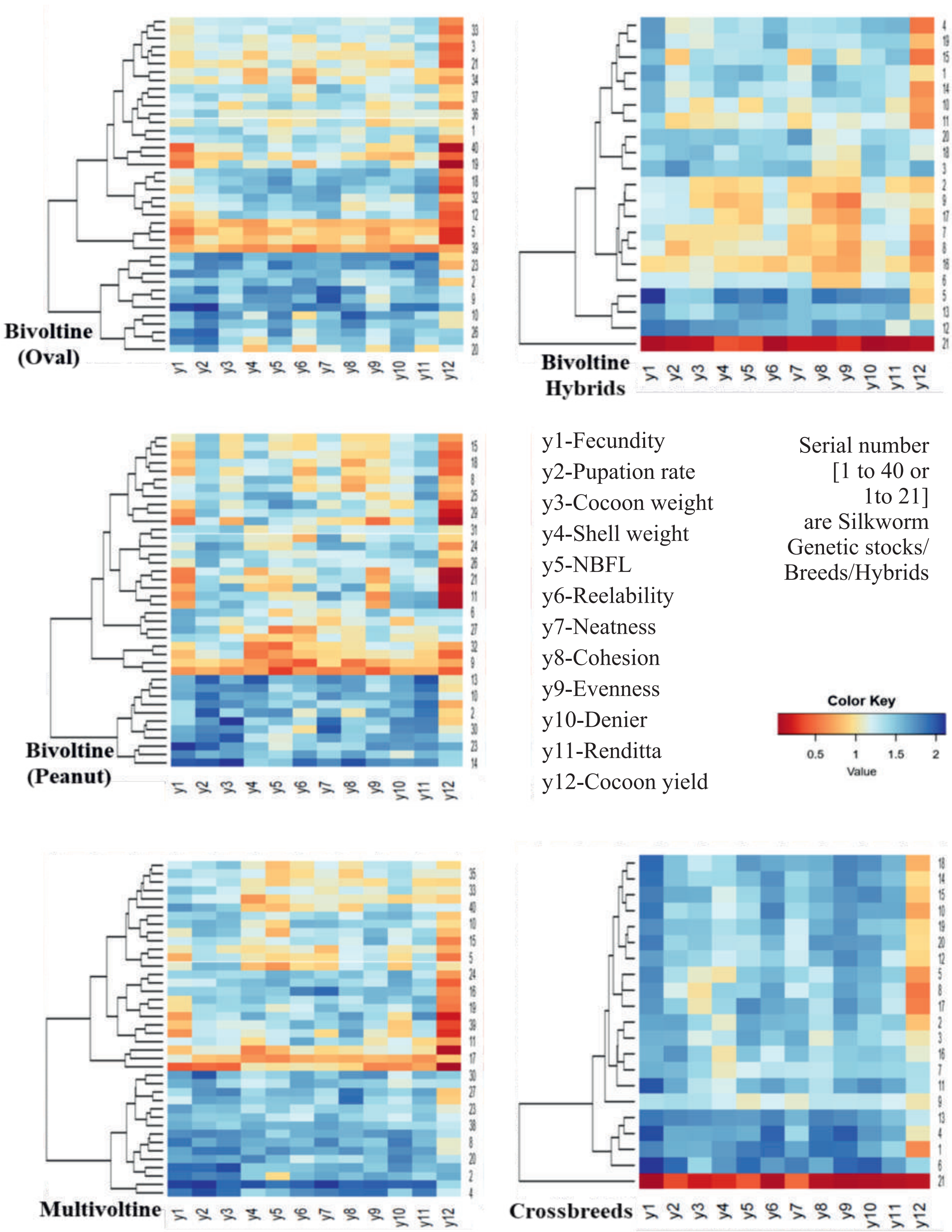


Figure 3: Cluster heat maps of silkworm breeds and hybrids

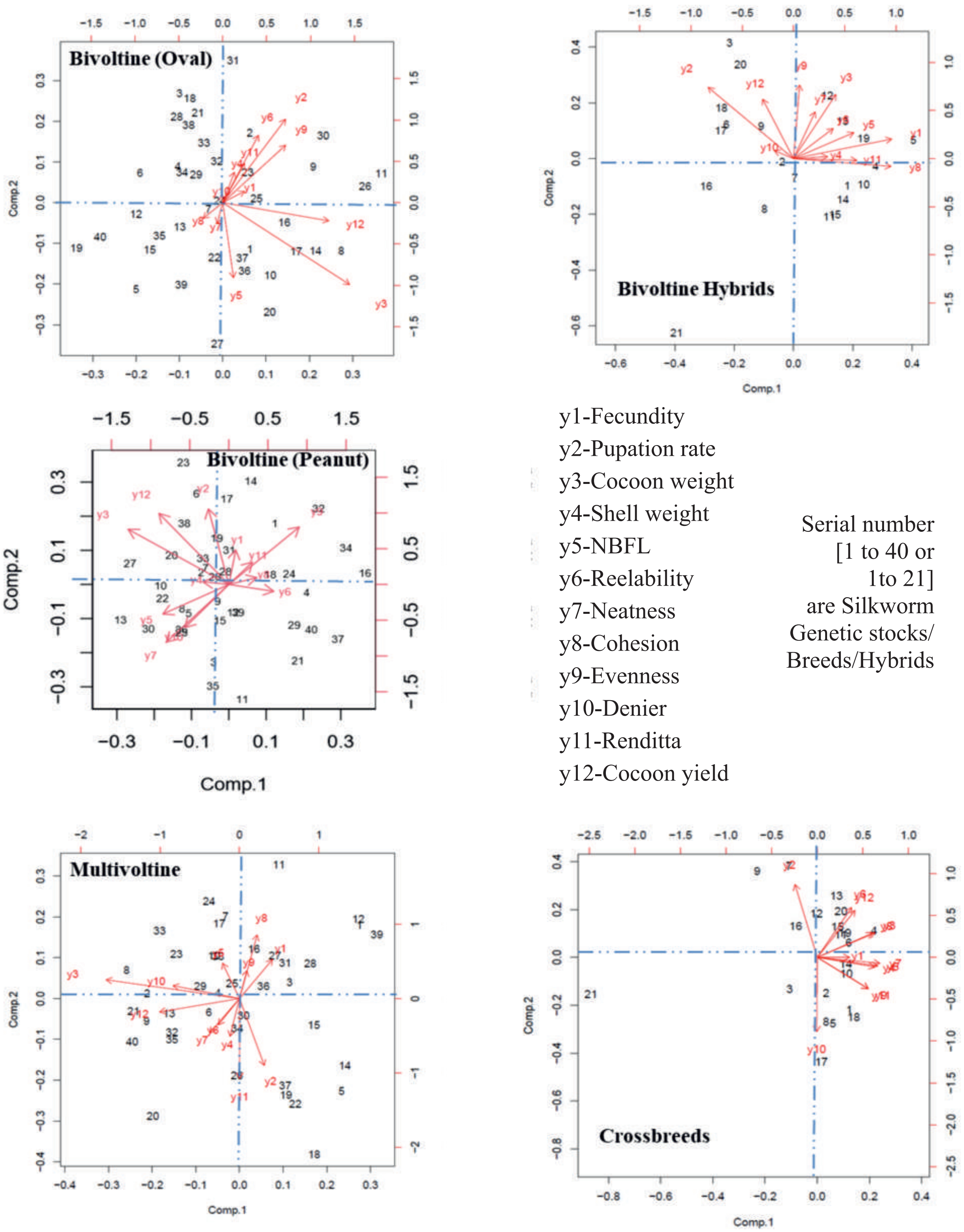


Figure 4: Biplot of silkworm traits in breeds and hybrids

Table 7: Comparative merits/demerits of evaluation indices for silkworm breeds/hybrids

Aspect	*ROBEVA-Bm*	Existing Method		
		Multiple Trait Evaluation (MTE; Mano *et al.,* 1993)	Sub-Ordinate Function (SF; Gower, 1971)	Joint Scoring (JS; Arunachalam and Bandopadhyay, 1984)
All high value characters	✓	✓	✓	✓
All low value characters	✓	✓	✓	✓
Both high & low value characters	✓	×	×	×
Outliers in data	✓	×	×	×
Multicollinearity	✓	×	×	×
Relative weightage	✓	×	×	✓
Clustering	✓	×	×	×
Visual interpretation	Simplified	×	×	×
Computation procedure	Simpler & Easier (R Program)	Easy	Easy	Cumbersome

degumming loss (Kosegawa, 2002). The hybrid authorization in India considers the multiple trait evaluation index (Mano *et al*., 1993) including overall rearing performance and post-cocoon characteristics.

The goodness of each index method is highlighted in Table 7, which reveals that *ROBEVA-Bm* is the most efficient and robust than multiple trait evaluation, sub-ordinate function and joint scoring systems for silkworm breeds/hybrids assessment. *ROBEVA-Bm* takes care of admixing of high & low-value traits, multicollinearity among the traits, influence of extreme values and possibility to assign relative weightages to meet the requirement of silkworm breeders. In addition, it facilitates grouping/clustering of genetic stocks/hybrids as high & low performers based on all the characteristics. Moreover, it is much easier & simpler for computation and could be accomplished through the ready-made/ready to use R codes (Appendix). *ROBEVA-Bm* is a multivariate statistical evaluation tool for effective selection of silkworm genetic stocks for initiating a breeding programme and identification of promising hybrid combinations for further exploitation.

If number of traits considered is more in an evaluation system like silkworm, the selection process becomes more complex. The number and choice of traits to be considered could be altered in the current evaluation method, *ROBEVA-Bm* to suit the desired targets of the breeder or a breeding programme. However, attention has to be paid on the number of test varieties, which should always be higher than the number of traits. In case, the number of test varieties is fewer, replication data could be utilized without adverse effects on the final outcome during the evaluation by *ROBEVA-Bm*.

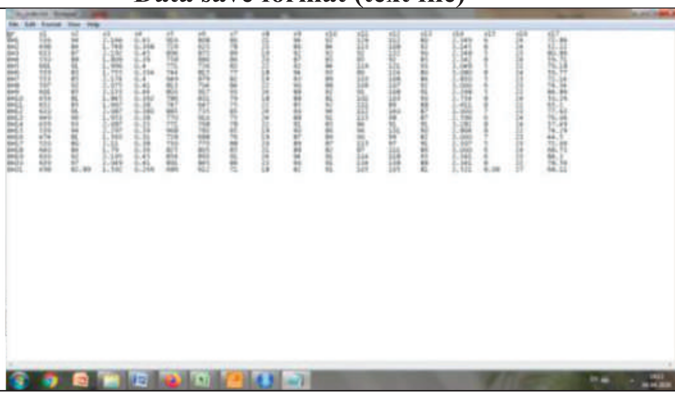
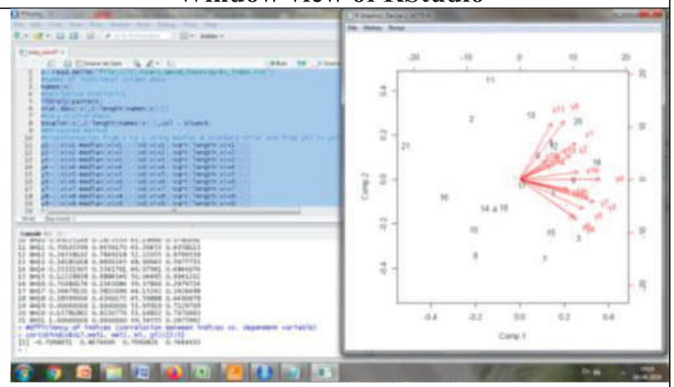
Conclusion

The study suggests *ROBEVA-Bm* as an appropriate choice/tool for efficient and robust evaluation of silkworm genetic stocks/breeds and hybrids based on principal component analysis and robust estimators for determining the best performer(s) from a mulberry silkworm breeding programme and also other fields of sericology. *ROBEVA-Bm* is much user-friendly for computing and interpretation of results utilizing graphical representations. The *ROBEVA-Bm* could be a potential tool in identifying the promising silkworm breeds/hybrids in trait-targeted breeding program readily used by silkworm breeders for evaluation purposes. The R program of *ROBEVA-Bm* is appended for ready use.

Appendix

R Program for *ROBEVA-Bm*

To perform ***ROBEVA-Bm,*** a readymade R code is provided for conducting multivariate analysis using RStudio:

Data save format (text file)	Window view of RStudio
	

Hybrids (name of hybrids with control), x1: Fecundity, x2: Pupation rate, x3: Cocoon weight, x4: Shell weight, x5: Non-breakable filament length, x6: Reelability, x7: Neatness, x8: Cohesion, x9: Evenness**, x10: Denier, x11: Renditta** and x12: Cocoon yield

```
#Import of data from text file to Rstudio
x<-read.delim("file:///I:/Final draft_1/mh_index.txt")

#Names of individual columns data
names(x)

#Descriptive statistics
library(pastecs)
stat.desc(x[,2:length(names(x))])

#Data scatteredness
boxplot(x[,2:length(names(x))],col = blues9)

#ROBEVA-Bm
#Transform or normalize x to y using min-max method and x10 & x11 are low index value
# Or replace min with median and min-max standard error

y1=(x$x1-min(x$x1))/(max(x$x1)- min(x$x1))
y2=(x$x2-min(x$x2))/(max(x$x2)- min(x$x2))
y3=(x$x3-min(x$x3))/(max(x$x3)- min(x$x3))
y4=(x$x4-min(x$x4))/(max(x$x4)- min(x$x4))
y5=(x$x5-min(x$x5))/(max(x$x5)- min(x$x5))
y6=(x$x6-min(x$x6))/(max(x$x6)- min(x$x6))
y7=(x$x7-min(x$x7))/(max(x$x7)- min(x$x7))
y8=(x$x8-min(x$x8))/(max(x$x8)- min(x$x8))
y9=(x$x9-min(x$x9))/(max(x$x9)- min(x$x9))
y10=(x$x10-max(x$x10))/(min(x$x10)- max(x$x10))
y11=(x$x11-max(x$x11))/(min(x$x11)- max(x$x11))
y12=(x$x12-min(x$x12))/(max(x$x12)- min(x$x12))
```

```
#Normalized values
a=cbind(y1,y2,y3,y4,y5, y6,y7,y8,y9,y10,y11,y12)

#Correlation
b=cor(a)

#Correlation(colour shades)
library(GGally) #install.packages("GGally")
ggcorr(a,cex=2)

#Eigen values & vectors
ev=eigen(b)

#Eigen values
lambs=ev$values

#Eigen  vectors
loads=abs(ev$vectors)

#Principal components
pc=(a%*%loads)

#Weighted average
wi=(pc%*%lambs)/sum(lambs)

#ROBEVA-Bm
ROBEVA-Bm=(wi-min(wi))/(max(wi)-min(wi))

# Hierarchical cluster heatmaps
library(gplots) #install.packages("gplots")
library(heatmap.plus) #install.packages("heatmap.plus")
library(RColorBrewer) #install.packages("RColorBrewer")

heatmap.2(pc, scale = "none",
        col = colorRampPalette(brewer.pal(10, "RdYlBu"))(256), trace = "none",
        density.info = "none", cexRow=.8, cexCol = .8, Colv = NA)

#Principal components
pc0=princomp(a)

#Biplot between 1st two PCs & breeds/hybrids
biplot(pc0, cex=0.6)

#Indices values
cbind(x[1], ROBEVA-Bm)

#Ranking of hybrids based on indices values
cbind(x[1],rank(1/ROBEVA-Bm))

#Percentile values at 80 & 50
quantile(ROBEVA-Bm, .8)
quantile(ROBEVA-Bm, .5)
```

REFERENCES

Anderson T. W. (2003) *An introduction to multivariate statistical analysis*, John Wiley & Sons, Inc., USA, pp. 1-650.

Anonymous (2020) *Statistical report of International silk commission* (https://www.inserco.org/) browsed on 26.09.2020

Arunachalam V. and Bandopadhyay A. (1984) A method to make decisions jointly on a number of dependent characters. *Indian J. Genet. Pl. Br.*, **44 (3)**: 419-424.

Balachandran N. and Kamble C. K. (2016) Evaluation and short listing of potential multivoltine silkworm germplasm using joint scoring method. *Int. J. Innov. Sci. Eng. Technol.*, **3 (11)**: 409-426.

Buhroo Z. I., Malik M. A., Ganai N. A., Kamili A. S. and Mir S. A. (2017) Rearing performance of some popular bivoltine silkworm (*Bombyx mori* L.) breeds during spring season. *Adv. Res.*, **9 (1)**: 1-11.

Cook R. D. (1977) Detection of influential observations in linear regression. *Technometrics*, **19 (1)**: 15–18.

Datta R. K., Basavaraja H. K., Mal Reddy N., Nirmal Kumar S., Suresh Kumar N., Ramesh Babu M., Ahsan M. M. and Jayaswal K. P. (2001) Breeding of new productive bivoltine hybrid,CSR12; CSR6 of silkworm (*Bombyx mori* L.*). Int. J. Ind. Entomol.*, **3 (2)**: 127-133.

Datta R. K., Basavaraja H. K., Nirmal Kumar S., Ahmad S. K., Chakma T. K. and Sivaprasad V. (2014) *Report of the technical committee on critical issues relating to the bivoltine silkworm breeds/hybrids*. Central Silk Board, Bangalore, pp.1-15.

Gower J. C. (1971) A general co-efficient of similarity and some of its properties. *Biometrics*, **27 (4)**: 857-871.

Gupta S. C. and Kapoor V. K. (1997) *Fundamentals of mathematical statistics*. Sultan Chand & Sons, New Delhi, pp.1-12.

Hemmatabadi R. N., Alireza S. and Shahabodin G. (2014) A review on correlation, heritability and selection in silkworm breeding. *J. Appl. Anim. Res.*, **44 (1)**:1-15.

Jin Y. X., Chen Y. Y. and Wu H. P. (2000) Performance of practical silkworm varieties for summer and autumn rearing in Zhejiang Province. *Bulletin of Sericulture*, **31 (2)**: 26-28.

Kee-Wook Sohn (2003) *Conservation status of sericulture germplasm resources in the world - II Conservation status of silkworm (Bombyx mori) genetic resources in the world*. FAO, Rome (http://www.fao.org/3/ad108e/ad108e00.htm#Contents)

Kosegawa E. (2002) *Conservation status of sericulture germplasm resources in Japan* **(**http://www.fao.org/3/ad108e/ad108e0i.htm**)**

Kumar M., Ahmad T., Rai A. and Sahoo P. M. (2013) Methodology for construction of composite Index. *Int. J. Agric. Stat. Sci.,* **9 (2)**: 639-647.

Kumar M., Majumder A., Manjunatha G. R. and Sanjeev K. (2015) Flower production index using principal component analysis. *J. Crop Weed*, **11 (1)**: 54-57.

Lakshmi H., Ramesh Babu M., Saha A. K., Chandrashekharaiah and Bindroo B. B. (2012) Studies on the season-wise evaluation of productive bivoltine silkworm (*Bombyx mori* L) hybrids in tropical condition. *Int. J. Integr. Sci. Innov. Technol.*, **1 (1)**: 20-30.

Mal Reddy N., Basavaraja H. K., Joge P. G., Nanje Gowda B., Kariappa B. K. and Dandin S. B. (2002) Studies on the utilization of bivoltine breeds and their hybrids as male components with Pure Mysore race. *Indian J. Seric.,* **41 (2)**: 124-129.

Mano Y., Nirmal Kumar S., Basavaraja H. K., Mal Reddy N. and Datta R. K. (1993) A new method to select promising silkworm breeds/combinations. *Indian Silk*, **31 (10)**:53.

Montgomery D. C., Peek E. A., and Vining G. G. (2001) *Introduction to Linear Regression Analysis*. 3rd Edition, Wiley, New York.

Ramesh Babu M., Lakshmi H., Prasad J., Seetharamulu J., Chandrashekharaiah and Goel A. K. (2005) Evaluation and selection of potential bivoltine parents for silkworm (*Bombyx mori* L.) breeding. *Indian J. Seric.*, **44 (1)**: 82-91.

Rangaswamy R. (2010) *Text book of agriculture statistics.* Kalyani Publishers, New Delhi, p. 252.

Rencher A. C. (2002) *Methods of multivariate analysis*. John Wiley & Sons, Inc., USA, pp. 1-548.

Sudhakara Rao P., Datta R. K., Ramesh Babum M. and Vijaya K. L. M. (2002) Breeding resource materials of *Bombyx mori* L., adaptive to tropical conditions. *Int. J. Ind. Entomol.*, **4 (2)**: 109-115.

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Research Paper

IDENTIFICATION AND CHARACTERIZATION OF A *p53* HOMOLOGUE (*Bmp53-240*) IN THE SILKWORM, *BOMBYX MORI*

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ABSTRACT

The *p53*, a well-known tumor suppressor gene, is a transcription factor with a key role in guarding genomic stability that can inhibit cancer formation. p53 has been implicated in apoptosis, cell control, and lifespan in model animals including humans, *Drosophila*, and zebra fish. Many apoptosis-related genes have been identified in the silkworm, *Bombyx mori*, a representative species in the order Lepidoptera and an effective model system. In the present study, a homologous sequence of *p53* with an open reading frame (ORF) of 723 bp, named as *Bmp53-240*, was amplified from pupae and BmN cells. Conservation analysis showed that *Bmp53-240* belonged to the *p53* super family and an over-expression of this gene inhibited cell viability of both Tn5 and BmN cells. However, it was difficult to determine whether *Bmp53-240* was regulated by *mdm2*, since its expression was almost at the transcriptional level and did not induce apoptosis via the mitochondrial pathway. Given that the gene was expressed at different stages of insect life cycle with no significant changes, *Bmp53-240* might be a basic regulatory form in insect development.

Key words: Apoptosis, Baculovirus, *Bmp53-240.*

INTRODUCTION

P53 was first described in 1979 as a cellular partner of simian virus (SV40) large T-antigen. It belongs to the p53 family composed of *p53*, *p63*, and *p73* (Hainaut and Wiman, 2009; Levine and Oren, 2009). *p63* and *p73* share significant structure and functional homologies with *p53*, especially in the DNA binding domain. Because of the alternative splicing, promoter usage, and codon initial sites, *p63*, *p73* and *p53* genes can express 6, 29 and 9 different isoforms in humans, respectively (Bourdon *et al.,* 2005). Together with *p63* and *p73*, *p53*s have unique functions, which form a family of transcription factors (Bourdon *et al.,* 2005; Marcel *et al.,* 2011).

The functions of *p53* are regulation of the cell cycle, induction of apoptosis, repair, aging, differentiation and growth, altered metabolism, and tumor suppression described in a variety of vertebrates, invertebrates, and protists (Mendoza *et al.,* 2003; Lu *et al.,* 2009; Lane *et al.,* 2010). Mammalian genomes contain three members of the *p53* family, while invertebrates have only one member which resembles *p53* (Yang *et al.,* 2002). Recent studies on analysis of expression patterns of *Drosophila* suggested that *p53* gene structure was found to be conserved through evolution (Bourdon *et al.,* 2005) with identification of three variants of *p53*.

The importance of *p53* has long been recognized and is required for transcriptional regulation of a number of *p53* targeted genes, including *bax*, *p21* and *mdm2*, to guarantee its stability and function (Bouvard *et al.,* 2000). Regulation of this gene has been described at both the mRNA and protein levels in response to different types of stress provided to the host. As an E3 ubiquitin ligase, *mdm2*, a major P53 repressor, is an essential regulator of P53 by controlling both the stability and the activity of P53 by negatively regulating the *p53*-mediated transactivation to ensure that its expression is maintained at a low level through an auto regulatory feedback loop (Moll and Petrenko, 2003).

Since the life spans of invertebrates are too short for them to develop cancer, the activity of *p53* in tumor suppression was an unlikely stimulus for its evolution. Furthermore, it was reported that homologues of *p53* in the non-mammalian models played an important role in the induction of apoptosis in various stress in response to DNA damage, but not for cell cycle arrest (Sogame *et al.,* 2003; Dichtel-Danjoy *et al.,* 2013).

Although a number of *p53* genes have been identified in insects, including *Drosophila*, *Spodoptera frugiperda*, and *B. mori*, the full-length sequence and the roles of *B. mori p53* gene remain elusive.

Experiments conducted in apoptosis research on *Drosophila* has confirmed that a conserved internal promoter of *p53* had an essential role in the control of *p53* gene family members (Bourdon *et al.,* 2002). However, there are still some differences among the mechanisms reported in the absence of Sickle family proteins (Cashio *et al.,* 2005; Xu *et al.,* 2009) and *mdm2* protein. Furthermore, Cytochrome-c, which has been proved to be essential in Sf 9 and BmN cells during Lepidopteran apoptosis, is dispensable for Caspase activation in *Drosophila* (Dorstyn *et al.,* 2002, 2004; Dorstyn and Kumar, 2006). These data suggest that apoptotic mechanisms in model organisms are variable and hence, cannot accurately reflect the apoptotic mechanisms in the silkworms.

With its draft genome sequence available, *B. mori*, is widely used for investigation of baculovirus biology (Mita *et al.,* 2004; Xia *et al.,* 2004), and is also a representative species in the order Lepidoptera that has an important economic value which significantly contributes to our understanding of invertebrate development. It also has become a model organism in the study of Lepidopteran and arthropod biology because of its miniature size and ease of culture. There are mainly two aspects in apoptosis research in silkworms; One aspect is extrinsic / intrinsic factors which can induce morphological changes in tissues by bringing in apoptosis in cells and generating apoptotic mutants in individual organs and tissues during metamorphosis (Kaneko *et al.,* 2006). Another aspect is gene cloning and its identification (Zhang *et al.,* 2010). According to the growing number of genetic tools available in *B. mori* research, many genes involved in developmental and disease processes have been identified. Using nucleotide and protein homolog comparison analyses on NCBI, four *Bmp53* homolog sequences were found. In this study, to gain novel insights into the gene structure and the function of *Bmp53*, we cloned the *Bmp53* variant gene and analyzed its functions with regard to cell growth and survival.

MATERIALS AND METHODS

Cell culture

The BmN cells (for virus infection and cell viability assay） and *Trichoplusia Ni* 5 (Tn 5) cells (cell viability assay) were maintained as monolayer in 25 cm^2 culture flasks (T25 flask) at 27 °C in TC-100 (for BmN cells) and TNM-FH (for Tn 5 cells) media supplemented with 10 % Fetal Bovine Serum (FBS) (Gibco, USA). Cells were regularly sub-cultured at an interval of three times a week in exponential phase by seeding at a density of 5×10^4 cells/ cm^2 area.

Sequence determination of *Bmp53*

The primers, Bmp-I-53-F and Bmp-I-53-R (Table 1) were designed based on the sequence data from the *B. mori* genome sequencing project with homology to other *p53* genes and were used to amplify the *Bmp53* gene fragment from silkworm pupae (for the wings development) and BmN cells, respectively. This amplified fragment was cloned into the pMD-18T vector (Takara, Japan) for sequencing analysis. The nucleotide blast (whole-genome shotgun contigs) on NCBI was used to analyze the sequence.

Table 1: Primers used

Primers for PCR	Sequence
Bmp-I-53-F	5'-GCTTAAATGAAACACGAAATCATGA-3'
Bmp-I-53-R	5'-CGAGGCGCTCTCCAGGGTGAAGAT-3'
Bmp-w-F	5'-ATGAAACACGAAATCATGA-3'
Bmp-w-R	5'- GTGAGTACTGCCTCCCCCGGGCCAC -3'
Enzyme-P-F	5'-TGGGGATCCATGAAACACGAAATCATGA-3'
Enzyme-P-R	5'-CCGCTCGAGGGCAGTACTCACGAGGCGCTCTCC-3'
Primers for QPCR	
Q-BmP53-F	5'-TCCAGGGCAATACAACTTCAG-3'
Q-BmP53-R	5'-TGGCGCGCACGTACATC-3'
Q-BmP53-240-F	5'-CGGACGACCCCGACTACTG-3'
Q-BmP53-240-R	5'-AGTACTCACGAGGCGCTCTCC-3'
Q-MDM2-F	5'-AGAGGTGAGCGTGGGCG-3'
Q-MDM2-R	5'-CGTTTGCGTTTACGTTTGG-3'
Q-Bm-A3-Actin-F	5'-TGCGTGACATCAAGGAGAAG-3'
Q-Bm-A3-Actin-R	5'-ATCTTTCGTTTCCGATGGTG-3'

Bmp-I-53-F/Bmp-I-53-R and Bmp-w-F/Bmp-w-R for sequencing; Enzyme-P-F and Enzyme-P-R for constructing BmP53-240 recombinant baculovirus; Underline represents restriction endonuclease sites.

The primers, Bmp-w-F and Bmp-w-R derived from the genomic sequences (from the KAIKObase) were used to amplify the full ORF of the *Bmp53 gene*. The primers are listed in Table 1.

Bioinformatic analysis of *Bmp53*

The NCBI nucleotide and protein databases BLAST algorithm and the KAIKObase were used to analyze the *Bmp53-240* homologous sequences. All the domains of the *p53* sequences of *B. mori* were predicted with NCBI Conserved Domain Research. Multiple sequence alignment of proteins was performed with Mega 5.0 and edited with GeneDoc.

Construction of the recombinant baculovirus expressing *Bmp5*3 gene

The primers, Enzyme-P-F and Enzyme-P-R (Table 1) were used to amplify *Bmp53-240*. The amplified fragment of *Bmp53-240* was inserted into the *Bam*H I and *Xho* I sites of baculovirus transfer vector pFastBac1 (pFB) and the recombinant transfer vector pFB-pie1-Bmp53-240 (driven by the *ie-1* promoter) was constructed. Using the bac-to-bac baculovirus expression system, the recombinant bacmids, vBm-pie1-Bmp53-240 and vAc-pie1-Bmp53-240, were harvested to generate the recombinant viruses.

Quantitative Real-time PCR

Total RNA was purified by TRIzol Reagent (ThermoFisher, USA), from pupae and BmN cells infected by *B. mori* nucleopolyhedrovirus (BmNPV) at 0, 2, 4 and 8 h post infection, according to the manufacturer's instructions. Reverse transcription reaction was performed using RT kit (Fermentas, USA). The relative mRNA levels of *Bmp53*, *Bmp53-240* and *mdm2* were analyzed by quantitative real-time PCR using TB Green® Fast qPCR Mix (Takara, Japan). *B. mori actin-A3* gene was used as an internal control. Quantitative real-time PCR was performed using an ABi-7500 QPCR System (ABI, USA) and the conditions were 94 °C for 5 min, and 40 cycles of 94 °C for 20 s, 58 °C for 20 s and 72 °C for 30 s. All primers are listed in Table 1.

Analysis of mitochondrial membrane potential by JC-1 staining

BmN Cells were seeded into 96-well plates at a density of 5×10^4 cells. Following 24 h incubation, the virus vBm-pie1-Bmp53-240 was added into BmN cells and incubated for further 2, 4 and 8 h. Wild-type BmNPV was used as a control. After washing with PBS buffer three times, the cells were stained with the dye JC-1 (5 µL JC-1 molecular probes in 5 mL complete media) for 30 min in the dark at 27 °C. Morphological alterations and mitochondrial membrane potential were determined by Live cell imaging microscopy (Leica DMI 4000, Germany) and by a fluorescence microplate reader (MD spectramax M2, USA).

Cell viability assay by counting kit-8 (CCK8)

Tn 5 cells and BmN cells were seeded in 96-well plate at a density about $2\text{x}10^4$ in TC-100 medium supplemented with 10 % FBS. Tn 5 cells were treated with the viruses vBmpie1-BmP53-240 and BmNPV (MOI of 1) for 0, 2, 4 and 8 h, while BmN cells were infected with vAc-pie1-BmP53-240 and *Autographa californica* multiple nucleopolyhedrovirus (AcMNPV) at MOI of 1. The cells in each well were incubated with 10 µL of CCK8 at 27 °C for about 4 h. Using a microplate reader, the optical density (OD) was measured for each well at 450 nm with a reference wavelength of 655 nm at each hour. The cell inhibitory rate was calculated according to the following equation:

The cell inhibitory rate = [1- (OD experiment - OD blank) / (OD control - OD blank)] × 100 %. Data are presented as mean ± standard deviation (SD) of three separate experiments. The Statistical Package for Social Sciences (SPSS) 18.0 software was used for data analysis. A P-value of < 0.05 was considered as statistically significant.

RESULTS

Cloning analysis of *B. mori p53* homologues

Using NCBI blast to analyze the *p53* gene in *B. mori*, four homologues were identified (Figure 1). Their typical ORF structure contains a core structure for DNA binding and Zinc binding with the differences in the flanking sides (Figure 2). Among these sequences, the longest one contained 2800 bp, which encoded a protein with 368 aa (AK381393.1) and the shortest one only encoded a 181 aa protein (GenBank: GQ426301.1) (Zhang *et al.,* 2010).

We designed a series of primers to amplify *Bmp53* according to the published sequences (GenBank: NM_001177410). Only a 720-bp long ORF was amplified from both BmN cells and pupae, using the forward primer designed according to the sequence of GenBank: HM773025.1 and the reverse primer designed according to the shortest ORF (GenBank: GQ426301.1) containing a termination codon. To confirm the termination of the ORF, we designed another reverse primer located downstream of the stop codon according to the available silkworm genomic sequence (KAIKAObase). The sequencing results indicated the presence of *Bmp53* variant encoding 240 aa in pupae and BmN cells, which was named as *Bmp53-240* (GenBank: KC243147). Furthermore, the *Bmp53* alignment with KAIKObase showed that the sequences (ORF) that were amplified were located on chromosome 16. However, when the longer cDNA

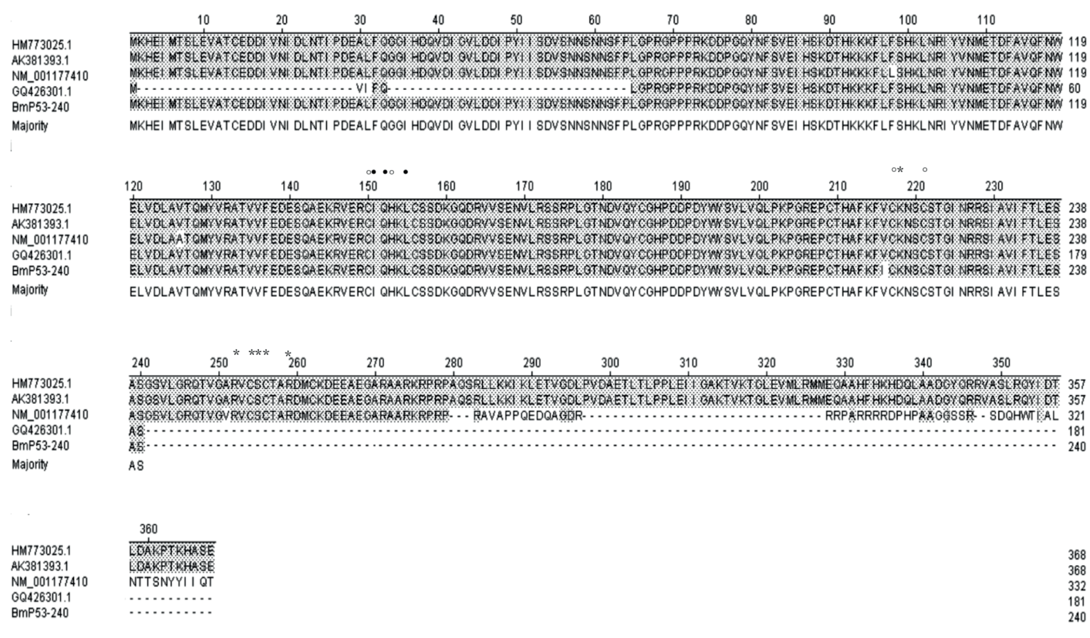

Figure 1: Protein sequence alignment of *Bmp53* conserved domains by MAGA 5.0

Similar amino acids are highlighted. Conserved amino acids involved in DNA or Zinc binding are indicated by symbols above the sequence that show the following amino acids interactions: * DNA binding site, ●contacting phosphate backbone, and ○ zinc binding.

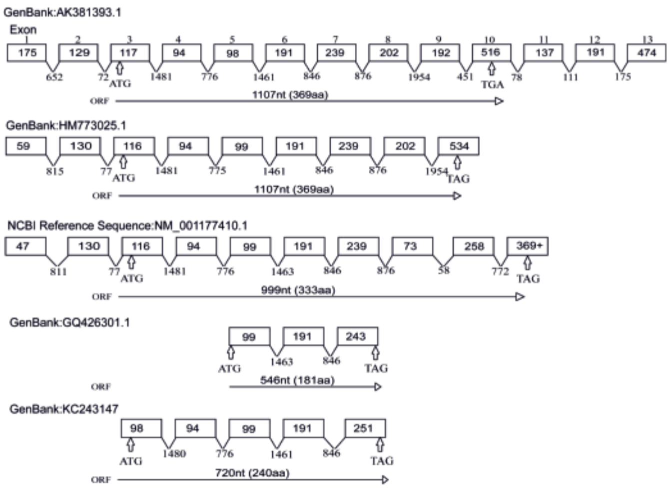

Figure 2: The splicing pattern of *Bmp53*

The numbers represent DNA markers in Kb. Exon/Intron organization of *p53*s from *B. mori*. The numbers indicate the size of the exons (in rectangles) or introns (shown as "∨" below the exons). The arrows labeled 'ORF' show the portion of the ORF encoded in the five mRNAs identified by ORF finder.

sequences were used to analyze chromosome localization, some exons were localized on other chromosomes also, such as *chr. 7* and *chr. 22*. These results implied that several homologue genes of *p53* in silkworm genome might be transcribed during insect development.

Bmp53, *Bmp53-240* and *mdm2* expression when challenged with virus infection

In order to detect the expression of *Bmp53* and *Bmp53-240*, and also to determine the *Bmp53* interaction with *mdm2* in *B. mori*, specific primers were designed to perform RT-PCR experiments. *mdm2* conserved domain sequence (GenBank: JF507604.1) was obtained from the silkworm database by BLAST search and the primers were designed according to this sequence.

In this experiment, the method of BmNPV infection at MOI of 1 was used to stimulate BmN cells to determine the expression changes of total *Bmp53*, *Bmp53-240* and *mdm2*. At the early stage of infection, the cell whole mRNA was used to amplify the sequences. The results showed that expression of *mdm2* was decreased and *Bmp53* was up-regulated (Figure 3A). However, the expression of *Bmp53-240* was not significantly changed

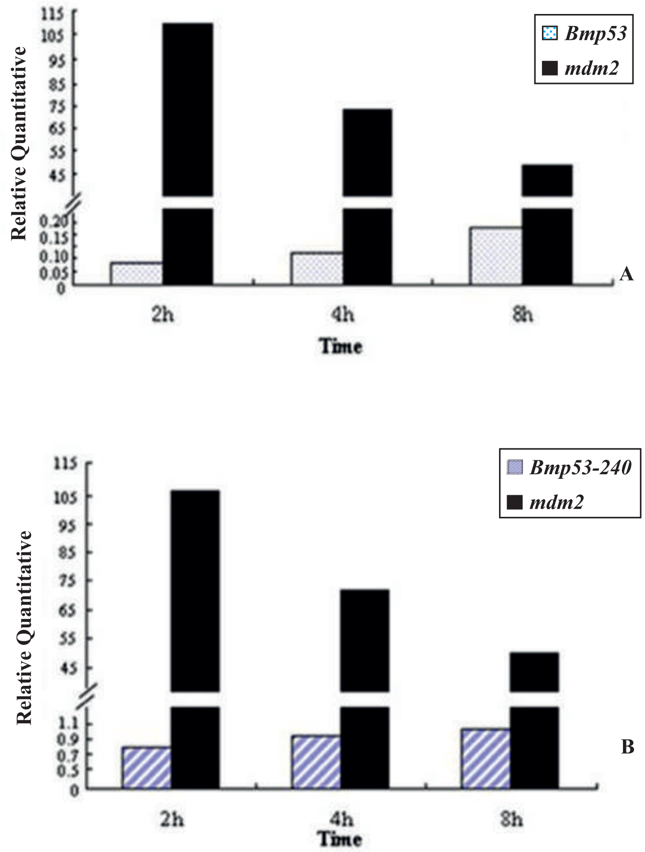

Figure 3: Relative mRNA levels of total *Bmp53*, *Bmp53-240* and *mdm2* analyzed in BmN cells induced with BmNPV

B. mori actin-A3 gene was used as an internal control. A - Expression levels of *mdm2* and total *Bmp53*. B - Expression levels of *mdm2* and *Bmp53-240.*

(Figure 3B). It implied that viral infection induced up-regulation of total *Bmp53* and down-regulation of *mdm2*, but caused no significant change to *Bmp53-240*, indicating that there are other components to the complete *p53* gene in *B. mori*.

Analysis of mitochondrial membrane potential by JC-1 staining

To gain insight into the relationship between *Bmp53-240* and apoptosis via the mitochondrial dependent pathway, we constructed a recombinant baculovirus vBm-pie1-Bmp53-240 containing the *Bmp53-240* CDS controlled by the BmNPV *ie-1* promoter. After this virus was incubated with BmN cells at 2, 4, and 8 h, the cells were stained with JC-1 dye to test mitochondrial membrane potential. JC-1, the fluorescent carbocyanine dye, forms aggregate and

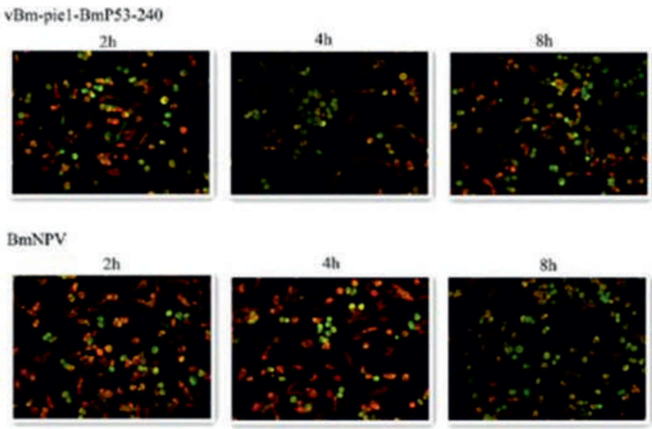

Figure 4: Analysis of mitochondrial membrane potential by JC-1 staining

Cells were treated as indicated, stained with JC-1 dye, and imaged under fluorescence microscope (× 200).

emits red fluorescence if the mitochondria are healthy with high potential, while JC-1 existing as monomeric form with green fluorescence indicates the loss of mitochondrial membrane potential/depolarization in the apoptotic and necrotic cells (Figure 4). The result showed that there was no significant change in the red-green fluorescence intensity ratio between cells infected with vBm-pie1-BmP53-240 and the ones infected with the wild-type BmNPV. It implied that *BmP53-240* might not induce cell apoptosis via the mitochondrial dependent pathway.

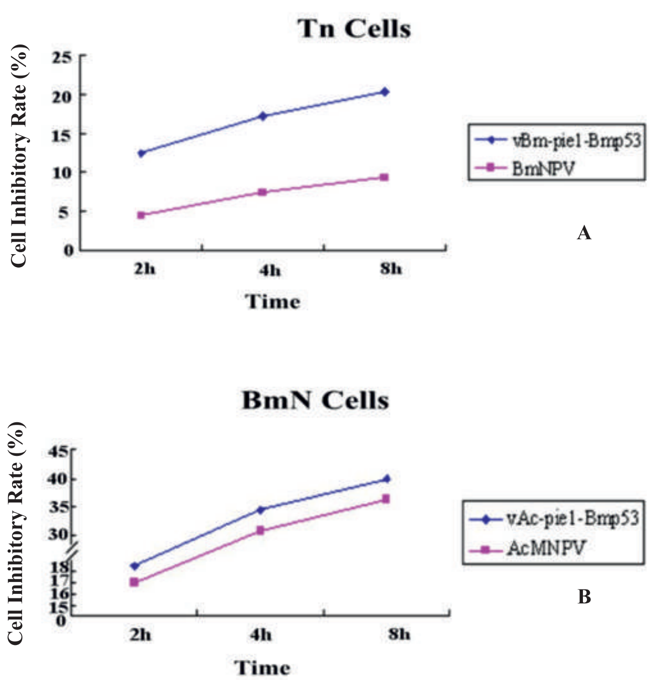

Figure 5: Cell activities tested by CCK8 assay

A - Cell inhibitory rate of vBm-pie1-BmP53-240 in the non-permissive Tn 5 cells;
B - vAc-pie1-BmP53-240 in BmN cells.

Effects of *Bmp53-240* on cell survival

To study the effects of *Bmp53-240* on cell survival, cell viability of BmN and Tn 5 cells were determined after expression of *Bmp53-240*, using a non-infectious recombinant virus vBm-pie1-BmP53-240 in Tn 5 cells or vAc-pie1-BmP53-240 in BmN cells. The results showed that the inhibitory effect on cell viability was significantly different between recombinant viruses and the wild-type viruses both in Tn 5 (Figure 5A) and BmN (Figure 5B) cells. Moreover, with prolonged incubation time, the inhibitory effect was enhanced. The results indicated that *BmP53-240* could inhibit cell viability.

DISCUSSION

Silkworm has become one of the best-characterized model organisms for genetic study, since the whole silkworm genome has been sequenced. The database provide *B. mori* a more appealing system for study of gene functions and protein-protein interactions (Zhang *et al.,* 2010).

Insects and mammals diverged about 700 million years ago during evolution. Under strong selection pressure, the striking conservation of *p53* between the two distant systems suggests that it is an early-evolved gene (Jin *et al.,* 2000). The *p53* gene might be structurally conserved across different species. P53, a key regulation factor, plays important roles in cell cycle, apoptosis, aging and so on. In insects, especially *Drosophila* contains a single *p53*-related gene, which has been proved to be important in controlling lifespan of the insect in a sex- and stage-dependent manner (Jin *et al.,* 2000; Lunardi *et al.,* 2010). The *p53* gene has also been identified in *S. frugiperda*. In the present study, an attempt has been made to identify *p53* homologue in *B. mori*. However, the full-length ORF of *Bmp53* could not be amplified since most of the *Bmp53* homologue sequences were spliced out by RACE assay. The ORF of the longest *Bmp53* sequence contained 368 aa, while the shortest sequence only has 181 aa. The difference might be explained by sequence polymorphisms in the silkworm because it undergoes complete metamorphosis with different morphological structures during its lifespan (James, 2019). In this paper, we designed a series of *p53* specific primers according to published sequences to amplify *Bmp53*, but only a 720-bp length sequence could be amplified from BmN cells and early-stage pupae using the reverse primer designed based on the shortest sequence which was also extended with a termination codon in 3' region by designing a reverse primer from available genomic sequence. Since, the sequence was detected in both pupae and BmN cells, it might be concluded that the gene might be essential for basic regulation of cell cycle in silkworms.

To investigate the function of *Bmp53-240*, analysis of mitochondrial membrane potential (JC-1 staining) and cell viability assays (CCK8) were performed. The results showed that it neither formed a regulatory feedback loop with *mdm2* nor induced cell apoptosis through the mitochondrial pathway. We constructed the recombinant virus with the *ie-1* promoter for *Bmp53-240* expression. When these viruses were incubated with Tn5 cells, they can enter the cells and express *Bmp53-240*， and have less influence on cells. The results indicated that *Bmp53-240* appeared to inhibit cell activity, suggesting that it may affect cell survival and/or growth. As the *p53* gene is polymorphic, *Bmp53-240* may be one of its splice variants with a role in cell regulation of *B. mori.*

In this paper, the variant transcript of *Bmp53* named *Bmp53-240* was cloned and sequenced. It appears that *Bmp53-240* is conserved among the predicted P53 proteins in *B. mori*. This evidence will help us to better understand the functions of *p53* by providing a convenient and simple genetic model to study the *p53* network.

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REFERENCES

Bourdon J. C., Fernandes K., Murray-Zmijewski F., Liu G., Diot A., Xirodimas D. P., Saville M. K. and Lane D. P. (2005) p53 isoforms can regulate p53 transcriptional activity. *Genes Dev.*, **18**: 2122-2137.

Bourdon J. C., Renzing J., Robertson P. L., Fernandes K. N. and Lane D. P. (2002) Scotin, a novel p53-inducible proapoptotic protein located in the ER and the nuclear membrane. *J. Cell Biol.*, **2**: 235-246.

Bouvard V., Zaitchouk T., Vacher M., Duthu A., Canivet M., Choisy-Rossi C., Nieruchalski M. and May E. (2000) Tissue and cell-specific expression of the p53-target genes: bax, fas, mdm2 and waf1/p21, before and following ionising irradiation in mice. *Oncogene*, **5**: 649-660.

Cashio P., Lee T. V. and Bergmann A. (2005) Genetic control of programmed cell death in *Drosophila melanogaster*. *Elsevier Ltd:* SEMIN. CELL DEV. BIOL., **2**: 225-235.

Dichtel-Danjoy M. L., Ma D., Dourlen P. *et al.* (2013) *Drosophila* p53 isoforms differentially regulate apoptosis and apoptosis-induced proliferation. *Cell Death Differ.*, **1**: 108-116 .

Dorstyn L. and Kumar S. (2006) A cytochrome c-free fly apoptosome. *Cell Death Differ.*, **7**: 1049-1051.

Dorstyn L., Mills K., Lazebnik Y. and Kumar S. (2004) The two cytochrome c species, DC3 and DC4, are not required for caspase activation and apoptosis in *Drosophila* cells. *J. Cell Biol.*, **3**: 405-410.

Dorstyn L., Read S., Cakouros D., Huh J. R., Hay B. A. and Kumar S. (2002) The role of cytochrome c in caspase activation in *Drosophila melanogaster* cells. *J. Cell Biol.*, **6**: 1089-1098.

Hainaut P. and Wiman K. G. (2009) 30 years and a long way into p53 research. *Lancet Oncol.*, **9**: 913-919.

Huang N., Clem R. J. and Rohrmann G. F. (2011) Characterization of cDNAs encoding p53 of *Bombyx mori* and *Spodoptera frugiperda*. *Insect Biochem. Mol. Biol.*, **8**: 613-619.

James W. T. (2019) The evolution of insect metamorphosis. *Curr. Biol.*, **23**: 1252-1268.

Jin S. K., Martinek S., Joo W. S. *et al.* (2000) Identification and characterization of a p53 homologue in *Drosophila melanogaster*. *Proceedings of the National Academy of Sciences of the United States of America*, **13**: 7301-7306.

Kaneko Y., Takaki K., Iwami M. and Sakurai S. (2006) Developmental profile of annexin IX and its possible role in programmed cell death of the *Bombyx mori* anterior silk gland. *Zool. Sci.*, **6**: 533-542.

Lane D. P., Cheok C. F., Brown C. J.,Madhumalar A., Ghadessy F. J. and Verma C. (2010) The Mdm2 and p53 genes are conserved in the Arachnids. *Cell Cycle*, **4**: 748-754.

Levine A. J. and Oren M. (2009) The first 30 years of p53: growing ever more complex. *Nat. Rev. Cancer*, **10**: 749-758.

Lu W. J., Amatruda J. F. and Abrams J. M. (2009) OPINION p53 ancestry: gazing through an evolutionary lens. *Nat. Rev. Cancer*, **10**: 758-762.

Lunardi A., Di Minin G., Provero P., Dal Ferro M., Carotti M., Del Sal G. and Collavin L. (2010) A genome-scale protein interaction profile of Drosophila p53 uncovers additional nodes of the human p53 network. *Proceedings of the National Academy of Sciences of the United States of America*, **14**: 6322-6327.

Marcel V., Olivier M., Mollereau B., Hainaut P. and Bourdon J. C. (2011) First International p53 Isoforms Meeting: 'p53 isoforms through evolution: from identification to biological function. *Cell Death Differ.*, **3**: 563-564.

Mendoza L., Orozco E., Rodriguez M. A. Garcia-Rivera G., Sanchez T., Garcia E. and Gariglio P. (2003) Ehp53, an *Entamoeba histolytica* protein, ancestor of the mammalian tumour suppressor p53. *Microbiology*, **149**: 885-893.

Mita K., Kasahara M., Sasaki S. *et al.* (2004) The genome sequence of silkworm, *Bombyx mori*. *DNA Res.*, **1**: 27-35.

Moll U. M. and Petrenko O. (2003) The MDM2-p53 interaction. *Mol. Cancer Res.*, **14**: 1001-1008.

Sogame N., Kim M. and Abrams J. M. (2003) *Drosophila* p53 preserves genomic stability by regulating cell death. *Proceedings of the National Academy of Sciences of the United States of America*, **8**: 4696-4701.

Xia Q. Y., Zhou Z. Y., Lu C. *et al.* (2004) A draft sequence for the genome of the domesticated silkworm (*Bombyx mori*). *Science*, **5703**: 1937-1940.

Xu D. B., Woodfield S. E., Lee T. V., Fan Y., Antonio C. and Bergmann A. (2009) Genetic control of programmed cell death (apoptosis) in *Drosophila*. *Fly*, **1**: 78-90.

Yang A., Kaghad M., Caput D. and McKeon F. (2002) On the shoulders of giants: p63, p73 and the rise of p53. *Trends Genet.*, **2**: 90-95.

Zhang J. Y., Pan M. H., Sun Z. Y., Yu Z. S., Liu D., Zhao D. H. and Lu C. (2010) The genomic underpinnings of apoptosis in the silkworm, *Bombyx mori*. *BMC Genom.*, **11**: 611.

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Research Paper

EXPANSION OF MULBERRY SERICULTURE IN MEGHALAYA USING GEOSPATIAL TOOLS AND GEOPORTAL

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ABSTRACT

Potential and suitable areas for expansion of mulberry sericulture in cultivable wastelands of Jaintia Hills district of Meghalaya were mapped using satellite remote sensing data, GIS and GPS tools. Identification of suitable areas for expansion of mulberry sericulture was based on land evaluation, using information on soil, slope, rainfall and temperature and requirements of crops as well as rearing of silkworms. The study reveals that only 2 % of cultivable wastelands of the experimental district are not suitable for expansion of mulberry sericulture. Highly suitable areas account for about 21.23 %, followed by moderately suitable and marginally suitable areas that cover 32.06 % and 46.71 % area, respectively. All thematic layers prepared for the study and all information collected from state sericulture department regarding cultivation practices, occurrence of pests and diseases, and different schemes for expanding the sericulture have been put in a geoportal titled 'Sericulture Information Linkages and Knowledge System' (SILKS) which was conceptualized and developed using open source GIS and put in the public domain (http://silks.csb.gov.in). The portal could make a significant impact in the state and a number of sericulture expansion activities have been taken up based on the study.

Key words: Geoportal, geospatial tool, mulberry sericulture, soil site suitability evaluation.

INTRODUCTION

Sericulture is an agro-based, age old industry with considerable employment potential. A very significant characteristic of this industry is its ability to provide gainful occupation for a size-able section of rural mass without dislodging them from their homesteads. The industry qualifies very well as a cottage – based rural industry, which can be practiced keeping in view, economics, technology as also specialization based on small working units, community ownership and common working place and utilizing local labour and resources. It is an effective tool of women empowerment as it can be carried out as a supplementary activity by women which they can align well with domestic activities without moving out of their houses. Different socio-economic studies have affirmed that the benefit-cost ratio in sericulture is the highest among agricultural crops of similar status (http://www.nistads.res.in/indiasnt 2008). Sericulture allows commercialization and diversification of farm enterprises. It is also an environment friendly farm activity because the food plants of Mulberry, Tasar, Eri and Muga silkworm are perennial crops protecting the soil from erosion. Employment generation in various sericulture activities in the country was estimated 82.50 million persons during 2015-2016. In India, sericulture is practiced largely by tribal communities. Meghalaya state is also not an exception. Among all the other parts of the country, Meghalaya produces both mulberry and non-mulberry silks consisting three types of silk out of the four varieties available in the world. Eri is produced extensively in almost all the areas of the state. It is reared not merely for silk production but also for its food value. The temperate climate of the state is suitable for the production of Bi-voltine mulberry silk which is in great demand. Average Mulberry raw silk production in Meghalaya is 10 Metric Ton during 2008 to 2017. The production reached an all time high of 28 Metric Ton in 2017 and a record low of 1 Metric Ton in 2012 (https://www.ceicdata.com/datapage/charts/o_india_textile-production-mulberry-raw-silk-meghalaya). Directorate of Sericulture and weaving, Govt. of Meghalaya has its own, 11 seed farms, 6 for Mulberry, 3 for Eri and 2 for Muga. There are 9 nurseries to raise planting materials in different districts and two training institutes located at Ummulong (Sericulture) and Mendipathar (Weaving) which are meant for imparting various courses of training and also issue of certificates. Sericulture and weaving in Meghalaya are the two most important cottage based, eco-friendly industries in the rural areas. These twin industries portray the cultural ethos and rich heritage of the people of the state. In Meghalaya, around 15,900 families are involved in handloom activities and 16,000 families in sericulture farming (http://megseriloom.gov.in/about_us.html, 2020).

India is the second largest producer of silk in the world with the total raw silk production of 35,261 MT during 2018-2019 which has increased by 10.52 per cent over the previous year, 2017-18 (31,906 MT). Among the four varieties of silk produced in 2018-19, Mulberry accounts for 71.50 per cent (25,213 MT), Tasar, 8.44 per cent (2,977 MT), Eri, 19.40 per cent (6,839 MT) and Muga, 0.66 per cent (232 MT) (https://economictimes.indiatimes.com/industry/cons-products/garments-/-textiles).

Even though our country is the second largest producer of silk in the world, it is limited to a few pockets and there was a sharp decline in mulberry area in some traditional mulberry silk producing states like Andhra Pradesh and Tamil Nadu. Sericulture industry has been struggling to cope with competition from countries, such as China and Japan, and government intervention in terms of regulating import duty was sought as early as 1938 (Rao, 1938). There is tremendous scope for improving silk production and quality by expanding sericulture to new potential areas and supporting farmers with up-to-date scientific information through appropriate dissemination system. In this context, geospatial tools comprising remote sensing (RS), geographical information system (GIS), global positioning system (GPS) and web technology have the potential of integrating, analyzing and disseminating satellite derived information for further expansion of sericulture in the country. Central Silk Board (CSB) has been pursuing the application of satellite remote sensing (RS) for sericulture development ever since the launch of the first operational remote sensing satellite, IRS-1A in 1988 (Navalgund *et al.*, 1991). CSB and ISRO in collaboration with the concerned State Sericulture / Textiles Departments applied the technology of RS and GIS for mulberry acreage estimation, garden condition assessment and for identifying suitable areas for introducing sericulture in non-traditional states (Nageswara Rao *et al.*, 1991; CSB, 1994).

ISRO and CSB carried out a joint venture, called SPAARS (survey of potential and actual area under sericulture with remote sensing), for mapping potential and actual areas under sericulture at 1:250,000 scale. Because of the coarse mapping scale, the information derived could not meet the requirement for district and block / taluka level planning. Later, an ambitious plan was taken up by CSB for implementing in 2008–09 to 2013–14 period, to identify and map additional potential areas for development of mulberry sericulture in 108 priority districts of 24 states of India. CSB and North Eastern Space Applications Centre (NESAC) in collaboration with State Remote Sensing Centres have recently completed the national project entitled "Applications of Remote Sensing & GIS in Sericulture Development" covering 108 districts from 24 states of the country (Handique *et al.*, 2016). Realizing the advantage of geospatial tools and web technology for expanding sericulture in the country, the study has been extended to another 70 priority districts covering 25 states of India. Under this project, NESAC has carried out the study in Jaintia Hills district of Meghalaya (Figure 1). The

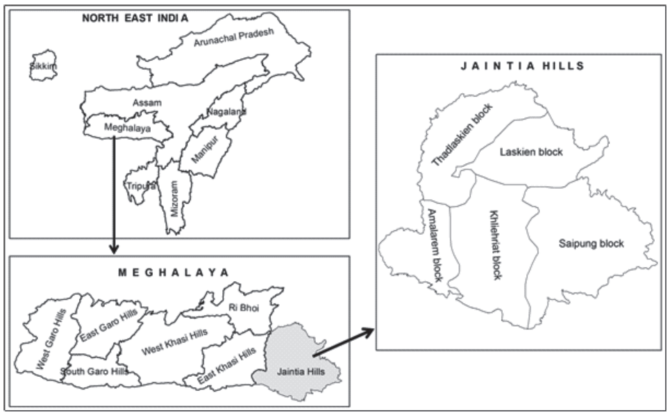

Figure 1: Location of the study area

study area was selected in consultation with officials from Directorate of Sericulture and weaving, Govt. of Meghalaya. Since many farmers are already practicing mulberry sericulture in the district, the state department has suggested taking up the study in Jaintia Hills district. It was also envisaged to update the geoportal SILKS by integrating the potential area maps along with soil, slope and other natural resources map and other non-spatial information collected from state sericulture department and CSB at district level.

MATERIALS AND METHODS

Due to the limited scope of expansion of plantations under silkworm food plants, emphasis was given to identify suitable areas within cultivable wastelands. IRS Resourcesat-2 LISS IV satellite data acquired during 2016–17 was used to delineate cultivable wasteland areas. Visual image interpretation technique was applied to extract various wasteland classes existing in the study area. Various scene elements, such as tone, texture, shape, size and association were considered during image interpretation. Ground truth data were collected to confirm various land use classes (Lillesand *et al*., 2004).

Evaluation of land, water resources and climatic requirements is the prerequisite for identifying potential areas for sericulture development that includes growing silkworm food plants and rearing of silkworms (Sys, 1985; Sys *et al*., 1991, 1993). Suitable areas for mulberry sericulture were identified based on evaluation of soil site suitability following the FAO guidelines (1976, 1983, 1985, 1990 and 2007). It provides information about different opportunities and constraints for use of the land and therefore, helps to take decision on optimal utilizations of resources, which is an essential prerequisite knowledge for land use planning and development. Moreover, during soil site suitability analysis, main limiting factors (*viz*., soil texture, drainage, fertility and slope) for the growing of crops are identified. This enables decision makers *viz*., land use planners, land users and agricultural support services to develop a crop management plan so that such constraints could be overcome to increase the productivity. Land are categorized into different suitability classes and sub classes based on climate, the terrain characteristics, soil properties *viz*., depth, texture, drainage, soil pH *etc*.

The existing soil map prepared at 1:50,000 scale by the North Eastern Space Applications Centre was used to generate four most important parameters *viz*., texture, drainage, depth and pH. The slope map was derived from 10m Carto DEM generated under SISDIP project for Meghalaya at NESAC. Temperature, humidity and rainfall map were generated by interpolating data collected from the class-I observatories of IMD and Automatic Weather Stations (AWS) established by ISRO. Different thematic maps related to soil, slope and climate were overlaid in GIS environment (ArcMap 10.3) and by using overlay function of Analysis Tools of ArcGIS software, a composite layer was prepared. The composite layer with attributes of all input layers was used to compare the requirements of mulberry sericulture with the existing land quality and values of degree of limitation ranging from 0 (suggesting no limitation) to 4 (suggesting very severe limitation) were assigned (Sys *et al*., 1993).

Table 1: Criteria for determination of land suitability classes

Suitability class	Criterion
S1: Highly suitable	Land units with no or only 4 slight limitations
S2: Moderately suitable	Land units with more than 4 slight limitations and / or no more than 3 moderate limitations
S3: Marginally suitable	Land units with more than 3 moderate limitations and / or one or more severe limitation
N: Not suitable	Land units with very severe limitation

Suitability classes of land were assigned according to the number and the intensity of limitations and classified as Highly Suitable (S1), Moderately Suitable (S2), Marginally Suitable (S3) and Not Suitable (N) (Table 1). Suitability sub classes were assigned based on major limitations or main kinds of improvement measures required for mulberry sericulture (FAO guidelines, 2007.

RESULTS AND DISCUSSION

Seven major land use classes were identified from the LISS IV images of year 2016-17. From the study, it is observed that treeclad areas are the most dominant land use that covers 57.61 % area followed by wastelands and forest that covers 25.12 % and 9.91 %, respectively. The wastelands are mostly open scrub (24.5 %), dense scrub, stony / barren rocky and riverine sands. In the forest area, mainly evergreen / semi evergreen plant species are available. Though agriculture is the mainstay of the district, the area under agriculture is only 3.30 % of the study district. Built up and water body areas occupy only 3.02 % and 0.95 %, respectively. Areas of very negligible size are found under shifting cultivation (0.09 ha).

The open and dense scrub lands (931 sq. km) which are cultivable, were considered for mapping of areas suitable for expansion of mulberry sericulture in the district. From the study, it is observed that 912 sq. km (98 %) of areas are suitable for expansion of mulberry sericulture. Only 19 sq. km of areas are not suitable for mulberry sericulture because of very steep slopes and strongly acidic soil (Figure 3). From the study, it is found that marginally suitable areas (46.71 %) are the highest which are mostly distributed on hill slopes (30-45 %), with coarse loamy soil texture and strongly acidic soil. Land units with no limitation or with a few / slight limitations are classified as highly suitable areas that cover about 21.23 % of the study area and these areas are found in very deep to deep soil with slightly acidic soil pH on hill slope (less than 15 %). Moderately suitable areas are found in moderately acidic soil with moderate soil depth on hill slopes (15-30 %) which occupy about 32.06 % of the area (Figure 2). Suitable areas are distributed in all 5 blocks of the study

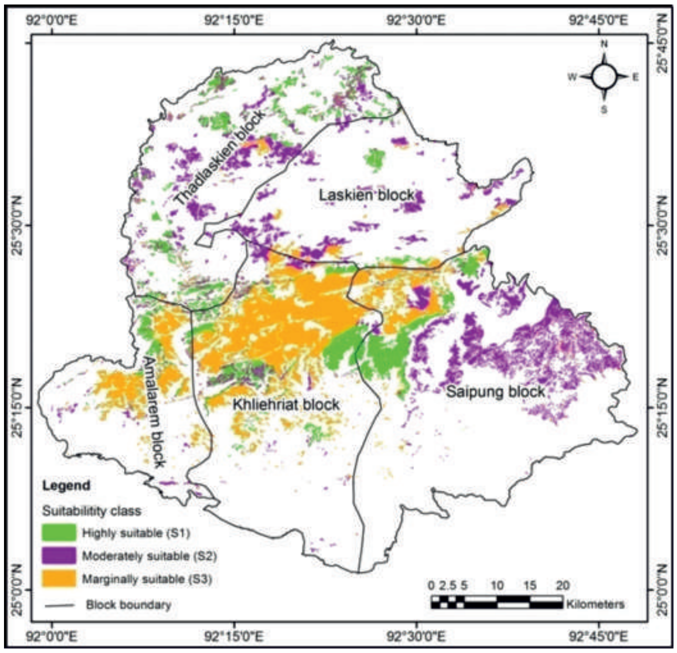

Figure 2: Areas suitable for expansion of mulberry sericulture in the study area

districts (Table 2). Total suitable areas are found the highest in Khliehriat block followed by Saipung, Thadlaskien, Amalarem and Laskein block (Table 2). Highly suitable areas are mostly distributed in Thadlaskien (32.18 %), Khliehriat (28.68 %) and Saipung (24.55 %) blocks (Figure 3).

Based on problems of soil and topography which causes various degrees of limitations for growing of mulberry plants, suitability classes were divided into 13 sub classes (Table 3). It is observed that slope, soil texture, soil depth and soil fertility (acidity) are the major limiting factors / problems because of which maximum of areas belong to marginally and moderately suitable categories for mulberry plantation expansion (Table 4). Based on

Table 2: Block-wise area (ha) under different suitability classes

Block	Suitability class			Total Area (ha)	% area
	High (S1)	Marginal (S3)	Moderate (S2)		
Laskien	926.67	2181.13	4961.57	8069.38	8.84
Amalarem	1899.62	7186.31	1104.28	10190.21	11.17
Thadlaskien	6232.93	1545.03	7674.05	15452.00	16.94
Saipung	4756.67	7284.97	12797.61	24839.26	27.22
Khliehriat	5555.81	24422.61	2713.13	32691.54	35.83
Total	19371.70	42620.05	29250.64	91242.40	100.00

Table 3: Block-wise area (ha) under different suitability sub classes

Suitability Sub class	Block					
	Amalarem	Khliehriat	Laskien	Saipung	Thadlaskien	Total (ha)
S1	1899.61	5555.81	926.67	4756.67	6232.93	19371.71
S2f	135.95	88.23	-	1032.92	-	1257.11
S2s	68.86	715.85	3137.13	3866.99	3320.48	11109.32
S2sf	31.73	58.63	-	0.18	-	90.55
S2t	702.27	1565.98	121.00	610.01	3003.89	6003.16
S2ts	123.73	261.22	1703.45	7286.17	1349.67	10724.24
S2tsf	41.73	23.21	-	1.35	-	66.28
S3f	1734.20	3093.63	1327.44	300.62	458.09	6914.00
S3s	5035.48	20451.91	469.01	5165.08	192.51	31314.00
S3sf		4.48	-	8.26	-	12.74
S3t	309.59	418.37	356.98	1692.80	883.54	3661.27
S3tf	28.53	164.58	26.66	35.24	7.43	262.44
S3ts	78.52	287.91	1.04	82.81	3.45	453.72
S3tsf	-	1.75	-	0.16	-	1.91
Total	10190.20	32691.57	8069.38	24839.28	15452.00	91242.43

Alphabets in 1 st column stand for suitability sub classes as per FAO land suitability classification; S1, S2 and S3 designate suitability classes as mentioned in Table 1; f, s and t stand for limitations due to soil fertility, soil texture and slope, respectively as mentioned in Table 4.

problems / limitations of the land, land users and planners can make decisions on crop management strategies to increase the crop productivity.

Development of SILKS geoportal

The SILKS geo-portal is based on client server principle where a browser sends request for a map through HTTP. The request is processed by the Mapserver, *e.g.*, fetching of map from database as per extend and then map styling as per symbologies defined in the mapfiles and finally output is sent to the web server which is then rendered on client's browser. The Portal framework is based on Mapserver and PHP / Mapscript. Mapserver has the ability to display dynamic maps via the internet and enable map querying on raster and vector database formats. The tools have been customized using Mapscript APIs. This framework comprises of set of configuration files for configuring Mapservermapfiles and layout and order of layers in the GUI. In our case, we use PHP to call Mapservermapscripts to create GIS tools, such as zoom-in, zoom-out *etc*. Mapscripts will take geospatial data or user click instances as output as some images, such as jpeg or png. A brief schematic diagram of SILKS portal is shown in Figure 3. The Mapservermapfile defines the inter-relationships among various objects within a given layer to be drawn. It also tells where the map data are to be fetched or connections to be established with the database storage. The definitions on how the layers are to be drawn based on layer attributes and files are explicitly described here. Mapfiles are then called within the portal framework configuration file where layer groupings, searching criteria and GIS tools to be made available on the GUI are added. The Javascripts are used to properly set the settings of each tool and their functionalities. The XMLs are used to store other relevant metadata of each layer and toolset. All the layers are made accessible through the web framework. The layouts, themes and icons have been judiciously selected and tested on the latest browsers for proper functionality and issues are resolved with minor modifications.

The SILKS geoportal was hosted in the public domain and can be accessed live at http://silks.csb.gov.in (Figure 4). It provides interactive maps of site suitability for silkworm food plants and other relevant spatial information, such as soil map, slope map, land use land cover map *etc*. for taking up planning activities. In addition, it also has other

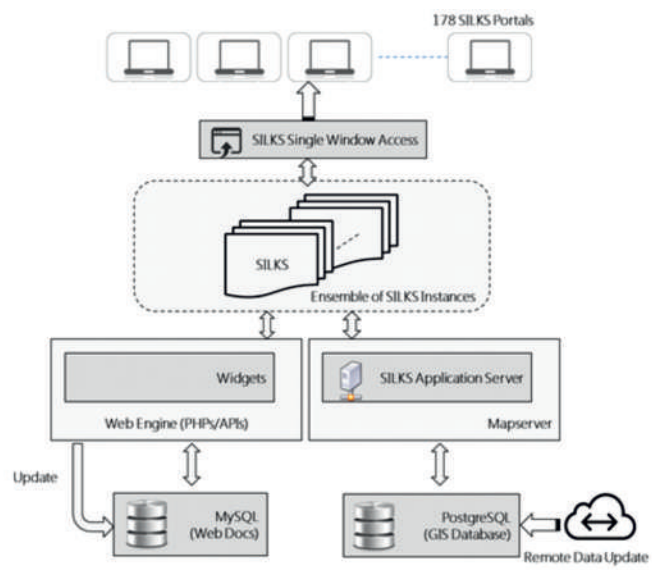

Figure 3: SILKS application architecture

Table 4: Different suitability sub classes and limitations / problems of the soil site

Sub class	Area (ha)	% area	Limitation / problem
S1	19371.71	21.23	No limitation
S2f	1257.11	1.38	Soil fertility (moderately acidic soil)
S2s	11109.32	12.18	Soil texture
S2sf	90.55	0.10	Soil texture and soil fertility
S2t	6003.16	6.58	Slope
S2ts	10724.24	11.75	Slope and soil texture
S2tsf	66.28	0.07	Slope, soil texture and soil fertility
S3f	6914.00	7.58	Soil fertility (strongly acidic soil)
S3s	31314.00	34.32	Soil texture
S3sf	12.74	0.01	Soil texture and soil fertility
S3t	3661.27	4.01	Slope
S3tf	262.44	0.29	Slope and soil fertility
S3ts	453.72	0.50	Slope and soil texture
S3tsf	1.91	0.00	Soil texture and soil fertility
Total	91242.43	100.00	

local planning and advisory services modules, specific for the districts and in their local languages. The portal is now made available in 12 languages, *viz*., English, Hindi, Telugu, Kannada, Assamese, Bengali, Mizo, Manipuri, Khasi, Garo, Ao-Naga and Sumi Naga. It has 16 major non-spatial modules and 2 spatial modules. Non-spatial modules are grouped into 3 categories, namely planning services, farmer's services and other services. Spatial layers are kept as natural resources information. Under natural resource information, layers are kept in two modules, namely potential sites for silkworm food plants and meteorological information. The available modules under planning services are on silkworm food plants production technologies, techniques of rearing silkworm, diseases and pest management of silkworm food plants, improved varieties of silkworm food plants, species of silkworm, processing of cocoons, infrastructure and equipment and allied sectors and occupations. Other services has modules *viz*., micro credit and self-help group, sericulture marketing, seed distribution centers, reeling & weaving centers and schemes and grants for farmers. Farmer's services module consists of weather and weather advisory, disease and pest forewarning and support services. Regular updating of information content in the portal requires continuous support from all stakeholders based on feedback from users, particularly the sericulture farmers. A series of hands on training was provided to officials of state sericulture department and other stakeholders on the use of SILKS geoportal. Recently, SMS based sericulture advisory was started in support of India Meteorological Department, which would be linked to SILKS portal for maintaining the database and evaluate feedbacks. A case study made by the Central Silk Board in NE region reveals more than 86 % accuracy in terms of mapping of potential areas for sericulture development, and has been boosting development of sericulture in the region. The SILKS portal has recorded more than 35,000 hits reflecting its wide usage through internet. Regular updating of information in the language of the wide range of users will be critical for successful use of the geoportal. Each stakeholder of the sericulture sector

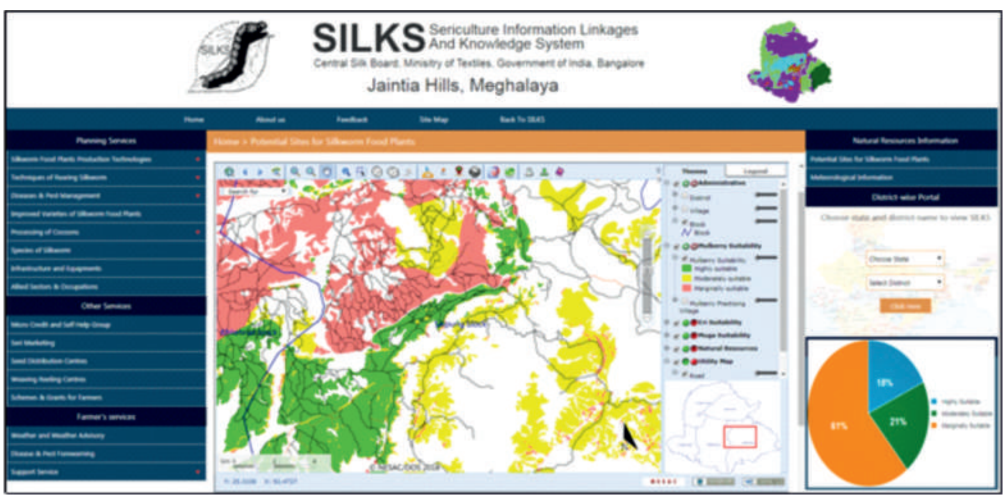

Figure 4: A page of SILKS geoportal (part of Jaintia Hills district, Meghalaya)

has to play an active role in utilizing the services of the portal, which will support expansion of sericulture in the north eastern states of India.

The SILKS mapping framework has new dynamic tools embedded within the map framework to interact with the map and extract useful information. The legend has been appropriately placed and dynamically displays the legend for the active / selected layers. The print / download tools allow for downloading and printing of the customized maps as per user's choices and selections. The GUI framework has been developed using various open source tools and follows OGC specifications for data interoperability. The necessary tools have been built on top of framework for basic navigation, map query, analysis, print and exporting of maps. The database schema has been designed and various data abnormalities have been properly checked before storing in the RDBMS. The Portal framework is based on Mapserver for rendering and processing of GIS maps on the browser and enables map querying on raster and vector database formats. The PHP / Mapscript APIs have been used to customize the web plugins. This overall SILKS framework comprises of set of configuration files for configuring Mapservermapfiles and layout and order of layers in the GUI. The map viewer can be expanded to full screen size for better visualization and interaction of the maps present within the district portal. Figure 3 shows the new mapping framework used for the portal.

The SILKS geoportal was demonstrated to officials of Directorate of Sericulture and weaving, Govt. of Meghalaya. Based on their feedback, the geoportal was updated and trained officers of the study district on utilization of database for expansion of mulberry sericulture. The findings of the study is being utilized by the funding agency, Central Silk Board and state sericulture department for expansion of mulberry sericulture in the district.

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REFERENCES

CSB (1994) *Manual of Satellite Remote Sensing Applications for Sericulture Development*, Central Silk Board, Bangalore.

FAO (1976) A framework for land evaluation. *Soil Bulletin*, Food and Agriculture Organization, United Nations, Rome, Italy, No. 32.

FAO (1983) Guidelines: land evaluation for rainfed agriculture. *Soil Bulletin*, Food and Agriculture Organization, United Nations, Rome, Italy, No. 52.

FAO (1985) Guidelines: land evaluation for irrigated agriculture. *Soil Bulletin*, Food and Agriculture Organization, United Nations, Rome, Italy, No. 55.

FAO (1990) *Manual of Sericulture*, United Nations, Rome, Italy.

FAO (2007) A framework for land evaluation. *Soil bulletin*, Food and Agriculture Organization, United Nations, Rome, Italy, No. 6.

Handique B. K., Das P. T., Goswami J.,Goswami C., Singh P. S., Prabhakar C. J., Bajpeyi C. M. and Raju P. L. N. (2016) Expansion of sericulture in India using geospatial tools and web technology. *Curr. Sci.*, **111 (8)**: 1312 -1318.

Lillesand T. M., Kiefer R. W. and Chipman J. W. (2004) *Remote Sensing and Image Interpretation*, 5^{th} Edition, John Wiley, New York. http://www.nistads.res.in/indiasnt 2008

Nageswara Rao P. P., Ranganath B. K. and Chandrashekhar M. G. (1991) Remote sensing applications in sericulture. *Indian Silk*, **30**: 7–15.

Navalgund R. R., Parihar J. S., Ajai and Nageswara Rao P. P.

(1991) Crop inventory using remotely sensed data. *Curr. Sci*., **61 (3&4)**: 162–171.

NESAC (2015) *Application of Remote Sensing and GIS in sericulture development*, North Eastern Space Applications Centre, Umiam, Meghalaya.

Rao R. N. (1938) Protection for Indian Sericulture. *Curr. Sci*., **7 (6)**: 263–266.

Sys C. (1985) *Land Evaluation: Part I, II & III*, State University Ghent Publication, Belgium.

Sys C., Van Ranst E. and Debaveye J. (1991) *Land evaluation. Part 1: Principles in land evaluation and crop production calculations*. Agricultural publications 7, 1. General Administration of Development Cooperation of Belgium, Brussels.

Sys C., Van Ranst E. and Debaveye J. (1993) *Land evaluation. Part 3: Crop requirements*. Agricultural publications 7, 3. General Administration of Development Cooperation of Belgium, Brussels.

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Research Paper

DEVELOPMENT OF MOTORIZED TASAR SILK REELING CHARKHA FOR ENHANCEMENT OF YARN PRODUCTIVITY AND QUALITY

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ABSTRACT

This study demonstrates the designing and fabrication of a Motorized Tasar Reeling Charkha (MTRC) with 4 ends which can be operated by single person. The speed of the reel can be set between 30 to 50 m /min and 350-400 g of 60 denier tasar silk yarn can be produced per day by single reeler. Also, jetteboutte being incorporated, it facilitates easy casting of tasar silk filament from single cocoon during mending of broken ends. The machine consists of simple driving mechanism which a reeler can maintain and repair easily. The size (denier) deviation of tasar silk yarn produced by this machine ranges from A to C grade, whereas other characteristics are between 1 and 3 as assessed with standard norms.

Key words: Charkha, croissure, jetteboutte, lea, non- broken, skein.

INTRODUCTION

Tasar silk owned by the tropical tasar silkworm, *Antheraea mylitta* Drury is well known for its luster, beauty, elegance and sensuality among the four silk varieties available in India. After harvesting, the cocoons are subjected for reeling to produce continuous filament yarns of desired denier. Production of yarn from tropical tasar cocoons was carried out earlier by using conventional thigh reeling (natwa) technique which is being practiced even now, though partially. But, it is unhygienic to the reeler as well as odd looking from social aspects. In addition, one reeler can produce hardly 40 to 50 g per day of eight hours by which minimum required earning also cannot be achieved. Different reeling appliances have been developed in the past decades for improvement of productivity and quality, such as Trivedi Reeling Machine, CTRS Reeling Machine (Jolly *et al*., 1979) *etc*. Later, a Motorized Reeling Cum Twisting Machine was developed for better productivity and quality (Sonwalkar, 1993; Kariappa *et al.*, 2005), as well as Wet Reeling Machine (Gupta *et al*., 2016). But the productivity is restricted between 150 to 200 g only. This is because there is speed limitation during filament withdrawal of tasar cocoons as well as different constraints of the machine. Before reeling, tasar cocoons are subjected for assessment of quality parameters on the basis of cocoon shell weight, filament length, filament denier and non- broken filament length (NBFL) in order to anticipate its reeling performance. Among the different quality characteristics, NBFL is the most important one from reeling point of view because reeling speed is directly proportional to NBFL (Lee, 1999). Mulberry silk yarn is produced by using state of the art reeling machines with higher speed (Somashekhar and Kawakami, 2002), whereas tasar is reeled at very low speed by using conventional machine (Sonwalkar, 1993; Kariappa *et al*., 2005). Maximum values for NBFL exist in the lower range with respect to its average value for tropical tasar cocoons because of excessive breaks during filament withdrawal (Das and Ghosh, 2007). The average NBFL for tropical tasar cocoons ranges between 150 and 250 m for different ecoraces, whereas it is above 500 m for mulberry variety due to very few breaks during filament withdrawal. This parameter establishes the reason for higher reeling speed at 100 m/ min in the case of mulberry as against only 30 to

50 m/min for tropical tasar cocoons (Munshi *et al*., 2015; Chattopadhyay *et al*., 2018). In addition, due to filament lapping on delivery roller and entanglements as well as breaks occurred due to excessive tension during filament withdrawal; frequent stoppages occur which cause loss of additional productivity (CSB, 2015).

Reeling of tasar cocoons are generally carried out in remote rural areas under decentralized sectors. So, the main requirement of the reeling machine is the simplest driving system along with either manual or electric or solar power operated system. Central Tasar Research and Training Institute (CTRTI), Central Silk Board, Ranchi has been expediting research activities for improvement of quality characteristics of tasar cocoons as well as design and fabrication of reeling machines with the simplest driving system suitable for rural tasar clusters. Twin Charkha developed by CTRTI, Ranchi is a simple machine not involving too many mechanisms and friction bearings (CSB, 2012). There are two wooden swifts of 1.50 m circumference mounted parallel on a common iron angle frame driven manually through handle attached with gear and bevel arrangement between the swift. The traverse mechanism for maintaining the width of laying hank on the swift is driven by thread belt and pulley arrangement. Three persons are required for operating this machine; one for rotating the handle and the other two for reeling. Each swift has four ends and the reelers sit on wooden stools facing the rotating swift. In the event of break, the swift can be stopped without affecting or stopping the other swift by detaching swift shaft from handle drive. However, one side (4 ends) of the machine has to stop during ends breaks for mending. Tasar cocoons are reeled in semi-moist condition on this machine. The path of the yarn is also simple. Filament ends from required number of cocoons are unraveled by the direct pull generated through rotation of swift and then passed through the thread guide and traverse guide before winding on wooden swift. The production capacity of this machine is about 1 kg untwisted tasar yarn with 60 denier fineness for eight hours operation. So, it is about 350 g per operator, since three persons are involved during reeling. During trials, it was found that the person rotating handle suffers from drudgery. Also, the presence of gum in the yarn makes it to stick on the surface of the swift bars resulting difficulty in removing the hank by collapsing it. Although in the event of casting a filament, it is dragged with other ends to the swift thereby producing hairs, loops *etc*. in yarn hank. Since untwisted yarn is produced by this machine, the cohesion between individual filaments is very low which causes difficulties during warping and weaving process. To overcome the difficulties as described above, CTRTI, Central Silk Board, Ranchi has taken up an initiative to design and fabricate a reeling machine with the following objectives.

1. Design and fabrication of a Motorized Tasar Reeling Charkha (MTRC) consisting of simple driving system suitable for tasar reeling cluster in rural areas.
2. Production of untwisted tasar silk yarn with better quality characteristics in terms of cohesion, tenacity and evenness, suitable for weft in fabric.
3. Reduction of drudgery to reelers through easy operating system.
4. Maximization of productivity as compared to other reeling appliances and significant increase in the earning of reelers.

DESIGN AND FABRICATION

Based on the concept of Twin Charkha, CTRTI, Ranchi, further designed and fabricated a modified model of New Reeling Machine / Charkha with 4 ends which can be operated by single person (Paul *et al*., 2013). A new concept of cocoon vibrator during reeling was introduced which helps to retain original shape of cooked cocoons thereby facilitating easy casting. The swift circumference is 1.5 m operated by 0.25 HP motor. Three croissure pulleys attachment through the yarn path provides better cohesion between filaments along with compactness. The yarn guides maintain the position of yarn for each end thereby maintaining uniform hanks of tasar yarn. Aluminium reeling basin consists of four sections which prevents entanglement of single filament between the individual ends. The speed of the reel is at 50 m /min and

275-300 g of 60 denier tasar yarn can be produced per day by single reeler. But, it was found very difficult for the reeler to identify the cocoon for which the yarn end has broken as well as for casting / mending the filament during breaks. The lacunae as mentioned above for New Reeling Machine have been overcome by development of Motorized Tasar Reeling Charkha (MTRC) by CTRTI, Ranchi. In this machine, the oscillating motion of cocoon tray (basin) is removed. In addition, for each end, jetteboutte is being incorporated which facilitates easy casting of tasar silk filament from single cocoon during mending of broken ends. Hence, the quality of tasar yarn will be better due to less defects like loose ends, slubs, hairs *etc*. In this machine, speed alteration facility by regulator has been provided which alters the motor rpm. So, the reeler can set the machine speed as per his convenience according to cocoon quality. The machine consists of simple driving mechanism which the reeler can maintain and repair easily.

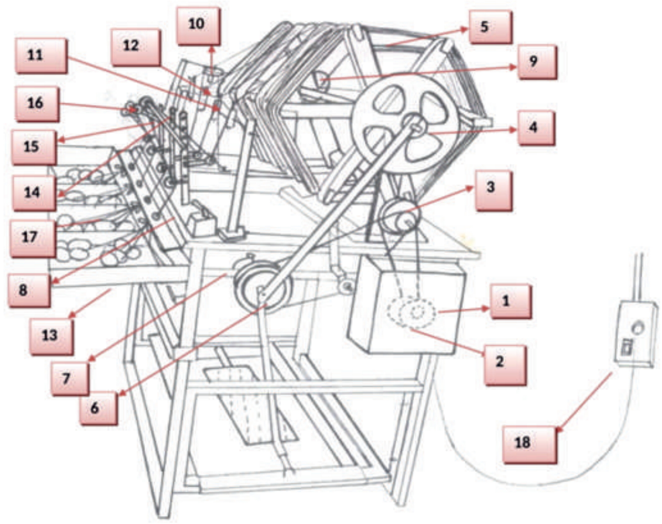

Figure 1: Sketch of Motorized Tasar Reeling Charkha

1. 0.25 HP Single Phase Motor; 2. Motor Pulley; 3. L.H.S. Pulley; 4. Swift Pulley; 5. Wooden Bar; 6. Intermediate Pulley; 7. Jetteboutte Pulley; 8. Jetteboutte; 9. R.H.S. Pulley; 10. Polymer Pulley; 11. Traversing Rod; 12. Yarn Guide; 13. Cocoon Tray; 14, 15 & 16. Croissure Pulleys; 17. Cocoons; 18. Electric Supply

The newly developed MTRC (Figures 1 and 2) is driven by 0.25 HP single phase motor (1). The motor pulley (2) transfers motion to the carrier (LHS) pulley (3). By revolution of the hexagonal reel swift pulley (4) from carrier pulley (3), tasar filament yarn is wound on the wooden bar (5) of the swift. From carrier pulley (3), the motion also transfers to intermediate pulley (6) by belt driving system and then motion is transferred to Jetteboutte pulley (7) which in turn revolves the Jetteboutte (8) for each end. Rotation of Jetteboutte (8) helps for easy mending of tasar filament yarn during breaks. There are 4 ends of Motorized Tasar Reeling Charkha (MTRC) and Jetteboutte is incorporated for each end. From the other side of the reel swift, the motion is transferred by RHS pulley (9) to another nylon polymer pulley (10) responsible for traversing motion. The rod for traversing motion is equipped with yarn guide (12) for each end connected with nylon polymer pulley (10). By rotation of polymer pulley (10), to and fro motion for traversing rod (11) occurs. The traversing rod (11) facilitates maintaining of hanks / leas width on wooden bars (5) of swift so that no entanglements occur for filaments between ends. The cocoon tray (13) has four

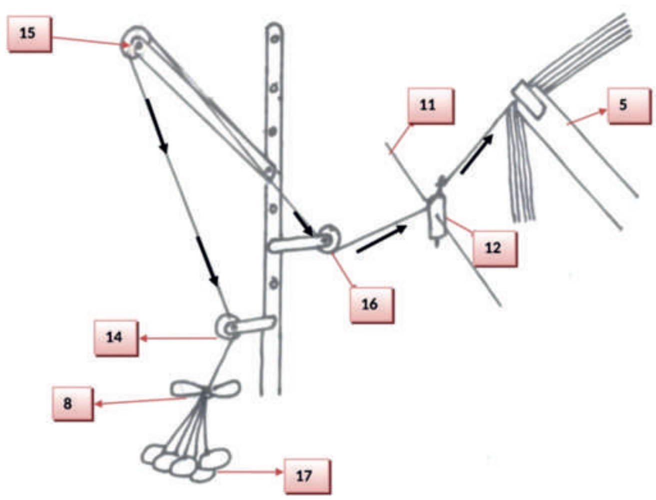

Figure 2: Sketch of yarn path during reeling by Motorized Tasar Reeling Charkha

5. Wooden Bar; 8. Jetteboutte; 11. Traversing Rod; 12. Yarn Guide; 14, 15 & 16. Croissure Pulleys; 17. Cocoons

sections which prevents mixing of cocoons between each end. As per the desired yarn denier, number of cocoons are decided and kept in each tray based on the assessment of single filament denier. For each end, yarn from required no. of cocoons (17) is passed through Jetteboutte (8), three croissure pulleys (14, 15 & 16) and then through yarn guide (12) of traversing rod before winding on the wooden reel swift bars (5). The circumference of the wooden reel swift is 1.5 m.

The machine parts consist of the simplest design that are easily available. Also, fabrication of each machine part even in rural areas in the case of replacement, can be done easily. Since no complicated driving systems are incorporated, it works out easy for the reelers to maintain. The hanks produced by this machine has a circumference of 1.5 m which can be directly taken for weft preparation (pirn winding) by the weaver for fabric production using handlooms. So, one operation *i.e.*, "Re – reeling" can be eliminated which is commonly followed for other reeling machines as post reeling operation.

Evaluation of MTRC through multi-locational field trials

During January 2015, multi locational trials were organized by Central Silk Board, Ministry of Textiles, Government of India at different places of India *i.e.*, Bero, Ranchi (Jharkhand), Godda (Jharkhand), Champa (Chhattisgarh), and Tantipara (West Bengal) using the prototype model of this machine (Figure 3). From trials data, it was found that maximum production per 8 hours (day) can be achieved by this machine and as per reelers' feedback, it is very easy to operate Motorized Tasar Reeling Charkha as compared to other reeling machines. The average production was found at about 300 g per day of 8 hours with 60 denier tasar filament yarn fineness. The

Table 1: Quality characteristics of tasar reeled yarns produced by Motorized Tasar Reeling Charkha (MTRC)

Quality parameter	Tasar cluster				Average
	Ranchi, Jharkhand	Godda, Jharkhand	Champa, Chhattisgarh	Tantipara, West Bengal	
Yarn fineness (denier)	62.60	72.00	90.40	69.70	73.70
Tenacity (g/d)	1.90	2.10	2.30	2.10	2.10
Breaking elongation (%)	15.00	19.00	20.00	21.00	18.80

working group constituted by Central Silk Board recommended this machine for each tasar silk cluster as the best, regarding production of tasar silk filament yarn to be used as weft. The quality characteristics of the tasar filament yarns produced in field trials are provided in Table 1.

New model of Motorized Tasar Reeling Charkha

The new model of MTRC is illustrated in Figure 4.

Efforts were continued for reducing the power consumption of the MTRC in order to operate the machine by solar power. In this new model, the driving systems are made very simpler with reduction of gears and pulleys as compared to the prototype one. This machine has been approved and recognized under Silk Samagraha Scheme of Central Silk Board, Ministry of Textiles, Government of India.

Figure 3: Prototype of Motorized Tasar Reeling Charkha

Figure 4: New model of Motorized Tasar Reeling Charkha

Quality characteristics and grading of tasar silk yarns produced by MTRC

Standard testing procedures as well as norms for different quality parameters regarding grading purpose are available for mulberry raw silk yarns, such as Bureau of Indian Standards (BIS 15090, 2002), International Organization for Standardization (ISO 21046, 2018 & ISO 15625, 2014), Chinese (Lee, 1999) *etc*. But, no such testing procedures or standards regarding grading are available for raw silk yarns produced from tropical tasar cocoons (*A. mylitta*). It's only recently that some standard testing procedures as well as norms for grading have been established (Bhat *et al*., 2019). The norms for different quality parameters are given in Table 2.

Tasar reeled yarns produced by the new model of MTRC were assessed for different quality characteristics as mentioned in Table 3.

The above quality characteristics were compared with the standard norms (Table 2) and it was found that size (denier) deviation existed from A to C, whereas other characteristics were between 1 and 3. So, it can be confirmed that very good quality yarns can be produced by the new model of MTRC with enhancement of productivity.

Table 2: Norms / standards for grading of tasar raw silk yarns' characteristics

Characteristic	Classification	Grade					
		A =<	B =<	C =<	D =<	E =<	F >
Co- efficient of variance (CV) (%) of size (denier)	40 d (4.5 tex) & below	8	12	18	25	30	30
		9	13	20	30	36	36
		10	16	24	32	38	38
		12	18	26	34	40	40
Class		**(1)**	**(2)**		**(3)**	**(4)**	**(5)**
Winding breaks (no.)	80 d (8.94 tex) & below	4	5		7	10	10
	Above 80 d (8.94 tex)	3	4		6	8	8
Class		**(1)** >=		**(2)** >=		**(3)** <	
Tenacity (g/d)		2.5		1.8		1.8	
Breaking elongation (%)		22		18		18	
Class		**(1)** >=		**(2)** >=	**(3)** >=		**(4)** <
Cohesion (no. of strokes)		20		15	10		10

Courtesy: CSTRI, Bengaluru & CTRTI, Ranchi.

Table 3: Quality characteristics of tasar reeled yarns produced by new model of Motorized Tasar Reeling Charkha

Sample	Quality characteristic						
	Winding breaks (breaks/5 skeins/30 min)	Size (denier)	CV (%) of size	Tenacity (g/d)	CV (%) of tenacity	Breaking elongation (%)	CV (%) of breaking elongation
1	9	82.63	9.31	1.90	11.60	23.70	7.60
2	13	77.89	8.45	2.20	10.10	25.20	13.80
3	11	77.96	7.13	2.00	10.20	23.00	9.60
4	15	72.09	12.02	2.20	14.20	23.20	18.50
5	6	73.59	14.58	2.00	10.30	24.80	4.50
6	5	76.42	15.39	2.30	23.10	24.20	11.60
7	8	76.54	11.14	2.50	10.80	21.70	8.30
8	4	72.36	12.55	2.20	9.20	20.40	10.70
9	2	98.09	19.18	1.90	12.60	22.40	11.90
10	6	70.21	9.13	2.40	8.90	19.30	10.60
11	2	94.62	9.62	2.50	9.00	20.90	11.20
12	5	84.09	8.53	2.20	8.90	18.30	11.30
13	3	77.06	18.24	2.10	15.40	17.80	15.80
14	3	84.29	16.84	2.10	20.00	19.80	15.50

Courtesy: CSTRI, Bengaluru & CTRTI, Ranchi.

Table 4: Cost of production for tasar reeled yarn using MTRC

Particulars	Details	
No. of working days		30
Production/ month (kg)	Reeled yarn (60/70 denier)	9.00
	Waste	3.60
	Pupa	3.00
Cost of machine & equipment (₹)	Motorized Tasar Reeling Charkha (MTRC) - 1 no.	28, 000.00
	Cooking Vessel- 1 no. (22 liters)	2, 500.00
	Cocoon storage rack – 1 no.	2, 500.00
	Yarn storage box- 1 no.	2, 000.00
	Total	35, 000.00
Recurring expenditure / month (₹)	Cocoon Daba 'A' grade 9000 nos @ ₹3.42 per cocoon	30, 780.00
	Chemicals* & fuels	500.00
	Miscellaneous	250.00
	Total	31, 530.00
Earning / month (₹)	Tasar reeled yarn @ ₹4600/- per kg	41, 400.00
	Waste @ ₹500/- per kg	1, 800.00
	Pupa @ ₹100/- per kg	300.00
	Total	43, 500.00
Profit per month (₹)		11, 970.00
Earning / day (₹)		399.00

*Newly developed, sodium carbonate and bi- carbonate cooking process

The cost of production for tasar reeled yarns by using MTRC is presented in Table 4 along with income generated for reelers.

It is revealed from Table 4 that due to higher productivity, the reeler can earn ₹400 per day and the newly developed cooking / softening process in combination of sodium carbonate and sodium bi-carbonate can also be followed (Khan *et al*., 2019).

Summary and conclusion

Central Tasar Research and Training Institute, Ranchi designed and fabricated a Motorized Tasar Reeling Charkha with 4 ends which can be operated by single person. Three croissure pulleys attachment through the yarn path provides better cohesion between filaments along with compactness. The yarn guides maintain the position of yarn for each end thereby keeping uniform skein of tasar yarn. Aluminum reeling basin consists of four sections which prevents entanglement of single filament between the individual ends. The speed of the reel can be set between 30 to 50 m /min and 300-350 g of 60 denier tasar yarn can be produced per day by single reeler. Further, incorporation of the jetteboutte facilitates easy casting of tasar silk filament from single cocoon during mending of broken ends. Hence, the quality of tasar yarn produced will be better due to fewer defects like loose ends, slubs, hairs *etc*. In this machine, speed alteration facility by regulator has been provided which alters the motor rpm. So, reeler can set the machine speed as per his convenience according to cocoon quality. The machine consists of simple driving mechanism which the reeler can maintain and repair easily. The size (denier) deviation of tasar silk yarns produced by this machine varies from A to C grade, whereas other characteristics are between 1 and 3 as assessed with standard norms.

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REFERENCES

Bhat P., Malali K. B., Mitra G., Nanjegowda B., Padaki N. V., Ghosh J., Khan Z. M. S. and Chattopadhyay D. (2019) *Grading of tasar raw silk yarn - development of method and procedures*, Report on concluded project carried out by Central Silk Technological Research Institute, Bangalore and Central Tasar Research and Training Institute, Ranchi under Central silk Board sponsored project, CYF- 7077.

BIS 15090 (2002) *Raw silk - grading and methods of tests (Parts 1 to 11)*, Bureau of Indian Standards, New Delhi.

Chattopadhyay D., Munshi R. and Chakravorty D. (2018) Studies on distribution of filament length and non-broken filament length for tropical tasar and muga silk cocoons vis-à-vis mulberry silk cocoons. *J. Text. Inst.,* **109 (9)**: 1202 - 1207.

CSB (2012) *Report on technology trials in post cocoon sector under special SGSY projects in Bihar and Jharkhand*, Central Silk Board, pp. 20- 21.

CSB (2015) *Report on multi location field trials on tasar reeling machines*, Central Silk Board, Bangalore, India.

Das S. and Ghosh A. (2007) Distribution of natural broken filament length for tasar silks. *J. Nat. Fibres,* **4 (2)**: 1 - 11.

Ghosh J. (2019) *Tasar Plus - Technical Information Leaflet,* Silk Technical Service Centre, Central Silk Technological Research Institute, Central Silk Board, Ministry of Textiles, Government of India, Cuttack, Odisha, India, pp. 6 - 7.

Gupta V. P., Das S. and Sinha S. K. (2016) *Tasar Technology Compendium*: *Tropical and Temperate Tasar Culture: host plant silk rearing, seed production and post cocoon technologies,* Central Tasar Research and Training Institute, Nagri, Ranchi, India. p. 20.

ISO 15625 (2014) *Electronic test method for defects and evenness of raw silk*, International Organization for Standardization, Geneva, Switzerland, pp. 1- 6.

ISO 21046 (2018) *Test method for determining the size of silk yarns*, International Organization for Standardization, Geneva, Switzerland, pp. 1- 6.

Jolly M. S., Sen S. K., Sonwalkar T. N. and Prasad G. K. (1979) Manual on Sericulture, Non-Mulberry Silk*, FAO Agricultural Services Bulletin*, Food & Agriculture Organization of United Nations, Rome, **4 (29)**: 94 – 96.

Kariyappa, Umesha M. and Somashekar T. H. (2005) CSTRI reeling cum twisting machine for tasar and muga. *Indian Silk*, **44 (1)**: 14 – 15.

Khan Z. M. S., Chattopadhyay D. and Sahay A. (2019) Optimization of cocoon softening procedure for tasar eco - races to achieve higher silk recovery, quality and retention of natural colour. *Sericologia*, **59 (3&4)**: 128 – 142.

Lee Y. (1999) Raw silk reeling: Reeling and testing manual, *FAO Agricultural Services Bulletin*, Food and Agriculture Organization of United Nations, Rome, No.**136**, pp. 61 & 107-117.

Munshi R., Chattopadhyay D. and Mitra G. (2015) Quality characteristics and reeling performance of muga and tasar silk cocoons in comparison with mulberry silk cocoons. *Indian J. Nat. Fibres,* **2 (1)**: 21- 28.

Paul T. K., Gahlot N. S., Sinha A. K., Javali U. C., Malali K., Paul A. K., Chattopadhyay D., Ray M. and Dewangan S. (2013) Development of new reeling machine for tropical tasar cocoons. *Annual Report 2012- 13,* Central Tasar Research and Training Institute, Central Silk Board, Ranchi, India, pp. 59- 60.

Somashekar T. H. and Kawakami K. (2002) *Manual on bivoltine silk reeling technology,* Central Silk Technological Research Institute, Central Silk Board, Bangalore, India, pp. 42- 58.

Sonwalkar T. N. (1993) *Handbook of Silk Technology*, 1st Edition, Willey Eastern Limited, New Delhi, India, pp. 72 – 106.

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Research Paper

BABY CORN- AN EXCELLENT AND COMPATIBLE INTERCROP FOR MULBERRY

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ABSTRACT

Effective utilization of natural resources is the main objective of intercropping. Several crops have been tried as intercrop in mulberry garden but, an attempt with baby corn is a new concept in India. Baby corn is one of the varieties of maize (*Zea mays*) and very popular as vegetable in many countries. Baby corn can be grown in all the seasons and in all types of soil under irrigated conditions, as mulberry. A field experiment in this line was conducted in an established mulberry garden at Karnataka State Sericulture Research and Development Institute (KSSRDI), Bengaluru, harvesting five crops of mulberry and baby corn. Results on yield and bioassay parameters reveal the profitability of growing baby corn as intercrop in mulberry, thus providing additional income to the farmer. Mulberry leaf yield ranged from 28,056 to 36,899 kg/ha/yr whereas, baby corn, from 5953 to 8285 kg/ha/yr. Apart from this, 20,980 to 31,409 kg/ha/yr of green fodder could also be obtained. Both corn and green fodder yield make an additional income of ₹3, 43,020 to 4, 87,645 apart from the regular income from sericulture even without spending any extra amount towards baby corn crop except for the expenditure met for seeds and labour spent on seed sowing and crop harvesting. The unique advantage of intercropping in mulberry garden with baby corn is that farmer can take up sericulture along with another agricultural component and practice dairy too, by utilizing the resources at the same time and hence, is a suitable option for small farmers.

Key words: Baby corn, income, intercrop, mulberry, spacing.

INTRODUCTION

Effective utilization of natural resources and suppression of weeds in the garden are the two important advantages of intercropping (Ahsan and Dhar, 1989). Intercropping in mulberry has no adverse effects on both growth and development of mulberry or silkworm, neither cocoon crop, nor its quantity and quality (Shankar, 2002). Though various crops have been tried as intercrop in mulberry garden, baby corn is an all new option. Of late, in Karnataka, farmers have been showing interest towards the system of small tree plantation in mulberry with the spacing of 6'x 6', 8'x 8' and 10'x 10' and this scheme of mulberry plantation provides sufficient space in between mulberry rows for the growth of baby corn and thereby farmer can utilize natural resources effectively. Proper initial establishment of tree mulberry plantation needs a span of 2-3 years. Until then, farmer can make use of mulberry garden for intercropping with baby corn and also, even after the establishment. Baby corn as offshoot of maize (*Zea mays)* is suited to tropical and sub-tropical climate. PAC 792, PAC 793, Pro-agro and Composite (Shakthimaan) are some of the cultivars of baby corn. Presently, more attention is being paid to explore its potential in India for export earning and higher economic returns to the farmers (Ramachandrappa *et al.*, 2004).

Baby corn can be cultivated in all types of soils and in all the seasons with crop duration of 60-65 days, as mulberry. It grows erect and hence, does not create shade for mulberry. It has fibrous root system that does not confront with the deep root system of mulberry. Apart from cobs, nutritious fodder is available for cattle. In general, baby corn plant is less prone to pests and diseases and does not necessitate any application of pesticides which are harmful to silkworms during rearing period. It generates employment opportunities for both urban and rural folk and good foreign exchange through export. All these merits qualify baby corn as an excellent and compatible intercrop.

MATERIALS AND METHODS

The field study was conducted in an established mulberry garden at Karnataka State Sericulture Research and development Institute (KSSRDI), Bengaluru during 2008-2010 under irrigated condition. The experiment was laid out in Randomized Complete Block Design (RCBD) using M5, S36 and DD (Vishwa) mulberry varieties under two systems of spacing *i.e.*, 2'x 2' and 3'x 3', with three replications each (Figure 1).The various treatment compositions were as following.

T1 - M5 with 2'x 2' spacing
T2 - M5 with 3'x 3' spacing
T3 - S36 with 2'x 2' spacing
T4 - S36 with 3' x3' spacing } + Baby corn
T5 - DD with 2'x 2' spacing
T6 - DD with 3'x 3' spacing

Figure 1: Mulberry plantation with baby corn as intercrop

Cultural practices were employed as per the package of practices recommended for mulberry under irrigated condition (Jolly, 1987) with the supplementation of NPK at 300:120:120 kg /ha/yr in five equal split doses. FYM at 20 tons/ha/yr was applied in two spilt doses during 1st and 3rd crop of mulberry. FYM was mixed thoroughly in the soil by light digging and ploughing which also made the soil suitable for sowing of baby corn seeds. No additional fertilizer or FYM was applied to baby corn. Baby corn seeds were sown within 8 to 10 days after the bottom pruning of mulberry in order to ensure the sprouting and initial establishment of seedlings before the fast sprouting and development of mulberry. The seeds were sown at a distance of 20 cm from plant to plant, at a depth of 2-3 cm (8 kg seeds/ha) and covered well. Soil moisture was maintained properly for good germination of the seeds. Twenty to twenty-five days after pruning, weeds were removed and recommended dose of chemical fertilizers were applied for mulberry. Care was taken while applying fertilizer to avoid damage to the seedlings of baby corn. Initially, the garden was irrigated at an interval of 3-4 days and later, once in a week based on the soil moisture condition. Fifty to fifty-five days after sowing, depending on the baby corn variety, tassel emergence occurs, usually 5 days prior to silk emergence. Tassels were removed immediately from all the plants to avoid pollination and to ensure good quality cobs. Though it is a labour consuming operation, it helps in keeping young cobs succulent, nutritious and tasty. Cobs were harvested between 8-14 days before seed formation at an interval of 2-3 days. An average of 3 cobs could be harvested from a plant. Harvesting was done preferably in the morning hours. After harvesting the cobs, green, succulent palatable and nutritious baby corn plants were harvested and used as green fodder or dried to be preserved and used as dry fodder for cattle. Mulberry shoot or leaf were harvested as per silkworm rearing schedule at the same time. Observation on yield parameters of mulberry was done between 65-70 days after mulberry pruning. Mulberry leaf yield was calculated by harvesting mulberry leaves from each micro plot and converting it into per hectare basis. Baby corn pods were harvested 3-4 times during a crop and the yield data were extrapolated as on to per hectare basis.

During the mulberry growth period, bio-assay was also conducted and data on larval weight prior to ripening, cocoon weight and cocoon shell weight were collected for three crops, analyzed and presented.

RESULTS AND DISCUSSION

Yield attributes in respect of mulberry and baby corn and bioassay parameters were recorded for five crops of mulberry with baby corn as intercrop. Statistically analyzed data on different parameters have in general shown that growing babycorn as an intercrop has no deleterious effect on both quality and quantity of mulberry leaf yield and silkworm rearing.

Mulberry leaf yield/ha/crop: Mulberry leaf yield differed significantly in all the five crops due to differences in plant spacing and mulberry varieties. It ranged from minimum of 28,506 kg/ha/yr in S36 variety with wider spacing (3'x3') to maximum, 36,899 kg/ha/yr in S36 variety with closer spacing (2'x 2') (Table1). Performance of DD variety in wider spacing was better (32751 kg/ha) compared to S36 (28506 kg/ha) and M5 (29901 kg/ha) varieties due to its wide spreading nature. Kasiviswanathan and Iyengar (1970) had earlier reported that high plant density offered the highest yield. The present observations on mulberry varietal leaf yield are on par with those reported by Sujathamma and Dandin (1998) except for DD variety (Table1).

Table 1: Mulberry leaf yield (kg/ha)

Treatment	Crop					Pooled
	I	II	III	IV	V	
T1	6039	7150	5310	8081	6491	33073
T2	7121	5527	4627	7610	5013	29901
T3	7821	8608	6519	7350	6599	36899
T4	5795	6839	5184	6170	4515	28506
T5	7914	8654	5067	8261	6109	36007
T6	9050	6513	4576	7930	4680	32751
F Test	HS	HS	HS	HS	HS	
CD @ 5 %	424	437	509	382	313	
CD @ 1 %	580	598	698	524	429	

T1: M5-2'x2'; T2: M5-3'x3'; T3: S36-2'x2'; T4: S36-3'x3'; T5: DD-2'x2'; T6: DD-3'x3'. All the treatments involved baby corn as intercrop.

Baby corn cob yield: Baby corn cob yield ranged from 5953 to 8265 kg/ha/yr. In closer spacing, yield was more, whereas in wider spacing, yield was less due to less number of baby corn plants/unit area (Table 2).

Table 2: Baby corn cob yield (kg/ha)

Treatment	Crop					Pooled
	I	II	III	IV	V	
T1	2603	755	1616	1263	1160	7396
T2	2904	924	1802	1298	929	7856
T3	2531	797	1741	2083	1114	8265
T4	2314	976	1592	1515	977	7375
T5	2119	805	1420	1290	1118	6752
T6	1649	943	1289	1064	1008	5953
F Test	HS	HS	HS	HS	HS	
CD @ 5 %	111	50	107	126	79	
CD @ 1 %	151	68	146	172	108	

Baby corn straw yield: Baby corn straw yield also differed significantly in all the five crops. Straw yield ranged from 20,980 to 31,409 kg/ha/yr. Here also, maximum yield (31,409 kg) was observed in closer spacing as against minimum (20980 kg) in wider spacing due to difference in plant population under both the systems of spacing followed (Table 3).

Table 3: Baby corn straw yield (kg/ha)

Treatment	Crop					Pooled
	I	II	III	IV	V	
T1	9706	3565	8449	4645	5044	31409
T2	8383	3933	6689	4747	4136	27838
T3	8387	3025	6853	8221	2885	29370
T4	9043	3467	6730	5751	3463	28454
T5	7914	2374	7492	4686	3781	24109
T6	5339	2743	5503	4107	3288	20980
F Test	HS	HS	HS	HS	HS	
CD @ 5 %	716	201	644	392	351	
CD @ 1 %	982	275	882	537	481	

Silkworm rearing parameters: Silkworm rearing was conducted using NB4D2 race. Silkworm rearing and cocoon parameters *viz.*, larval weight, cocoon weight, shell weight and shell percentage also differed significantly. T3 *i.e.*, S36 variety with closer spacing (2'x

Table 4: Larval weight (g)

Treatment	Crop			Average
	I	II	III	
T1	3.883	3.360	3.477	3.573
T2	3.820	3.415	3.562	3.599
T3	3.870	3.697	3.690	3752
T4	3.840	3.117	3.612	3523
T5	3.851	2.970	3.445	3.422
T6	3.955	3.406	3.503	3.621
F Test	NS	HS	HS	
CD @ 5 %	-	1.03	0.7	
CD @ 1 %	-	1.42	0.96	

Table 5: Cocoon weight (g)

Treatment	Crop			Average
	I	II	III	
T1	1.602	1.788	1.741	1.710
T2	1.650	1.850	1.709	1.736
T3	1.696	1.993	1.679	1.789
T4	1.590	1.827	1.773	1.731
T5	1.698	1.735	1.656	1.696
T6	1.650	1.881	1.673	1.735
F Test	NS	HS	HS	
CD @ 5 %	-	0.455	0.323	
CD @ 1 %	-	0.623	0.443	

Table 6: Cocoon shell weight (g)

Treatment	Crop			Average
	I	II	III	
T1	0.338	0.313	0.293	0.315
T2	0.343	0.330	0.300	0.324
T3	0.353	0.360	0.308	0.340
T4	0.339	0.323	0.326	0.329
T5	0.336	0.289	0.291	0.305
T6	0.327	0.324	0.297	0.316
F Test	NS	HS	HS	
CD @ 5 %	-	0.07	0.07	
CD @ 1 %	-	0.10	0.10	

2') fared better for larval weight (3.752 g) cocoon weight (1.790 g), shell weight (0.340 g), whereas shell percentage was recorded higher in wider spacing (19.12) (Tables 4, 5, 6 and 7).

Table 7: Cocoon shell %

Treatment	Crop			Average
	I	II	III	
T1	20.99	17.92	16.82	18.57
T2	20.80	17.69	17.57	18.69
T3	20.73	18.07	18.35	19.05
T4	21.29	17.69	18.38	19.12
T5	19.82	17.81	17.52	18.22
T6	20.37	17.36	17.72	18.49
F Test	S	NS	HS	
CD @ 5 %	0.41	-	0.31	
CD @ 1 %	-	-	0.42	

Economics: By doing intercropping, farmer acquires an additional benefit over the regular income from sericulture. According to the study, 5953 to 8265 kg/ha/yr baby corn can be harvested which amounts to ₹ 2,38,120 to 3,30,600 (₹40/kg baby corn). Baby corn straw yield ranging from 20,980 to 31,409 kg/ha/yr amounts to ₹1,01,900 to 1,57,045 (₹5/kg). Totally, from both baby corn and green fodder, farmer will get an additional income of ₹ 3,40,020 to 4,77,450 /ha/yr apart from the regular income from sericulture without spending any extra amount except the cost of baby corn seeds, as no additional inputs were applied for baby corn plants.

Table 8: Economics of intercropping

Treatment	Baby corn yield (kg/ha/yr)	Income/ ha/yr (₹)	Baby corn straw yield (kg/ha/yr)	Income/ ha/yr (₹)	Total income /ha/yr (₹)
T1	7396	2,95,840	31409	157045	4,52,885
T2	7856	3,14,240	27838	139190	4,53,430
T3	8265	3,30,600	29370	146850	4,77,450
T4	7375	2,95,000	28454	142270	4,37,270
T5	6752	2,70,080	24109	120545	3,90,625
T6	5953	2,38,120	20380	101900	3,40,020

Conclusion

Getting maximum return per unit area is the right strategy for modern agriculture in the competitive world. Though several crops have been tried as intercrop in mulberry garden, the present trial with baby corn is an all new attempt. The study revealed that intercropping with baby corn ensures enhanced income from unit area of land besides offering employment and livelihood opportunities to rural community. However, further studies are needed to standardize the attributes of spacing, mulberry plant height and inputs for sustainable intercropping system.

REFERENCES

Ahsan M. M. and Dhar K. L. (1989) Studies on intercropping of short duration crops with mulberry. *Indian J. Seric*., **28 (2)**:194-199.

Jolly M. S. (1987) *Appropriate Sericulture Techniques.* Central Sericultural Research and Trainng Institute, Mysore, India, p. 175.

Kasiviswanathan K. and Iyengar M. N. S. (1970) Effect of plant densities, methods of leaf harvest and nitrogen fertilization on the leaf yield of irrigated mulberry in Mysore state. *Indian J. Seric*., **9 (1)**: 43-48.

Miles C. (2005) Baby corn research project 1998,Washington State University, On-Farm Research, pp. 1-7. http://agsyst.wsu.edu/babycorn98.htm

Ramachandrappa B. K., Nanjappa H. V., Thimmegowda M. N. and Soumya T. M. (2004) Production management for profitable Babycorn cultivation. *Indian Farming*, **54 (5)**: 3-7.

Shankar M. A. and Devaiah M. C. (2002) *Intercropping in rainfed mulberry*. University of Agricultural Sciences, Bangalore, India, p. 90.

Sujathamma P. and Dandin S. B. (1998) Evaluation of mulberry (*Morus* Spp.) genotypes for yield under Rayalseema condition of Andhrapradesh. *Indian J. Seric*., **37 (1)**: 13-16.

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Research Paper

FLUORESCENCE DISPOSITION OF INDIAN MULBERRY SILK COCOONS AND ITS EFFECT ON REELING PERFORMANCE AND QUALITY OF RAW SILK

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ABSTRACT

The Indian silk cocoons possess fluorescence characteristics rendering added luster to the silk products, as being preferred by the consumers. In the present study, two varieties of cocoons *viz*., multi-bivoltine crossbreed (PM × CSR2 race) and bivoltine hybrid (CSR2 x CSR4 race) cocoons harvested during the same seasons were examined for the fluorescence attributes as well as reeling performance and quality characteristics. In the multi-bivoltine category, fluorescence trait was observed in all the cocoons whereas, in bivoltine, only some of the cocoons were found to possess it. Those bivoltine cocoons observed under Ultraviolet light rays and sorted out, were classified as having blue and pale yellow fluorescence and multi-bivoltine cocoons as displaying dark yellow fluorescence. The cocoon characteristics*, viz*., average filament length, non-breakable filament length, single cocoon filament denier; reeling characteristics, *viz*., reelability, renditta, raw silk percentage, raw silk recovery percentage and waste generated during reeling; the quality characteristics*, viz*., tenacity, elongation and cohesion of raw silk as well as the whiteness and yellowness index characteristics on computer colour matching system, were examined. It could be observed that dark / pale yellow fluorescent cocoons presented better reelability characteristics compared to blue fluorescent cocoons. The cocoons sorted out under UV light were photographed and analyzed using Image J software for RGB colour values to ascertain the significance of fluorescence level both in the cocoon and silk. We could detect a clear demarcation among the red, blue and green colour pixels intensity peaks from the blue, pale yellow and dark yellow fluorescent mulberry silk cocoons as well as raw silk reeled from them.

Key words: Fluorescence, image analysis, reelability, ultraviolet rays, whiteness index.

INTRODUCTION

Photoluminescence is a process that produces light using light energy. Two forms of photoluminescence, fluorescence and phosphorescence, are defined by the length of time the emitted light continues to glow. Fluorescence refers to the immediate release of light, where light is emitted within a fraction of a second after excitation. Ultraviolet fluorescence is a mechanism in which UV radiation excites chemicals in an object and causes them to release visible light. On comparing conventional colours with fluorescent colours, fluorescent colours use a larger portion of both the visible spectrum and the lower wave lengths.

Fluorescence occurs when the absorbed radiation is in the ultraviolet region of the spectrum, and hence, is invisible to the human eye. The emitted light from the silk cocoon is in the visible region which gives the fluorescent substance, a distinct colour that can be seen only when exposed to UV light. Multi-bivoltine cocoons have been shown to be highly influenced by fluorescence characteristics, in turn making all the cocoons lustrous, which we termed as dark yellow fluorescence, whereas in bivoltine cocoons, fluorescence characteristics are observed only in some of the cocoons which are classified as pale yellow fluorescence and blue fluorescence.

Fluorescence characteristics of different varieties of cocoons reared in China have been studied (Chen Keping and Lin Changqi, 1988). Using pure yellow and pure purple fluorescent cocoons as raw materials, the relation of the fluorescence of silkworm cocoon with its reelability was studied and a positive correlation could be established between the reelability and cocoon fluorescence (Xiaohua, 1999). Cocoon shells exhibiting yellowish white fluorescence (F-YW) and dark blue fluorescence (F-DB) from a commercial strain (Kinshu × Showa) were studied under UV excitation and found that the yellowish white fluorescent material deposited in the middle layer of the cocoon shell affected the fluorescence of the cocoon shell in F-YW race of cocoons (Kurioka and Yamazaki, 2010). Experimental analyses of the relation between fluorescent lustre and quality of mulberry cocoons were made on the Chinese bivoltine and high silk yield breed, Su 5Su 6 and established that the yellowish white fluorescent cocoon is higher in non-breaking length of bave, reelability percentage and silk yield than the purplish blue fluorescent cocoon (Xiaohua, 1999).

Various *Bombyx mori* races have been studied in Japan too for their fluorescence characteristics [Masatoshi (Takahama) Ichida *et al*., 2010]. Japanese and Chinese scientists used biotechnological tools to induce fluorescence properties in the larval stage to get the fluorescence coloured cocoons, by developing transgenic silkworm races (Masahiro Tomita *et al*., 2003; Chen Keping and Lin Changqi, 1997). However, such experiments were not attempted in India on fluorescent cocoons especially in relation to their reeling characteristics. Hence, the present study is an effort to ascertain the influence of mulberry silk cocoons having pale yellow, blue and dark yellow fluorescence characteristics on the reeling performance and quality of raw silk, which may support in development of these features in Indian mulberry silkworm races.

MATERIALS AND METHODS

Raw material: Samples of commercially available bivoltine hybrid (CSR2 x CSR4 race) and multi-bivoltine cross breed (PM x CSR2 race) cocoons raised in Karnataka state, India, during all seasons of 2018 ~ 2019 were used for the study.

From the nine lots of cocoons procured initially, three hundred good cocoons per category were selected from each lot for experimentation.

Drying conditions: The cocoons were dried in Batch type hot air drier following the temperature pattern of 110-100-85-70-55 °C for multi-bivoltine crossbreed and 115-100-85-70-55 °C for bivoltine hybrid cocoons for a period of 5 hours. The degree of drying achieved was 39 – 41 % for both the varieties of cocoons.

Deflossing: The dried cocoons were deflossed for removing the outermost entangled flossy layer for better segregation of fluorescent cocoons.

Segregation of cocoons for fluorescence: The deflossed cocoons were exposed to ultraviolet light, TLD 18w / 8, having wavelength of 280 ~ 315 in Colour cabinet (model Spectra LUX – II) for segregation of cocoons having pale yellow and blue fluorescence in the bivoltine cocoons (Figure 1) and dark yellow fluorescence in the multi-bivoltine cocoons (Figure 2). It was observed that in the bivoltine cocoons that displayed fluorescence, about 35 % exhibited pale yellow, and 65 %, blue fluorescence, whereas in the multi-bivoltine cocoon lots, 100 % of cocoons were having dark yellow fluorescence colour. The mulberry silk cocoons exposed to UV light in Colour cabinet are shown in Figures 1 and 2 (Kurioka and Yamazaki, 2010).

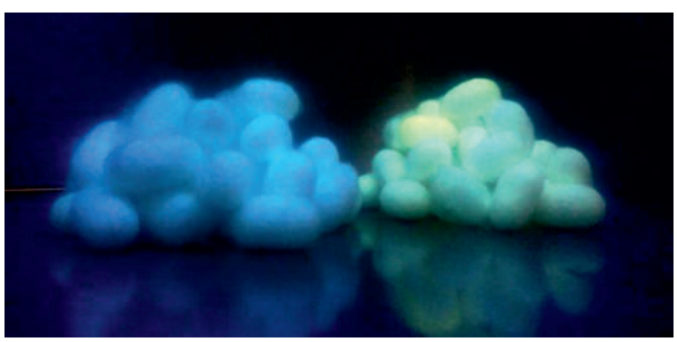

Figure 1: Bivoltine hybrid silk cocoons with blue and pale yellow fluorescence

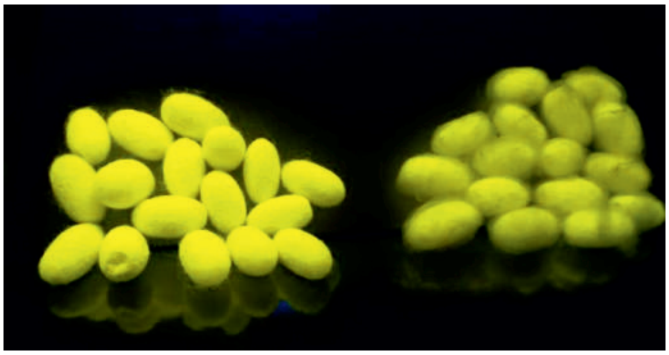

Figure 2: Multi-bivoltine cros breed silk cocoons with dark yellow fluorescence

Cooking conditions: The hot air dried and segregated cocoons were cooked using two-pan, following the temperature profile of 65 - 90 - 70 - 96 - 96 - 80 °C for 3 minutes and 65 - 92 - 70 - 96 - 96 - 80 °C for 5 minutes for multi-bivoltine crossbreed and bivoltine hybrid cocoons, respectively.

Brushing conditions: The cooked cocoons were manually brushed at 80 °C using paddy husk brush and then transferred to reeling basin for picking at 45 °C.

Reeling conditions: Reelability test was conducted as per the standard procedure developed by CSTRI. The cooked cocoons were reeled on 3 ends of multiend reeling machine, maintaining fixed number of cocoons to a reeling end. The temperature of reeling bath was maintained at 45 °C and reeling speed, at 120 m/min.

Silk quality testing: The raw silk after reeling was assessed for quality characteristics, *viz*., tenacity, elongation and cohesion as per the Bureau of Indian Standards (BIS, 2002). The testing equipment, *viz*., Serigraph tester and Duplan cohesion tester supplied by Toyo Sangyo Consulting Inc., Japan, were used for the study.

Whiteness and yellowness Index testing: The mulberry silk cocoons having fluorescence characteristics were tested in spectrophotometer to measure the whiteness and yellowness index characteristics of the cocoon lots.

Measurement of fluorescence: In order to measure the fluorescence colour of the cocoons, the cocoons were subjected to ultraviolet light having wavelength of 280 ~ 315 in Colour cabinet model Spectra LUX II and images were captured in digital camera, model Canon EOS 1300D. The photographs taken in respect of blue, pale yellow and dark yellow fluorescence cocoons as well as the silk reeled from the cocoons were analyzed using digital image processing techniques with the software, Image J. The corresponding images of the cocoons and raw silk were measured for red, green and blue colours and analyzed.

Cocoon / silk parameters: The characteristics, *viz*., average filament length, non-breakable filament length, single cocoon filament denier, reelability percentage, renditta, raw silk percentage and waste % on silk weight were recorded while reeling multi-bivoltine cocoons and both categories of bivoltine cocoons, *i.e.,* cocoons having blue and pale yellow fluorescence. The quality data, *viz*., tenacity, elongation and cohesion were registered after testing raw silk reeled from different varieties of cocoons.

The blue and pale yellow fluorescence exhibited by bivoltine cocoons (Figures 3 a & 4 a) and dark yellow fluorescence displayed by multi-bivoltine cocoons were photographed (Figure 5 a). These cocoons were reeled and the raw silk samples were exposed to UV light and photographed too (Figures 3 b, 4 b, 5 b). All these photographs were analyzed using Image J software and the histograms of red, green and blue colour measures were observed for both cocoons and raw silk. RGB images were having three channels, *viz*., red, green and blue and each channel contains 8 bit. Computer monitors generate colours for display by mixing red, green and blue light. Therefore, RGB images can dictate directly how much of each colour should be used; the values in each channel really do determine the final image appearance (Peter Bankhead, 2014).

The whiteness and yellowness index characteristics of the cocoon lots were also measured. The data thus obtained

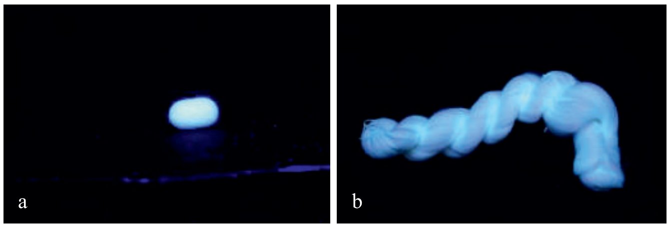

Figure 3: Blue fluorescent bivoltine cocoon (a) and raw silk (b)

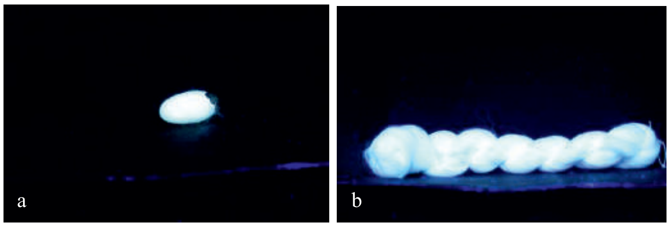

Figure 4: Pale yellow fluorescent bivoltine cocoon (a) and raw silk (b)

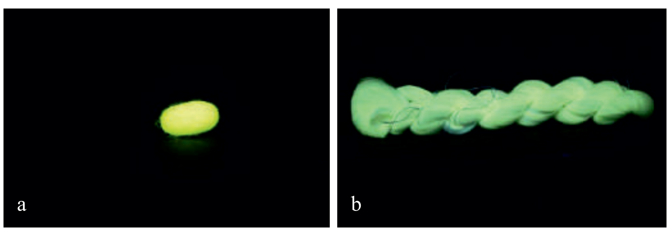

Figure 5: Dark yellow fluorescent multi-bivoltine cocoon (a) and raw silk (b)

were analyzed statistically using SPSS package.

RESULTS AND DISCUSSION

The results of analysis of variance of data on influence of fluorescence characteristics of Indian mulberry silk cocoons on reelability and quality characteristics and the mean data are presented in Tables 1 and 2, respectively. It could be observed from the results that significant differences exist among the blue, pale yellow and dark yellow fluorescent mulberry silk cocoons in terms of reelability and quality characteristics (Table 1). It is quite visible that pale yellow fluorescent bivoltine cocoons perform better than blue and dark yellow fluorescent cocoons in terms of reelability characteristics, *viz*., average filament length, non-breakable filament length, single cocoon filament denier, renditta, raw silk percentage and waste (%) on silk weight. On the contrary, the mean data (Table 2) reveal that dark yellow fluorescent multi-bivoltine cocoons have the maximum reelability percentage. Among the bivoltine cocoons, pale yellow fluorescent ones exhibited more reelability than the blue fluorescent category. This may be attributed to the racial character. The present results are in a similar line with those reported by Xiaohua (1999) wherein he claimed that yellowish white fluorescent cocoon is higher in non-breaking length of bave and reelability. Further, the bivoltine cocoons having pale yellow fluorescence have displayed more whiteness and yellowness indices compared to blue fluorescent cocoons, whereas yellowness index of dark yellow multi-bivoltine cocoons in general was significantly higher than that of bivoltine cocoons.

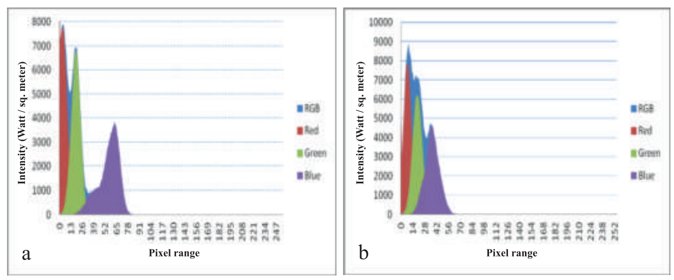

Figure 6: RGB values of blue fluorescent bivoltine cocoon (a) and raw silk (b)

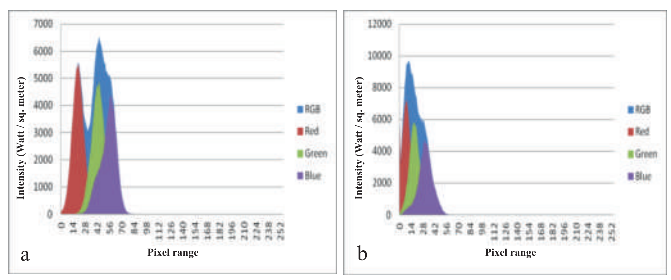

Figure 7: RGB values of pale yellow fluorescent bivoltine cocoon (a) and raw silk (b)

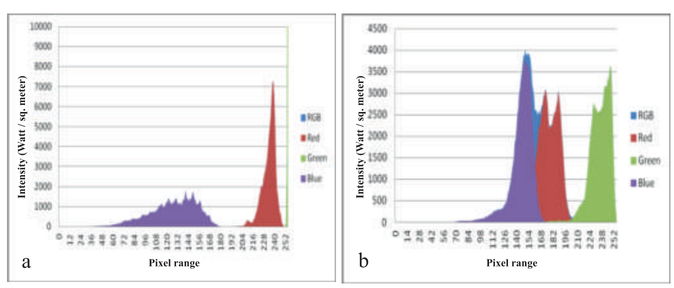

Figure 8: RGB values of dark yellow fluorescent multi bivoltine cocoon (a) and raw silk (b)

Table 1: Analysis of variance for data on influence of fluorescence characteristics of Indian mulberry silk cocoons on reeling and quality characteristics

Characteristic	Comparison	Sum of Square	DF	Mean sum of square	F-Value	Significance
Filament length (m)	Among groups	344234	2	172117	19.347	0.000**
	Within groups	213507	24	8896		
	Total	557742	26			
Non-breakable filament length (m)	Among groups	173809	2	86904	4.238	0.027*
	Within groups	492175	24	20507		
	Total	665985	26			
Single cocoon filament denier (d)	Among groups	0.584	2	0.292	13.632	0.000**
	Within groups	0.514	24	0.021		
	Total	1.097	26			
Reelability (%)	Among groups	525.338	2	262.67	3.419	0.049*
	Within groups	1843.685	24	76.82		
	Total	2369.023	26			
Renditta	Among groups	6.928	2	3.464	41.338	0.000**
	Within groups	2.011	24	0.084		
	Total	8.939	26			
Raw silk (%)	Among groups	32.533	2	16.267	42.362	0.000**
	Within groups	9.216	24	0.384		
	Total	41.7749	26			
Waste (%) on silk weight	Among groups	115.87	2	57.936	9.406	0.001**
	Within groups	147.83	24	6.150		
	Total	263.69	26			
Tenacity (g/d)	Among groups	0.052	2	0.026	3.960	0.033*
	Within groups	0.159	24	0.007		
	Total	0.211	26			
Elongation (%)	Among groups	81.42	2	40.711	28.155	0.000**
	Within groups	34.70	24	1.446		
	Total	116.13	26			
Cohesion (strokes)	Among groups	16388	2	8194	25.215	0.000**
	Within groups	7799	24	324.97		
	Total	24187	26			
Whiteness index	Among groups	5084.31	2	542.15	496.786	0.000**
	Within groups	122.81	24	5.117		
	Total	5207.12	26			
Yellowness index	Among groups	29050.78	2	14525	4327	0.000**
	Within groups	80.56	24	3.357		
	Total	29131	26			

*- Significant at 5 % ; ** - Significant at 1 %.

Based on the image analysis, the graphs on RGB measurement were derived for blue and pale yellow fluorescent bivoltine and the dark yellow fluorescent multi-bivoltine cocoons which are shown in Figures 6 a, 7 a and 8 a. Similarly, the RGB measurements of raw silk reeled from blue, pale yellow and dark yellow fluorescent cocoons are shown in Figures 6 b, 7 b and 8 b.

The Figures 6 a & 7a depict that, blue fluorescent cocoons have red, green and blue colour pixel intensity peaks at 7732, 6801 & 3853 compared to corresponding colour peaks of pale yellow fluorescent cocoons at 5539, 4885 &

Table 2: Influence of fluorescence characteristics of Indian mulberry cocoons on reeling and quality characteristics

Characteristic	Fluorescence type	N	Mean	Standard deviation	Std error	Minimum	Maximum
Filament length (m)	Blue	9	939	56.7	18.91	819	1000
	Pale yellow	9	1063	149.7	49.90	919	1296
	Dark yellow	9	787	32.61	10.87	724	825
Non-breakable filament length (m)	Blue	9	715	112.6	37.54	602	900
	Pale yellow	9	868	216.5	72.16	662	1112
	Dark yellow	9	684	44.36	14.79	628	745
Single cocoon filament denier (d)	Blue	9	3.14	0.16	0.05	2.82	3.31
	Pale yellow	9	3.00	0.16	0.05	2.71	3.24
	Dark yellow	9	2.78	0.11	0.04	2.62	2.95
Reelability (%)	Blue	9	76.13	11.3	3.70	66.11	92.0
	Pale yellow	9	80.60	9.84	3.28	70.32	95.0
	Dark yellow	9	86.88	3.23	1.08	82.35	92.0
Renditta	Blue	9	6.74	0.14	0.05	6.52	6.95
	Pale yellow	9	6.20	0.31	0.10	5.85	6.75
	Dark yellow	9	7.44	0.37	0.12	7.00	8.00
Raw silk (%)	Blue	9	14.84	0.31	0.10	14.39	15.34
	Pale yellow	9	16.16	0.79	0.26	14.81	17.10
	Dark yellow	9	13.47	0.66	0.22	12.50	14.29
Waste (%) on silk weight	Blue	9	13.78	2.55	0.85	10.16	18.46
	Pale yellow	9	11.02	2.34	0.78	7.36	15.00
	Dark yellow	9	16.09	2.55	0.85	11.83	18.75
Tenacity (g/d)	Blue	9	3.68	0.05	0.02	3.60	3.80
	Pale yellow	9	3.77	0.05	0.02	3.70	3.85
	Dark yellow	9	3.68	0.12	0.04	3.50	3.80
Elongation (%)	Blue	9	21.23	1.46	0.49	19.50	23.80
	Pale yellow	9	23.48	0.91	0.30	21.90	24.60
	Dark yellow	9	19.23	1.17	0.39	17.80	21.40
Cohesion (strokes)	Blue	9	84.53	18.94	6.31	65.00	125.8
	Pale yellow	9	126.8	23.71	7.90	95.00	159.0
	Dark yellow	9	68.33	7.35	2.45	55.00	76.0
Whiteness index	Blue	9	44.68	2.80	0.93	40.25	48.25
	Pale yellow	9	41.82	2.45	0.82	37.80	44.36
	Dark yellow	9	14.24	1.22	0.41	12.40	15.80
Yellowness index	Blue	9	13.77	2.05	0.68	10.10	15.40
	Pale yellow	9	11.02	0.59	0.20	10.20	12.20
	Dark yellow	9	81.93	2.35	0.78	78.30	85.40

4366. However, the pixel range of red, green and blue colour of blue fluorescent cocoons was found to be 0 ~ 30, 0 ~ 45 & 13 ~ 97 as against that of pale yellow fluorescent cocoons at 0 ~ 58, 13 ~ 85 & 17 ~ 99. The results provide a clear indication that though blue colour fluorescence is predominant in bivoltine cocoons, some of the cocoons exhibit more intensity pixels, which impart them pale yellow fluorescence. The multi-bivoltine cocoons having dark yellow fluorescence reported red, green and blue colour pixel intensity peaks at 7262, 3503 & 1809 with the pixel range of 182 ~ 255, 252 ~ 255 & 34 ~ 182, thus indicating a totally different pixel range of colours compared to bivoltine cocoons. Multi-bivoltine cocoons have shown a clear shift in pixel range of blue, red & green colours from 17 ~ 99 to 34 ~ 182; 0 ~ 58 to 182 ~ 255 and 13 ~ 85 to 252 ~ 255 compared to pale yellow bivoltine cocoons (Figure 8 a).

Similarly, the raw silk reeled from blue fluorescent bivoltine cocoons has shown red, green and blue colour pixel intensity peaks at 7249, 5789 & 4686 and pixel range of 0 ~ 42, 0 ~ 50 & 0 ~ 65 compared to pixels intensity peaks at 7844, 6248 & 4600 and pixel range of 0 ~ 32, 0 ~ 48 & 0 ~ 72 for pale yellow bivoltine cocoons (Figures 6 b & 7 b). Figure 8 b explains the red, green and blue colour pixels intensity peaks at 3053, 3654 & 3786 and pixel range of 108 ~ 209, 156 ~ 255 & 64 ~ 175 for dark yellow multi-bivoltine raw silk. These findings substantiate the reasons for differences in fluorescence nature among bivoltine and multi-bivoltine cocoons and raw silk.

Based on the spectrophotometer analysis of whiteness and yellowness index of mulberry cocoons, it is found that multi-bivoltine cocoons possess more yellowness, whereas bivoltine cocoons possess more whiteness index (Table 2).

Conclusion

Based on the above results and discussion, it is inferred that the pale yellow fluorescent bivoltine cocoons have shown significant improvement in reelability and quality characteristics compared to blue fluorescent bivoltine cocoons. The dark yellow fluorescent multi-bivoltine cocoons have shown significantly higher reelability percentage, however, other reeling and quality characteristics of both blue and pale yellow bivoltine cocoons have shown significant improvement over that of dark yellow multi-bivoltine cocoons, in association with the optimum drying, cooking and reeling conditions adopted. Further, based on the image measurement of fluorescence of cocoons, it could be observed that though blue colour fluorescence is predominant in bivoltine cocoons, some of the cocoons exhibit more intensity pixels, which impart them pale yellow fluorescence. The multi-bivoltine cocoons having dark yellow fluorescence have shown totally different pixel range of colours compared to bivoltine cocoons and also have shown a clear shift in blue, red & green colours compared to pale yellow bivoltine cocoons. The results reveal positive implications of fluorescence property of silk cocoons on reelability and hence, needs to be detected and utilized while developing new silkworm races.

REFERENCES

BIS (2002) *Raw silk testing and grading*, Bureau of Indian Standards, India, pp. 4-18.

Chen Keping and Lin Changqi (1988) Studies on the fluorescent colours of silkworm cocoons I. Fluorescent colours of different varieties of cocoons. *Acta Sericologia Sinica*, **14 (1)**: 2.

Chen Keping and Lin Changqi (1997) Genetic analysis on cocoon fluorescence colour in *Bombxy mori*. *Acta Sericologia Sinica*, **23 (1)**: 2.

Kurioka A. and Yamazaki M. (2010) Fluorescence spectrophotometric analysis of the yellowish white fluorescent cocoon shell of *Bombyx mori. J. Silk Sci. Tech. Jpn.*, **18**: 57-61.

Masahiro Tomita, Hiroto Munetsuna, Tsutomu Sato, Takahiro Adachi, Rika Hino, Masahir Hayashi, Katsuhiko Shimizu, Namiko Nakamura, Toshiki Tamura and Katsutoshi Yoshizato (2003) Transgenic silkworms produce recombinant human type III procollagen in cocoons. *Nat. Biotechnol.,* **21**: 52-56.

Masatoshi (Takahama) Ichida, Ayumi Noguchi, Yoshimi Fuji, Hiromi Suwa, Manami Kawamoto and Yoshiko Mirua (2010) The measurement of fluorescence of the *Bombyx mori* cocoons for the ultra violet rays. *J. Silk Sci. Tech. Jpn.*, **19**: 37-44.

Peter Bankhead (2014) *Analyzing fluorescence microscopy images with Image J*, Queen's University, Belfast, pp. 125-131.

Xiaohua Y. (1999 a) On the relation between fluorescent luster and quality of mulberry cocoons. *Acta Sericologia Sinica*, **25 (1)**: 22-26.

Xiaohua Y. (1999 b) Study on the reaction of fluorescent colours of cocoon with reelability. *Silk Monthly*, p. 06.

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Research Paper

GROWTH AND PERFORMANCE OF BIVOLTINE SILK PRODUCTION IN INDIA

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ABSTRACT

The bivoltine silk production presented healthy rates of growth in major silk producing states as well as in the country as a whole during the period from 1999-00 to 2018-19. Tamil Nadu and Maharashtra recorded tremendous growth in bivoltine silk production that transformed these two states, with bivoltine accounting for more than 90 % of the total mulberry silk production. Varying pattern and magnitude of instability in bivoltine silk production were recorded across the states. The regression analysis indicated that various programmes implemented for promotion of bivoltine sericulture, automatic reeling machines and cocoon yield, were the factors contributing significantly for bivoltine silk production in Karnataka.

Key words: Bivoltine, compound annual growth rate, instability, production, productivity.

INTRODUCTION

India is the second largest raw silk producing country in the world. However, about 72 % of the mulberry silk produced in the country is obtained from the silkworms with the parentage of multivoltine breeds. Bivoltine silk, which is reeled from bivoltine hybrid cocoons, performs better than silk produced by the crossbreed or multivoltine hybrid silkworms in terms of quality and productivity (Jayaswal *et al.,* 2001; Kumaresan, 2002; Dandin *et al.,* 2005). As adequate quantity of high quality silk is not produced within the country, India imports large quantities of bivoltine raw silk mainly to meet the demands of the high speed power looms (Naik and Babu, 1993; Rajesh, 2012).

In India, multivoltine silk has been produced traditionally. Bivoltine silkworms are native of temperate regions. Since nineteen seventies, various attempts have been made to popularize bivoltine silkworm rearing in the tropical regions of the country with the R&D support. However, the real breakthrough in popularizing bivoltine hybrid silkworm in the country transpired only after implementation of three phases of Japan International Cooperation Agency (JICA) assisted projects of five years each from 1992 to 2007. The Cluster Promotion Programme (CPP) implemented by the Central Silk Board in coordination with the State Sericulture Departments since 2008 has further helped to consolidate the gains realized in the JICA assisted projects and provided a fillip to the bivoltine silk production in the country.

Considering the advantages of bivoltine silk over that of multivoltine in terms of productivity and quality and also to reduce the import dependence on raw silk to meet its domestic requirements, it is essential to increase the production of bivoltine silk in India. In this background, a study was undertaken to analyse the current status, growth and factors contributing for growth in bivoltine silk production in the country.

DATA AND METHODOLOGY

The present study is purely based on the time series secondary data. The statistics on silk production and other variables used in the study were collected for the period between 1999-00 and 2018-19 from statistical publications and Annul Reports of Central Silk Board, Government of India, Bengaluru. The statistical tools used for the analysis of the data are furnished below:

Growth analysis

The growth in silk production was analyzed by using the exponential growth function of the form.

$Y = ab^t e_t$ ... (1)

Where

Y = Dependent variable for which growth rate is estimated

a, b = Regression coefficients

t = Time variable

e = Error term

The compound growth rate is obtained for the logarithmic form of equation (1) as below:

$lnY = lna + t\ lnb + lne_t$ ... (2)

The per cent compound growth rate (g) is computed by using the relationship

$g = (Antilog\ of\ lnb - 1) \times 100$ ... (3)

Stability analysis

The comparative stability in silk production was analyzed using instability index. Instability index is defined as the standard deviation of the residuals from the trend (Massell, 1970). A variety of instability indices are available in the literature ranging from simple to complex ones (Sarada *et al.*, 2006). In the present study, the variability was estimated by using instability index as standard deviation of natural logarithm ($\frac{Y_{t+1}}{Y_t}$) where, Y_t is the silk production in the current year and, Y_{t+1} is for the next year (Ray, 1983). This index is unit free, very robust and measures deviations from the underlying trend (Chand and Raju, 2008). When there is no deviation from trend, $\frac{Y_{t+1}}{Y_t}$ is constant and thus standard deviation is zero. If the series fluctuates more, $\frac{Y_{t+1}}{Y_t}$ also fluctuates more and standard deviation increases and *vice versa.*

Regression model

A regression model was fitted to analyse the factors contributing for bivoltine silk production in Karnataka. Algebraically, the regression model can be written as:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + \mu \quad ... (4)$$

Where Y = Bivoltine silk production in Karnataka (MT)

X_1 = Farmers directly supported under bivoltine promotion programmes (No.)

X_2 = Average annual price premium for bivoltine cocoons (₹ / kg)

X_3 = Automatic reeling units installed (No.)

X_4 = Average cocoon yield (kg/100 DFLs)

a = Intercept

b_is = Regression coefficient of the i^{th} variable (i = 1 to 4)

μ = Random term

The regression coefficients were tested for their consistency by using t test.

$$t = \frac{b_i}{SE(b_i)} \quad ... (5)$$

Where b_i = Regression coefficient of i^{th} variable

SE = Standard error

RESULTS AND DISCUSSION

The bivoltine silk production increased from 373 MT in 1999-00 to 6,987 MT in 2018-19 in India at a compound growth rate of 14.92 % per annum, while the overall mulberry silk production grew at a modest rate of 2.79 % during the same period (Table 1). High rate of growth in bivoltine silk production was due to the concerted efforts of both Central and State Government in promotion of bivoltine silk production in the country.

If we look into the stability in silk production, the bivoltine silk had higher instability in production compared to cross breed silk. Higher fluctuations in the production of bivoltine silk compared to cross breed silk may be due to rapid increase in bivoltine silk production and varying responses of farmers to agro-climatic conditions and fluctuating prices for bivoltine cocoons. Similary, high instability in food grains production as an inevitable

Table 1: Growth and instability in bivoltine and cross breed silks in India during 1999-00 to 2018-19

Particulars	Raw silk production (MT)				Share in total mulberry silk production (%)	
	1999-00	2018-19	CAGR@ (%)	Instability Index	1999-00	2018-19
Bivoltine	373	6987	14.92**	17.07	2.67	27.57
Cross breed	13571	18358	1.31**	5.79	97.33	72.43
Total (Mulberry silk)	**13944**	**25345**	**2.79****	**5.78**	**100.00**	**100.00**

** - Significant at 1 %; @ - Compound Annual Growth Rate.

consequence of rapid agricultural growth was reported by Hazell (1982) and there was little that could be effectively done about it. The fast pace of growth in bivoltine silk production compared to crossbreed silk production resulted in steep increase in the share of bivoltine silk production in total mulberry silk production in the country from a mere 2.67 % in 1999-00 to 27.57 % in 2018-19.

Growth in bivoltine silk production

The mulberry sericulture is practiced in 26 states in India, out of which Karnataka, Tamil Nadu, Andhra Pradesh, Maharashtra, Jammu & Kashmir, Assam, Manipur and Uttar Pradesh are the major bivoltine silk producing states. Though West Bengal is the third largest mulberry silk producing state in the country, it does not produce appreciable quantity of bivoltine silk.

When the state-wise production of mulberry raw silk is considered, Karnataka is the largest producer with 11,592 MT during 2018-19 followed by Andhra Pradesh (7,476 MT). The three southern states, namely Karnataka, Tamil Nadu and Andhra Pradesh put together accounted for 78.12 % of the total bivoltine silk production in the country during 2018-19. The bivoltine raw silk production grew from 212 MT in 1999-00 to 2,067 MT in 2018-19 at a growth rate of 9.48 % per annum in Karnataka (Table 2). Tamil Nadu and Maharashtra recorded a very high growth rate of 30.47 % and 35.29 %, respectively. Andhra Pradesh and Uttar Pradesh recorded growth rate of 16.27 % and 18.89 %, respectively, in bivoltine silk production during the study period, which were above the national growth rate of 14.92 %. However, Jammu & Kashmir, which is a traditional bivoltine silk producing state, recorded a modest growth rate of 2.83 %.

Jammu & Kashmir and Assam produce only bivoltine silk. Karnataka and Andhra Pradesh recorded a modest growth of 0.95 % and 1.28 %, respectively in cross breed silk production. While Tamil Nadu and Maharashtra registered declined growth in crossbreed silk production, the total mulberry silk production grew at a decent rate of 8.11 % and 13.83 %, respectively. This clearly indicates that a large portion of cross breed cocoon producers must have switched over to bivoltine cocoon production. Uttar

Table 2: Growth in bivoltine and cross breed silk production in major bivoltine silk producing states in India (1999-00 to 2018-19)

State	Bivoltine silk production (MT)			Cross breed silk production (MT)			Total mulberry silk production (MT)		
	1999-00	2018-19	CAGR@ (%)	1999-00	2018-19	CAGR@ (%)	1999-00	2018-19	CAGR@ (%)
Karnataka	212	2067	9.48**	7909	9525	0.95*	8121	11592	1.69**
Tamil Nadu	23#	1926	30.47**	672	146	-4.42*	672	2072	8.11**
Andhra Pradesh	114#	1465	16.27**	3757	6011	1.28*	3757	7476	2.26**
Maharashtra	6$	489	35.29**	26	8	-11.71*	26	496	13.83**
Manipur	23	124	11.13**	33	13	-2.51NS	57	137	7.48**
Jammu & Kashmir	85	118	2.83**	-	-	-	85	118	2.83**
Uttar Pradesh	10	107	18.89**	6	124	22.94**	17	231	20.36**
Assam	19	69	9.13**	0.2	-	-	19	69	9.13**
Other states	24	621	19.00**	1168	2531	4.45**	1189	3152	5.38**
India	**373**	**6987**	**14.92****	**13571**	**18358**	**1.31****	**13944**	**25345**	**2.79****

** - Significant at 1 %; * - Significant at 5 %; NS - Non-significant; @ - Compound Annual Growth Rate; # - Statistics pertains to 2001-02; $- Statistics pertains to 2006-07.

Table 3: Instability in bivoltine silk production in major silk producing states in India (1999-00 to 2018-19)

State	Instability Index
Karnataka	25.96
Tamil Nadu	27.39
Andhra Pradesh	34.87
Jammu & Kashmir	11.21
Assam	25.35
Maharashtra	44.59
Manipur	26.42
Uttar Pradesh	45.01
Others	21.36
India	**17.07**

Pradesh recorded high growth in bivoltine as well as cross breed silk production.

Due to modest growth in cross breed silk production, Karnataka and Andhra Pradesh recorded a slow growth of 1.69 % and 2.26 %, respectively in total mulberry silk production. It's interesting to note that the small silk producing states *viz.,* Maharashtra, Uttar Pradesh, Assam and Manipur recorded impressive growth in mulberry silk production compared to the traditional mulberry silk producing states.

Instability in bivoltine raw silk production

Instability in bivoltine raw silk production at the state and country level was determined through standard deviation of natural logarithm, for the period between 1999-00 and 2018-19 and the results are presented in Table 3. Jammu & Kashmir recorded very less growth and as a consequence, less instability in bivoltine silk production. It is traditionally a pure bivoltine silk producing state and did not experience wide fluctuations in the silk production during the period. On the other hand, Maharashtra and Uttar Pradesh registered high growth in bivoltine silk production coupled with high instability. These two states are relatively new to bivoltine sericulture and the research, extension, input support and marketing infrastructure are not developed to the extent of that in traditional states, which may attribute for more fluctuations experienced by them in bivoltine silk production compared to other states. The other states had moderate amount of instability in bivoltine silk production.

Table 4: Share of bivoltine in total mulberry silk produced during 1999-00 and 2018-19

State	Share of bivoltine in mulberry silk production (%)	
	1999-00	2018-19
Karnataka	2.61	17.83
Tamil Nadu	3.42[#]	92.94
Andhra Pradesh	3.03[#]	19.60
Jammu & Kashmir	100.00	100.00
Assam	98.96	100.00
Maharashtra	23.08[$]	98.44
Manipur	39.82	90.46
Uttar Pradesh	59.35	46.62
Others	2.01	19.70
India	**2.67**	**27.57**

Share of bivoltine in the total mulberry silk production

The share of bivoltine silk in the total mulberry silk production increased significantly from 2.67 % in 1999-00 to 27.57 % in 2018-19 (Table 4). A glance at the state-wise performance indicates that the share of bivoltine silk increased from mere 3.42 % in 1999-00 in Tamil Nadu to whopping 92.94 % in 2018-19. Similarly, its share increased significantly from 1999-00 to 2018-19 in Maharashtra and Manipur also. On the other hand, the share of bivoltine silk in the total mulberry silk production declined from 59.35 % in 1999-00 to 46.62 % in 2018-19 in Uttar Pradesh.

Growth in bivoltine cocoon yield

The productivity growth is essential for any industry for sustaining output growth over the long run as input growth alone is insufficient to generate output growth because of diminishing returns to input use. The productivity improvement in bivoltine silk production was measured in terms of bivoltine cocoon yield per 100 DFLs, as the state-wise time series statistics related to bivoltine raw silk production / ha was not available.

Among the major bivoltine silk producing states, the cocoon yield levels were the highest in Tamil Nadu

Table 5: Growth in bivoltine cocoon yield in major bivoltine silk producing states in India during 1999-00 to 2018-19

State	Cocoon yield (kg/100 DFLs)		
	1999-00	2018-19	CAGR[@] (%)
Karnataka	31.10	65.23	2.81*
Tamil Nadu	39.90#	77.62	3.15**
Andhra Pradesh	37.90#	59.18	2.37**
Maharashtra	41.05$	57.58	3.38**
Manipur	41.49	48.67	1.79**
Jammu & Kashmir	22.82	29.50	1.81**
Uttar Pradesh	6.17	53.65	9.87**
Assam	20.79	48.18	1.38NS
Other states	17.77	30.26	4.93**
India	**24.56**	**62.70**	**4.38****

** - Significant at 1 %; * - Significant at 5 %; NS - Non-significant; @ - Compound Annual Growth Rate; # - Statistics pertains to 2001-02; $- Statistics pertains to 2006-07.

(77.62 kg/100 DFLs) in 2018-19 followed by Karnataka (65.23 kg/100 DFLs). The cocoon yield levels in these two states were above the national average of 62.70 kg/100 DFLs in 2018-19. During 1999-00, the cocoon yield levels of Andhra Pradesh, Maharashtra and Manipur were above the national average. But the growth rates in the cocoon yield levels were not sufficient enough to surpass the national average during 2018-19. The cocoon yield levels grew at a robust rate of 9.87 % in Uttar Pradesh to reach 53.65 kg/100 DFLs in 2018-19 from paltry 6.17 kg/100 DFLs in 1999-00. Jammu & Kashmir recorded the least cocoon yield of 29.50 kg/100 DFLs in 2018-19.

Factors influencing bivoltine raw silk production in Karnataka

Karnataka is the largest bivoltine as well as cross breed silk producing state in the country. A multiple regression analysis was carried out using time series data for the period between 1999-00 and 2018-19 to identify the factors influencing the growth in bivoltine raw silk production in Karnataka. After considering several variables in the regression model, the variables, such as cocoon yield, price premium for bivoltine cocoons, number of automatic reeling units established and the number of farmers covered under the bivoltine programmes implemented by the government agencies, were identified to capture the variations in bivoltine raw silk production in Karnataka. The results of the regression analysis are presented in Table 6. The coefficient of multiple determination (R^2) of the regression function was 0.965, implying that 96.5 % of variation in bivoltine raw silk production could be explained by the variables included in the function.

Table 6: Regression coefficients of variables influencing bivoltine raw silk production in Karnataka

Variable	Regression coefficient	Standard error	t statistic	P value
Constant	0.255	111.970	0.002	0.998
No. of farmers	0.048	0.009	5.329	0.000
Cocoon yield	16.317	4.055	4.024	0.001
Automatic reeling units	31.322	5.389	5.812	0.000
Price premium	-5.635	2.278	-2.473	0.026

$R^2 = 0.965$

The regression coefficient of the variable, number of farmers covered under the bivoltine programmes implemented by the government agencies (0.048) was highly significant (p> 1%) and positive. The regression coefficient implies that if there is increase in coverage of one additional farmer under the bivoltine promotion programme keeping all other variables constant, the silk production would increase by 48 kg. Das and Angadi (2016) observed that the government implemented JICA projects significantly impacted to improve the bivoltine silk production in India. The intensive bivoltine promotion programmes not only help to enhance the silk production but also would facilitate for the diffusion of the technologies from adopted farmers to other farmers and increase their yield and income levels. Ahmad *et al.* (2019), Sreenivasa Rao *et al.* (2019), Aslam *et al.* (2020) and many more studies indicated that the CPP had helped to increase the cocoon yield and income levels of the farmers in the area, where the programme was implemented.

Positive and highly significant regression coefficient of 16.32 for cocoon yield implies that a unit increase in cocoon yield would increase 16.32 units in bivoltine raw silk production. The major issue in the production of bivoltine cocoon in India is its crop instability as bivoltine silkworms are highly susceptible to diseases compared to crossbreed silkworms (Kawakami, 1999). Adoption of improved technologies for bivoltine crops ensures crop stability and higher cocoon yield. Further, the higher cocoon yield would motivate the farmers to go for bivotine silkworm rearing.

Before establishment of automatic reeling machines in India, the bivoltine cocoons were used either in multi-end reeling machines or cottage basin machines. While 2A-3A grade silk can be reeled out of the multi-end reeling machines, cottage basin machines are note able to deliver high grade silk. Therefore, the bivoltine silk reeled out of cottage basins fetched less price than cross breed silk. Automatic reeling units are preferred for their consistency in producing high quality bivoltine raw silk. Highly significant coefficient of automatic reeling machine (31.32) in the regression model indicates that one automatic reeling unit would increase the bivoltine silk production by 31.32 MT.

The coefficient of price premium for bivoltine cocoons was statistically significant ($p>5$ %) but, was negative. The sign of the regression coefficient was against the expectation, as it is generally expected that the farmers would prefer to produce bivoltine cocoons, if they get better price over crossbreed cocoons. The price movement of cocoon depends on many factors, such as cocoon arrivals (supply), demand for cocoons, government policies (customs duty, anti-dumping duty on silk, price incentives for bivoltine cocoons *etc*.) *etc*. The negative sign for premium price for bivoltine cocoons may be due to increased premium prices for bivoltine cocoons when there was reduction in bivoltine cocoon production due to adverse agro-climatic conditions and pest and disease incidences. Rajesh (2012) observed that the price differential between bivoltine and cross breed was narrow and sometimes prices even fell below that of cross breed, which was partly due to the fact that the reelers were hesitant to offer a higher price for bivoltine cocoon because of low prices experienced by the reeling industry for their produce.

Summary and conclusion

While the bivoltine silk production grew at a compound growth rate of 14.92 % per annum during 1999-00 to 2018-19, the total mulberry silk production recorded a modest growth of 2.79 % during the same period. The fast pace of growth in bivoltine silk production resulted in steep increase in its share in total mulberry silk production in the country from a mere 2.67 % in 1999-00 to whopping 27.57 % in 2018-19. Tamil Nadu and Maharashtra recorded a very high growth in bivoltine silk production. Varying pattern and magnitude of instability in mulberry silk production were recorded across the states. Maharashtra and Uttar Pradesh had high amount of instability in bivoltine silk production compared to other states.

The regression analysis on various factors contributing for growth in bivoltine silk production in Karnataka indicated that number of farmers covered under bivoltine sericulture promotion programmes, automatic reeling machines and cocoon yield have contributed significantly for growth in bivoltine silk production in the state.

Though there was a decent growth in bivoltine silk production in Karnataka and Andhra Pradesh, it still accounts for less than 20 % of the total mulberry silk production and hence, these states require more thrust in this direction. The bivoltine promotion programmes have yielded fruitful results in increasing bivoltine silk production in the country. Automatic reeling machines can be promoted to increase the bivoltine silk produced in the country in general and increase the quality of silk produced in the country in particular. There is also a need for large scale promotion of stabilization measures, such as crop insurance, minimum support price *etc.,* to face the consequences of production and price fluctuations.

REFERENCES

Ahmad H. R., Khan G. A. and Ghosh M. K. (2019) Impact of bivoltine Cluster Promotion Programme on cocoon productivity and quality in Bandipora area of Jammu & Kashmir state. *J. Pharmacogn. Phytochem.*, **8 (1):** 1572-1575.

Aslam M., Kant A. K., Kimothi R. C. and Tripathi P. M. (2020) Impact of Cluster Promotion Programme on silk industry in Uttarakhand. *J. Entomol. Zool. Stud.*, **8 (1):** 182-186.

Chand R. and Raju S. S. (2008) Instability in Indian agriculture during different phases of technology and policy. *Discussion Paper No-1*, National Professor Project, National Centre for Agricultural Economics and Policy Research, Indian Council of Agricultural Research, New Delhi, India.

Dandin S. B., Basavaraja H. K. and Suresh Kumar N. (2005) *Silkworm Breeds and Hybrids at Galore*, Central Sericultural Research and Training Institute, Mysore.

Das R. C. and Angadi B. S. (2016) Impact of JICA Projects on Indian Sericulture: A Replicable Model for Other Countries, *24th International Congress on Sericulture and Silk Industry*, August 10-14, 2016, Bangkok, Thailand, http://qsds.go.th/isccongress24th/documents/Oral/Session%206/Session%206%20-%20R.C.%20Das.pdf, Accessed on May 27, 2020.

Hazell P. B. R. (1982) Instability in Indian Food Grain Production, *Research Report No. 30*, International Food Policy Research Institute, Washington, D.C., U.S.A.

Jayaswal K. P., Rama Mohana Rao P., Ahsan M. M. and Datta R. K. (2001) Bivoltine Silkworm Breeding Strategies in the Tropics, Global Silk Scenario-2001, *Proceedings of the International Conference on Sericulture*, Oxford and IBH Publishing Co., Calcutta, pp. 222-232.

Kawakami K. (1999) *Standard new practical technologies for commercial bivoltine silkworm rearing*, Japan International Cooperation Agency, Promotion of Popularizing the Practical Bivoltine Sericulture Technology Project, Central Sericultural Research and Training Institute, Mysore.

Kumaresan P. (2002) Quality silk production: Some economic issues. *Econ. Polit. Wkly.*, **XXXVII (39):** 4019-4022.

Massell B. F. (1970) Export instability and economic structure. *Am. Econ. Rev.*, **60 (4):** 618-630.

Naik G. and Babu K. H. (1993) *Demand and Supply Prospects for High Quality Silk*, Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi.

Rajesh G. K. (2012) Diffusion of agricultural innovations in India - The case of bivoltine hybrid technology in South Indian sericulture. *Int. J. Agron. Plant Prod.*, **3 (10):** 374-384.

Ray S. K. (1983) An empirical investigation of the nature and causes for growth and instability in Indian agriculture: 1950-80. *Indian J. Agric. Econ.*, **38 (4)**: 459-474.

Sarada C., Ravisankar T., Krishnan M. and Anandanarayanan C. (2006) Indian seafood exports: Issues of instability, commodity concentration and geographical spread. *Indian J. Agric. Econ.*, **61 (2):** 238-252.

Sreenivasa Rao T. V. S., Balaji Chowdary N., Venkata Ramana P., Sudhakar P., Vijaya Naidu B., Kiran Kumar K. P. and Pankaj Tiwari (2019) Bivoltine sericulture development in coastal area of Andhra Pradesh through Cluster Promotion Programme (CPP). *Int. J. Rec. Acad. Res.*, **1 (7):** 358-365.

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Research Paper

TWIST OPTIMIZATION OF MUGA SILK YARNS FOR DEVELOPMENT OF DIVERSIFIED FABRICS BY RETAINING ITS NATURAL GOLDEN COLOUR

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ABSTRACT

The golden yellow Muga silk is produced only in Assam and other North-Eastern states of India by the Muga silkworm, *Antheraea assamensis*. It is the costliest natural textile fiber in the world. The present study was aimed towards the improvement of Muga yarn quality by optimization of twists and development of new Muga silk fabric products in the form of Crepe and Chiffon for its wider application in Muga silk garment making. Reeled Muga yarn of 60 / 70 denier (average of 65 denier) was used for this study. Twisting was done for both directions *i.e*., Z-Twist (clockwise) and S-Twist (counter clock wise). It was found that even at 2000 TPM twist level, it retains tenacity of 3.30 -3.40 gram per denier and elongation of 33.00 -36.00 per cent. The Muga Crepe fabric woven out of these yarns has 82 picks per inch in warp and 54 picks per inch in weft. Muga Chiffon fabrics of 36 inches width were woven by using 60 / 70 denier Muga yarn. Warp consisted of 2S + 2Z yarns of 2000 TPM and weft, S-Twist of 2000 TPM. The woven Muga fabric has a resultant weave of 84 ends and 58 picks per inch. Apart from achieving Crepe and Chiffon effect in Muga fabric, its natural golden colour was also retained by following standardised fabric finishing processes. In the natural golden coloured fabric thus produced, Crepe and Chiffon effect was obtained with 18 % crimp in width in the case of golden Muga Crepe and in the case of Chiffon, crimp of about 18 % was found in length, while crimp width for Chiffon was about 15 %. The fabric so produced has been found suitable for stitching garments.

Key words: Chiffon, Crepe, crimp, elongation, golden colour, Muga silk, natural colour, tenacity, twisting.

INTRODUCTION

The golden yellow Muga silk yarn is exclusively produced in the North-East Indian state of Assam and adjoining areas by Muga silkworm (*Antheraea assamensis*). It is considered to be the most expensive natural commercial textile fiber in the world. Presently, Muga raw silk yarn is sold at about US$ 300.00 – 325.00 per kilogram. Prevailing cost for about one 1 square meter of plain Muga silk fabric is about 30.00 – 45.00 US$. India is producing around 200 metric tons of Muga raw silk annually.

However, Muga silk products are confined to plain weave with sized Muga warp, and limited traditional loom finished Muga fabrics like “Mekhala, Chaddar and Sarees” are made for local consumption. This study was taken up with an objective of improving Muga yarn quality by optimization of twists and to develop new Muga silk fabric products in the form of Muga Crepe and Muga Chiffon for its wider application in manufacturing Muga silk garment clothing.Though general literature are available on Mulberry silk Crepe and Chiffon (Somashekar, 2001), no scientific information has so far been published on weaving of Muga silk fabrics wiith Crepe and Chiffon effects.

In order to increase the demand for Muga silk products in other parts of India and for venturing in foreign export, Muga silk product diversification is felt essential. The output of this work would support in expanding Muga silk fabric product base and diversification of products for wider marketing. As golden yellow Muga silk is unique in the world due to its natural colour, all precautions were taken in this study to retain its natural colour during product diversification.

With the above objective, the present study comprised of the following attributes:

I. Twisting of Muga raw silk yarn and twist optimization for weaving diversified Muga silk fabrics.

ii. Weaving attempts on developing high tech fabrics like Crepe and Chiffon with twisted Muga silk yarns for product diversification.

iii. Standardisation of Muga silk fabric finishing techniques for retaining natural colour in Muga high tech fabrics.

iv. Seam study on Muga silk Crepe and Chiffon fabrics in preparation to use as dress materials and garments.

MATERIALS AND METHODS

Reeled Muga raw silk

Commercial Muga silk cocoons are available only during two seasons every year: once during April-June (*Jethua* crop) and again during October-December (*Kotia* crop). It has an average shell weight of 0.40 -0.60 grams, average filament length of 425 – 575 metre and single filaments are of 4.5 -6.0 denier. In this study, the reeled Muga raw silk yarn of 60 / 70 denier (average of 65 denier) of major commercial crop, October-December was used. These yarns were produced on conventional Muga reeling machine "*Bhir*"/ indigenous improved Muga reeling devices.

Muga silk twisting

Twisting is the process of increasing compactness of filament in silk thread to resist their splitting during further processing. This is achieved by winding raw silk threads into multi-spiraled thread. Twisting increases the strength of a yarn and creates compression for packaging. It gives more uniform fabric texture and better comfort properties and hence, is an indispensable means of improving certain yarn properties and satisfying textile requirements that cannot be fulfilled by untwisted silk yarns (Sanmugandam, 2007).

The machine (Make: Yamada Tekko - Japan) used for up twisting has two side 25 x 25 spindle semi-arc type spindle frame and the production per spindle per hour is as stated below:

(I) 750 TPM , 65 denier , 2.5 g/sp/hour
(ii) 1000 TPM , 65 denier, 2.0 g/sp/hour and
(iii) 2000 TPM, 65 denier, 1.0 g/sp/hour

Speed of take up drum was increased or reduced to increase TPM. Take up drum diameter is 5 cm, drum length, 8 cm and spindle barrel diameter is 3cm. Distance of twisting path was fixed as 60 cm and twist direction as per requirement *i.e.*, either Z -twist or S-twist. Spindle speed was maintained constant. Spindle driving speed was fixed at 5500 rpm. Muga silk yarn count was average of 65 deniers. Tangential belt drive system by using one single long belt to drive all the spindles through a centralized tensioning arrangement was applied. Package capacity of take up drum was 100 g. Pre-twist soaking of yarn was done in water with 2 % soap solution and 1 % coconut oil.

With futuristic object related to shuttle-less weaving of Muga silk fabric by continuous cone weft yarn feeding, the cone winding test of Muga silk twisted yarn was also conducted on precision cone winder.

Twist-setting

Twist-setting was done by steaming in conventional steaming chest. Steam setting was applied for slightly longer duration as Muga silk sericin is less hydro-soluble in comparison to that of mulberry (Sonwalkar, 2001).

Muga silk weaving

Sectional warping drum was used for warp making. The weaving was done on 2 x 2 Japanese Tsudakoma Under-pick power-loom (Yang, 2007). Weaving for Muga Crepe and Chiffon in natural golden colour was also conducted in 2 x 2 indigenous drop box power-looms. In Muga Crepe fabric weaving, reeled untwisted Muga yarns of 60 / 70 denier with 0-Twist was used as warp thread.

Since Muga silk yarn is reeled by wet reeling method by keeping cocoons in hot water and "croissure" effect is also given during reeling, workable cohesion is obtained in reeled silk yarn. In addition to this, very low hydro-solubility of sericin also helps in proper irreversible-fixing of cohesion during reeling. Hence, properly reeled Muga silk yarn works as warp with proper strength in untwisted form too.

Weft yarn used in Muga Crepe silk weaving was of 2 pick S twisted + 2 pick Z twisted, each of 60 / 70 denier with 2000 TPM twist.

Muga Chiffon silk fabrics of 36 inches width were woven by using 60 / 70 denier Muga yarn. In warp, 2S + 2Z yarns of 2000 TPM were used and weft, consisted of yarns of S –Twist of 2000 TPM (Shehata, 2015).

Product definition

Crepe: These are plain-woven fabrics characterized by uniformly distributed "Grains" throughout the body of the fabric, forming a crinkled surface. This is called 'crepe effect', (Raichurkar and Shymasundar, 1989). The crinkles are produced by contraction to the extent of 15 to 20 per cent of highly twisted yarn in weft directions.

Chiffon: It is a very soft and flimsy plain-woven silk texture, consisting of the finest singles yarn, (Somashekar, 2001) which are hard and woven with the gum (Shimizu Masanori *et al*., 1972). The fabric is delicate but relatively strong. The changes in the weight are brought about by varying the warp / weft denier. The thread spacing and twist are also influencing factors in Chiffon to some extent.

Fabric finishing

With the object of getting Crepe and Chiffon effect in Muga fabric by retaining its natural golden colour, the fabric was subjected to different processing treatments, such as degumming in soap -soda solution for durations of 1 hour and 30 minutes, and 3 hours, and soaking- cum-boiling in alkaline banana-trunk extract.

Seam test

Prior to the process of garment making, Muga silk fabric seam test was conducted with Singer sewing machine having 0.70 mm size needle, running at 1000 seam / minute and having 14 seam / inch density by using Seam test Methodology "ASTM D 1683". Sewing thread of polyester ply yarn of about 26 tex was used as this is considered compatible to Muga silk (Itagi and Basu, 2012). All specimens were ironed at standard temperature and conditioned at 27 °C and 65 % RH for 24 hours before testing. The fabric so produced was found suitable for stitching garments. Seam study was done on lock stitch machine.

The tensile strength and seam efficiency were calculated as following.

$$\text{Tensile strength (TS)} = \frac{\text{Maximum load in warp direction} + \text{Maximum load in weft direction}}{\text{Cross section area}}$$

$$\text{Seam efficiency} = \frac{\text{Seam strength}}{\text{Fabric strength}} \times 100$$

Various properties of the experimental fabrics were compared with those of the control one *i.e.*, Muga silk fabric woven with untwisted yarn. Testing standards, such as ASTM D3574-17 (2002) and ASTM D6193-92 (2004) were adopted for this purpose.

Further, Muga Fabric Colour Retention Test was conducted with advanced spectrometer based on the norms developed by CMC (Colour Measurement Committee) and CIE (Commission International for Illumination).

RESULTS AND DISCUSSION

The twisting process revealed that Muga raw silk yarns respond very well in the twist range of 1950 -2000 TPM. In this range, it has tenacity of 3.2 -3.4 gram per denier, elongation of 34.10 – 34.80 % and crimp performance of 21.8 -23.6 % (Tables 1, 2). However, it is observed that in the twist range that is above 1950 -2000 TPM, there is a tendency of tenacity reduction. Hence, 1950-2000 TPM has been considered as optimum twist level.

Under the cone winding test, the yarn was wound conveniently at 360 metre / minute on cone of 6 ° angle with 3 breaks / hour / cone (Table 3).

Table 1: Impact of Muga silk twisting (Z)

TPM	Twist	Crimp (%)	Tenacity (g/denier)	Elongation (%)
Control (0)	No-twist	5.5	3.3	34.3
1252	Z	9.1	3.7	36.9
1503	Z	12.7	3.5	35.7
1806	Z	16.4	3.4	35.2
1953	Z	21.8	3.4	34.8
2204	Z	27.3	2.8	33.1

Table 2: Impact of Muga silk twisting (S)

TPM	Twist	Crimp (%)	Tenacity (g/denier)	Elongation (%)
Control (0)	No-twist	5.5	3.4	36.9
1252	S	7.3	3.5	35.5
1503	S	10.9	3.6	35.2
1806	S	18.2	3.3	34.4
1953	S	23.6	3.2	34.1
2204	S	29.1	2.7	32.8

Muga Crepe & Chiffon silk fabric woven on 2 x 2 drop box power-loom in 36” width, when subjected to various processing treatments behaved differently. Colour retention was found only in the case of banana-trunk extract by restricting fabric weight loss to 6 % only and the treatment results are presented in Table 4.

Table 3: Cone winding performance of twisted Muga yarn

Particulars	Description
Cone type	HDP cone , 6 ° angle
Winding speed	360 meter / minute
Breaks / Cone spindle	3 breaks / hour
Purpose	Shuttle-less weaving

The muga silk fabric thus produced had the natural golden sheen with 18 % crimp in width in the case of Crepe. In Chiffon, the weft direction had crimp of about 18 % and in warp direction, it was about 15 %.

Table 4: Fabric processing for Crepe and Chiffon effects

Particulars	Description
Soaking medium	Banana trunk extract pH 9+
Soaking duration	3 hours
Boiling	10 % soap solution
Boiling duration	30 minutes
Weight loss	6 % (processing loss)
Calendaring	Felt calendaring

A comparison of Muga Crepe and Chiffon silk fabrics with Muga silk fabric woven with untwisted yarn (control) revealed that fabric unit weight (gsm), fabric thickness, cover factor, crimps, tensile load, elongation, surface roughness & compressibility are considerably superior in Muga Crepe and Chiffon silk fabrics. Results of these properties also aligned with featuring of Crepe and Chiffon effects (Tables 5, 6).

The woven Muga Crepe silk fabric has 82 and 54 picks per inch in warp and weft, respectively,whereas the Chiffon one has 84 ends and 58 picks per inch.

Table 5: Muga silk fabric particulars

Particulars	Unit	Control	Crepe	Chiffon
Muga reeled silk	Denier	60 / 70	60 / 70	60 / 70
Warp twist	TPM	NIL: ZERO	NIL: ZERO	2000 (2 S & 2 Z)
Weft twist	TPM	NIL: ZERO	2000 (S & Z)	2000 S (S or Z)
Ends	EPI	84	84	84
Picks	PPI	52	54	58

Table 6: Fabric properties

Particulars	Unit	(Muga) Control	Crepe	Chiffon
General properties				
Weight	GSM	51	53	56
Thickness	mm	0.29	0.41	0.36
Cover factor	%	15.15	17.07	18.09
Crimp (Length)	%	3.17	3.42	15.03
Crimp (Width)	%	4.57	18.18	18.10
Tensile properties				
Load (Warp way)	kgf	46.7	47.0	51.7
Load (Weft way)	kgf	38.1	38.7	39.2
Elongation (Warp way)	%	44.2	46.0	49.8
Elongation (Weft way)	%	42.9	43.3	43.7
Surface roughness				
Warp direction	micron	1.9	2.1	2.85
Weft direction	micron	2.2	2.9	2.75
Fabric compression				
Pressure range 50 – 500 Pa	%	11.3	16.1	14.8

Table 7: CMC: Colour Measurement Committee: Muga fabric colour retention test

Fabric	Harter lab value of colour X	Y	Z	Colour change CMC- DE* Textile	Brightness (%)
Muga Control	32.84	33.39	22.27	0.00	21.42
Muga Crepe	32.84	33.28	22.26	0.12	21.41
Muga Chiffon	32.84	33.24	22.25	0.17	21.40

*DE Value less than 0.50 indicates colour uniformity and purity

Muga silk fabric indicating that the colour has been retained, this becomes more clear as DE in both cases is less than 0.50 (Tables 7, 8). Muga sericin is strong and very low in water solubility and even resistant to mild alkaline solution. Hence, even after the treatment of boiling for softening and relaxing effect, the natural colour was retained in the fabric. Muga Crepe and Chiffon silk fabric remains more compact even after sericin softening and twist relaxing for Crepe and Chiffon effect due to very low sericin loss during softening treatment.

Table 8: CIE: Commission International for Illumination; Muga silk fabric colour test

Fabric	Colour value as per CIE – Colour coordinates: L-Light	(a) -green +red	(b) -blue, +yellow	Used in pigments, Paints & Textiles: C-Chrome	H-Hue	Colour change CIE-DE* Lab reading: DE
Muga Control	64.47	4.30	20.33	20.07	78.07	0.00
Muga Crepe	64.36	4.31	20.33	20.07	78.03	0.14
Muga Chiffon	64.35	4.31	20.33	20.07	78.01	0.17

*DE Value less than 0.50 indicates colour uniformity and purity

Table 9: Muga silk fabric Seam test

Factor	Unit	Muga Control	Muga Crepe	Muga Chiffon
Machine (Singer)	Single needle	Lock stitch	Lock stitch	Lock stitch
Needle size	0.70 mm dia	10 / 70	10 / 70	10 / 70
Speed	SPM	1000	1000	1000
Stitch density	SPI	14	14	14
Poly. Sewing thread	Tex (Z/S)	20	20	20
Fabric load (Warp way)	kgf	46.70	47.00	51.70
Seam tensile load (Warp way)	kgf	30.80	34.50	38.40
Seam efficiency (Warp way)	%	65.95	73.40	74.27
Fabric load (Weft way)	kgf	38.10	38.70	39.20
Seam tensile load (Weft way)	kgf	22.60	23.10	25.30
Seam efficiency (Weft way)	%	59.32	59.69	64.54

Both the norms (CMC and CIE) adopted for colour retention test confirmed a perfect match to that of control

The achieved seam efficiency was higher in Muga Crepe and Chiffon silk fabrics in comparison to untwisted Muga silk fabrics (Table 9).

The results along with the newly developed products (Figure 1, 2) were presented before silk weavers, processors, garment makers *etc*. and the stake holders were convinced with this good initiative in the direction of diversification of Muga silk products and hence, recommended for their production on commercial scale.

Figure 1: Muga Crepe silk fabric

Figure 2: Muga Chiffon silk fabric weaving in powerloom

The following are the conclusions drawn out of the present experiment.

- Muga silk yarn responds very well to raw silk twisting treatment up to about 2000 TPM without affecting yarn strength.

- It is possible to weave Muga Crepe and Chiffon silk fabrics with yarn of medium denier by keeping slightly lower ends and picks density.

- Natural colour in Muga Crepe and Chiffon silk fabrics can be retained and crimp effect in fabric is obtained by fabric processing treatments, such as longer soaking in banana-trunk extract and boiling, thereby eliminating the drastic degumming treatment.

- Comfort properties of Muga Crepe and Chiffon silk fabrics in terms of elongation and fabric compression are superior to those of conventionally woven Muga silk fabric with support of warp sizing.

- Muga Crepe and Chiffon silk fabrics have displayed fabric colour properties at par with conventional Muga fabrics and they respond very well to seams during garment making.

Limitations

As single cocoon filament denier of Muga filament is in between 4.5 - 6.0 denier, the common practice is to reel Muga silk thread of 60 / 70 denier and accordingly, Muga reeled yarn of this range was used for this study.

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REFERENCES

Itagi A. A. and Basu A. (2012) Drape behaviour of silk apparel fabrics with radial seams. *Indian J. Eng. Res. Technol.*, **1 (8)**: 1 -11.

Raichurkar P. and Shymasundar H. R. (1989) On wrinkle recovery of crepe silk fabrics. *Indian Text. J.,* **6 (June)**: 54-59.

Sanmugandam D. (2007) Study on two for one twisting (TFO), World of Garment –Textile- Fashion, Knowledge/ Fibre 2 Fashion.com, SITRA, Coimbatore-641014. www.fibre2fashion.com

Shehata Z. (2015) The Study of the effect of the juxtaposition of specific materials on some seam properties. *Life Sci. J.,* **12 (3)** http://www.lifesciencesite.com 195.

Shimizu Masanori *et al*. (1972) *Hand Book of Silkworm Rearing*, *Silk Fabrics*, Fuji Publishing Co Ltd, Tokyo, Japan, p. 248.

Somashekar T. H. (2001) *CSTRI norms for process parameters, performance & productivity in silk preparatory and weaving*, Central Silk Technological Research Institute, Bengaluru.

Sonwalkar T. N. (2001) *Hand Book of Silk Technology*, New Age International Pvt Ltd., New Delhi, p. 284.

Yang X. H. (2007) Evaluation and control principle of Crepe effect on fabrics. *Text. Res. J.*, **77 (10)**: 779 -784.

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Research Paper

INDIA'S TRADE INTENSITY IN SILK

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ABSTRACT

The status and intensity of India's silk trade were analysed using the United Nations' COMTRADE data for the period between 2001 and 2019. The Indian silk exports declined at -3.30 % per annum during the period from 2001 to 2019. The export intensity analysis indicated that the major export intensive markets for Indian silk were generally under-represented for the exports of Chinese silk. The United States of America (USA) market was over-represented for the exports of Indian silk goods, but was under-represented for Chinese silk exports. However, China had better export intensiveness compared to India for the exports of value added silk items. The European Union (EU) market was under-represented for the exports of both Indian and Chinese silk goods. The export intensiveness of Indian silk goods have been declining in the EU market since 2005.

Key words: Compound annual growth rate, exports, Export Intensity Index.

INTRODUCTION

The production and international trade of silk has a long history. Many countries across Asia, Europe, Africa and Latin America have been practising sericulture. However, owing to various factors, such as changes in socio-economic conditions of farmers, dreaded silkworm diseases, competition from synthetic fibres, economic and political reasons and other local factors, the silk production has reduced drastically in many countries leaving only China and India as the major silk producing countries. These two countries put together account for about 97 % of the global silk production. Though the European countries have stopped producing the raw silk, the silk processing activities still exist in a large scale in some countries, such as Italy, France, Germany and the United Kingdom (UK). These counties import raw silk primarily from China and produce silk fabrics and other value added products thereby playing a leading role in global silk trade.

With the distinction of the second largest producer and the largest consumer in the world, India has a tradition bound vibrant silk industry. India produced 35,820 MT raw silk during 2019-20. Besides, India imported 3,315 MT raw silk during 2019-20 to fill the demand supply gaps in the industry. India being a leading producer of silk, is expected to play a major role in the global trade in silk. The liberalization of trade barriers after the establishment of World Trade Organization (WTO) and the economic and trade reforms adopted by India since 1991 had a major impact and redefined India's silk trade on the international platform. In this scenario, an attempt is made here to study the status and intensity of India's silk trade with its partners. Besides, India's export trade intensity in selected silk commodities were compared with that of China, which is the largest exporter of silk.

DATABASE AND METHODOLOGY

The present study was based on the time series data pertaining to the period between 2001 and 2019 compiled from COMTRADE database of United Nations. The disaggregated data obtained under the chapters of 50 (silk) and 62 (articles of apparel, accessories, not knit or crochet) were used for analysing the performance of silk goods exported from India. Only the major silk items traded in the world market, which are available in the COMTRADE database, were used in the present study. Percentage shares and growth rates were worked out to understand the status of silk trade between India and its trade partners.

Trade Intensity Index is a measure of the extent to which one country's exports / imports differ from the former's share in the world trade. This concept was first used by Kojima (1964) and thereafter, it was adopted in many trade related studies. The intensity of trade is determined by both the complementarity of the commodity mixes of imports and exports in the bilateral relationships. Foroutan (1998), Chow and Kellman (1999) and many other studies revealed that mere volume of a trade flow from country y to x alone is not enough to unravel the relative importance of the trade linkage for country y or x completely. In contrast to the trade volume measure, the trade intensity index is an explicit measure of the relative importance of the trade linkage between two countries.

The Export Intensity Index (EII) is defined for a country i's exports to country j as the share of country i's exports going to country j relative to the share of country j's imports in the world imports. The implications of the EII is whether country i's exports to a country j is having a greater presence in its export basket vis-à-vis the world's export inclination to that country. If the index is greater than unity, it implies that country i's exports to that market has been intensive. The index can be expressed as:

$$EII_{ij} = \frac{X_{ij}/X_i}{M_j/M_w}$$

Where,

EII_{ij} = Export Intensity Index (EII) of trade of country i with country j
X_{ij} = Exports of country i to trading partner j
X_i = Total exports of country i
M_j = Total imports of country j
M_w = Total world imports

RESULTS AND DISCUSSION

The total export of silk from India increased from US$ 3,202 million in 2001 to the highest level of US$ 5,312 million in 2006 but started declining in the subsequent years and reached US$ 1,694 million in 2019 (Table 1). Overall, the Indian silk exports registered a negative compound growth of -3.30 % per annum during the period between 2001 and 2019. The United States of America (USA) and the United Arab Emirates (UAE) were the major markets for Indian silk. These two markets put together accounted for 41.11 % of India's total value of silk exports in 2019. While silk exports to the USA grew negatively from 2001 to 2019 at -3.95 % per annum, the silk exports to the UAE recorded a positive growth of 3.26 % per annum.

The silk exports to China recorded a high growth rate of 9.12 %, which was mainly due to the increase in export of silk wastes (HS code: 5003) from India in the recent years. South African and Malaysian markets also grew positively for Indian silk exports at a compound annual growth rate (CAGR) of 6.18 % and 0.28 %, respectively. The remaining markets recorded negative growth during the period between 2001 and 2019.

Export intensity of India and China with their trading partners

Export intensities were calculated separately for India's and China's exports in silk goods for four different periods *viz.,* 2001, 2005, 2010, 2015 and 2019 in an attempt to explore the potential of their trade expansion in silk goods and the results are presented in Table 2. The USA and UAE are the prime partners for the Indian silk exports. While the UAE was over-represented in the exports of Indian silk goods during all the periods, the export intensity reduced for USA during 2010 and 2015, but increased considerably during 2019. Malaysia, Singapore, South Africa and the UK were over-represented in the exports of Indian silk goods, whereas France and Italy, the major silk consuming European countries, had under-representation for the exports of silk goods from India.

Table 1: Silk exports from India to its major export markets during 2001 to 2019

Partner	2001		2005		2010		2015		2019		CAGR for 2001-2019 (%)
	Value (million US$)	% share	Value (million US$)	% share	Value (million US$)	% share	Value (million US$)	% share	Value (million US$)	% share	
USA	933	29.13	1387	26.69	580	12.19	326	13.30	434	25.61	-3.95
UAE	143	4.46	277	5.34	410	8.63	535	21.81	262	15.50	3.26
China	26	0.80	50	0.97	121	2.55	141	5.73	135	7.95	9.12
UK	234	7.31	420	8.09	438	9.22	192	7.81	92	5.43	-4.80
France	118	3.69	201	3.88	161	3.38	101	4.12	67	3.97	-2.92
Italy	205	6.42	443	8.52	197	4.13	101	4.13	63	3.74	-6.01
Germany	218	6.80	305	5.87	226	4.75	97	3.96	55	3.26	-6.96
Singapore	124	3.86	155	2.98	105	2.20	43	1.77	46	2.70	-5.11
South Africa	14	0.42	45	0.87	24	0.50	16	0.66	42	2.49	6.18
Malaysia	31	0.97	47	0.90	143	3.01	118	4.81	33	1.94	0.28
Others	1158	36.15	1865	35.89	2352	49.44	783	31.89	464	27.42	-4.69
World	**3202**	**100.00**	**5195**	**100.00**	**4757**	**100.00**	**2454**	**100.00**	**1694**	**100.00**	**-3.30**

CAGR - Compound annual growth rate

The EII increased substantially for China and became more than one during 2015 and 2016, indicating over-representation of Indian silk goods exports to this country in recent years. The increase in the value of exports and EIIs are primarily due to increase in exports of silk wastes substantially to China in the recent years. On the other hand, the value of EII declined over the period for Germany.

The USA, Singapore, South Africa and the UK were over-represented in the exports of Indian silk goods, but these markets were under-represented for the exports of Chinese silk goods. Though the UAE and Malaysia were over-represented for the Chinese silk exports also, the EIIs for India were higher than that of China. Italy, which is an important market for silk was over-represented for Chinese silk but under-represented for Indian silk. France and Germany were under-represented for the exports of both Indian and Chinese silk goods. The analysis clearly shows that India maintains better trade linkages with its top 10 silk export markets compared to China. India had better linkages especially with the USA and the UAE, which is reflected through higher EIIs compared to that of China.

Table 2: Silk export intensities of India and China with India's major trading partners

Partner	India					China				
	2001	2005	2010	2015	2019	2001	2005	2010	2015	2019
China	0.26	0.33	0.72	1.96	1.95	-	-	-	-	-
France	0.75	0.75	0.60	0.64	0.50	0.16	0.31	0.31	0.28	0.23
Germany	1.12	1.28	0.94	0.73	0.87	0.87	0.70	0.66	0.74	0.77
Italy	0.78	1.05	0.42	0.34	0.30	1.26	1.31	1.24	0.97	1.16
Malaysia	3.47	3.15	6.14	9.47	5.81	0.86	1.89	4.05	4.19	4.50
Singapore	3.64	3.63	3.15	2.32	2.16	0.99	2.13	2.17	0.52	0.13
South Africa	3.92	4.60	3.27	3.49	18.63	0.13	0.26	0.20	0.19	0.64
UAE	-	5.52	-	12.74	7.95	-	1.58	-	1.64	0.66
UK	1.51	1.45	1.94	1.62	1.33	0.25	0.33	0.35	0.45	0.52
USA	1.31	1.34	0.91	0.93	2.19	0.87	0.80	0.79	0.82	0.83
Others	0.74	0.70	0.88	0.63	0.52	1.23	1.22	1.15	1.25	1.26

Export intensities in different silk goods

The export intensities were also computed for the different silk goods for the USA, which is the largest market for the Indian silk goods. As the silk consumption in Western European countries are quite high, the trade intensity indices were also worked out for the entire region by considering the exports to the European Union (EU).

Export intensities of India and China with the USA in silk goods

The values of commodity-wise India's and China's EII with the USA are given in Table 3. The USA had under-representation in India's total exports (all commodities) in 2005 and 2010, which is evident from export intensity value of less than one. However, the export intensity values of total exports increased significantly in 2015 and 2019 and India maintained a relatively good and balanced trade with the USA.

In the similar pattern, the export intensity values of overall silk goods reduced from 1.34 in 2005 to 0.91 in 2010 and 0.93 in 2015 but increased to 2.19 in 2019. The values, in general, indicate that the US market was over-represented in the exports of silk goods from India in 2001 and 2005, but became less intensive in 2010 and 2015. The US market once again became over-represented for Indian silk exports in 2019.

The values of EII of silkworm cocoons, raw silk and silk yarn were significantly more than one for most of the periods, but it should be noted that neither India is a large exporter nor the USA is a major importer of these items. The USA was under-represented in the exports of major value added Indian silk goods, such as women's/girls' blouses, shirts and shirt-blouses, shawls, scarves, mufflers, mantillas, veils and the like and ties, bow ties and cravats. The USA had over-representation in the silk fabrics with the EII values well above normal level of one. Silk fabrics, with a share of 59.01% of the total value of Indian silk goods exported to the USA, is obviously the major item in the India's silk export basket for the USA.

Table 3: Export intensities of India and China with the USA in silk goods

Product code	Product Label	India					China				
		2001	2005	2010	2015	2019	2001	2005	2010	2015	2019
5001	Silkworm cocoons suitable for reeling	-	75.27	0.00	0.00	0.00	-	0.00	0.00	0.00	613.46
5002	Raw silk "non-thrown"	32.68	915.36	8.55	5.85	50.14	0.00	1.80	0.02	0.00	0.00
5003	Silk waste, incl. cocoons unsuitable for reeling, yarn waste and garnetted stock	1.39	0.78	0.00	0.11	1.08	0.44	0.34	0.16	0.64	0.01
5004	Silk yarn (excluding that spun from silk waste and that put up for retail sale)	4.64	22.09	0.44	2.90	3.81	0.53	0.13	0.06	1.41	7.70
5005	Yarn spun from silk waste (excluding that put up for retail sale)	3.23	1.34	12.16	22.28	27.29	0.43	0.32	0.49	0.62	0.32
5006	Silk yarn and yarn spun from silk waste, put up for retail sale	0.35	1.69	0.83	1.40	1.57	0.00	0.06	0.19	2.08	0.36
5007	Woven fabrics of silk or of silk waste	2.01	2.07	1.77	3.18	7.15	0.33	0.51	0.53	0.50	0.47
620610	Women's or girls' blouses, shirts and shirt-blouses of silk or silk waste	0.62	0.72	0.90	0.80	1.58	1.10	1.25	1.52	1.38	1.64
621410	Shawls, scarves, mufflers, mantillas, veils and similar articles of silk or silk waste	0.75	0.67	0.73	0.32	1.28	1.25	1.37	1.95	1.66	2.84
621510	Ties, bow ties and cravats of silk or silk waste	0.34	0.03	0.04	0.08	0.09	0.80	1.54	1.75	1.53	1.50
	All silk goods	1.31	1.34	0.91	0.93	2.19	0.87	0.80	0.79	0.82	0.83
	All products	1.03	0.98	0.82	1.09	1.23	1.10	1.28	1.38	1.29	1.22

Table 4: Export intensities of India and China with the EU in silk goods

Product code	Product Label	India					China				
		2001	2005	2010	2015	2019	2001	2005	2010	2015	2019
5001	Silkworm cocoons suitable for reeling	5.09	1.56	69.86	0.00	1.55	0.00	0.00	6.87	0.00	0.06
5002	Raw silk "non-thrown"	0.38	1.40	1.85	0.00	0.00	0.42	0.43	0.58	0.64	0.75
5003	Silk waste, incl. cocoons unsuitable for reeling, yarn waste and garnetted stock	0.36	0.06	0.01	0.12	0.26	0.90	1.11	1.17	1.12	2.16
5004	Silk yarn (excluding that spun from silk waste and that put up for retail sale)	0.16	0.86	0.15	0.12	0.02	1.40	0.84	0.57	0.60	0.53
5005	Yarn spun from silk waste (excluding that put up for retail sale)	2.83	7.08	3.83	1.30	0.05	0.99	1.68	0.86	0.81	0.89
5006	Silk yarn and yarn spun from silk waste, put up for retail sale	1.01	1.91	0.66	1.12	0.43	0.10	0.33	0.06	0.87	0.67
5007	Woven fabrics of silk or of silk waste	1.33	1.35	1.06	1.28	0.95	0.57	0.66	0.95	0.80	0.87
620610	Women's or girls' blouses, shirts and shirt-blouses of silk or silk waste	0.77	0.92	0.93	0.51	0.66	0.40	0.31	0.72	0.79	0.82
621410	Shawls, scarves, mufflers, mantillas, veils and similar articles of silk or silk waste	0.86	1.13	0.95	0.51	0.38	0.72	0.59	0.84	0.83	0.78
621510	Ties, bow ties and cravats of silk or silk waste	0.14	1.84	0.09	0.94	0.28	0.68	0.84	0.79	0.78	0.92
	All silk goods	1.06	1.21	0.96	0.69	0.54	0.62	0.60	0.72	0.70	0.76
	All products	0.59	0.57	0.54	0.54	0.52	0.42	0.49	0.57	0.50	0.52

China had higher values of EII compared to India for its total exports (all commodities) indicating that the USA was more over-represented for China's total exports compared to India's total exports to the USA. However, USA was under-represented in China's total export of silk goods. The USA was over-represented in China's exports of value added items such as women's or girls' blouses, shirts and shirt-blouses of silk or silk waste, shawls, scarves, mufflers, mantillas, veils and similar articles of silk or silk waste and ties, bow ties and cravats of silk or silk waste. But, the USA market was under-represented for India's export of these value added items. In the broad categories of raw silk, silk yarn and silk fabrics, India's export intensity was higher and more than one for most of the periods. But, the USA market was under-represented in the Chinese exports of raw silk, silk yarn and silk fabrics.

Export intensities of India and China with the EU in silk goods

A similar exercise is carried out for India's and China's export intensities with the EU and the results are shown in Table 4. The EU was under-represented in India's total exports (all commodities) for all the periods, but over-represented in overall silk goods in 2001 and 2005, but became under-represented during the further periods. The table also reveals that India's export intensity in total exports and overall silk goods exports decreased consistently during the period between 2001 and 2019.

For all the items except cocoons and silk waste, the value of EII increased from 2001 to 2005 and the EU market was over-represented for India's exports of silkworm cocoons, raw silk, silk yarn, woven fabrics, shawls, scarves, mufflers, mantillas, veils and similar articles and silk ties, bow ties and cravats in 2005.

In the broad categories of raw silk, silk yarn, silk fabrics, women's or girls' blouses, shirts and shirt-blouses, shawls, scarves, mufflers, mantillas, veils and similar articles and silk ties, bow ties and cravats, India's export intensity decreased steadily and became under-represented in the year 2019. The EU was under-represented in all the export items except silkworm cocoons suitable for reeling, in 2019. However, the silkworm cocoon is not a major traded item for India. As in the case of trade intensity with the USA, India maintained high level of export intensity in woven fabrics of silk, with the EU also.

China maintained under-representation for overall exports (all commodities) and for total silk commodities for all the periods. The EU market was over-represented only for Chinese exports of silk wastes in 2010, 2015 and 2019. The Chinese exports of all other commodities were under-represented in EU. However, the EII values were higher during 2019 compared to 2001 for most of the items indicating an increasing export intensity for Chinese silk products in the European market.

Summary and conclusion

The Indian silk exports declined at -3.30 % per annum during 2001 to 2019. Among the top ten trade partners, the UAE, China, South Africa and Malaysia recorded positive growth for silk exports. The major markets, which were more export intensive for Indian silk goods, were generally under-represented for Chinese silk. The USA, Singapore, South Africa and the UK were over-represented in the exports of Indian silk goods, but were under-represented for the exports of Chinese silk goods. Though the UAE and Malaysia were over-represented in both the exports of Indian and Chinese silk, the EIIs for India were higher than that of China.

The USA market was over-represented in the export of silk fabrics, which is India's major item of silk exports. Though The USA market was under-represented in China's total silk exports, China had better export intensiveness compared to India for the exports of value added items such as women's or girls' blouses, shirts and shirt-blouses of silk or silk waste, shawls, scarves, mufflers, mantillas, veils and similar articles of silk or silk waste and ties, bow ties and cravats of silk or silk waste.

The EU market was under-represented in the exports of both Indian and Chinese silk goods. While the export intensiveness of Indian silk goods has been declining in the EU market, the export intensiveness of Chinese silk goods is improving. The declining export intensiveness in the EU market may be one of the reasons for overall declining export performance of Indian silk goods in the last decade.

India should take strong measures to increase its trade relationship and the compatibility between its exports and global imports of major importing countries to improve its trade in silk goods. The Indian silk exporters should concentrate on fashion, technology, quality and services to compete in the major silk consuming markets. The exporters should actively conduct personal visits, participate in trade fairs and concentrate on Customer Relationship Management (CRM) with the buyers for promoting their products in the international market.

REFERENCES

Chow P. and Kellman M. (1999) A Test of the Linder Hypothesis in Pacific NIC Trade 1965-1990. *Appl. Econ.*, **31 (3)**: 175-182.

Foroutan F. (1998) Does Membership in a Regional Preferential Trade Arrangement Make a Country More or Less Protectionist? *World Econ.*, **21 (3)**: 305-333.

Kojima K. (1964) The Pattern of International Trade among Advanced Countries. *Hitotsubashi J. Econ.*, **5 (1)**: 16-36.

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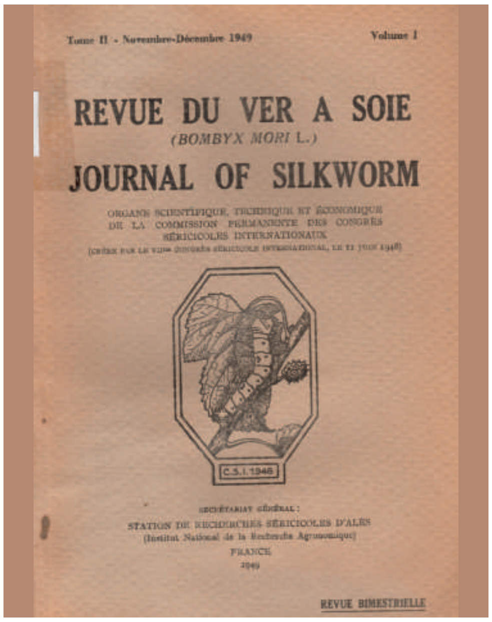

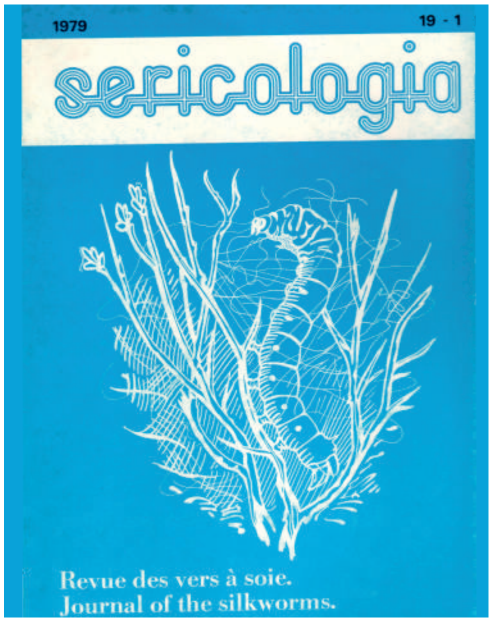

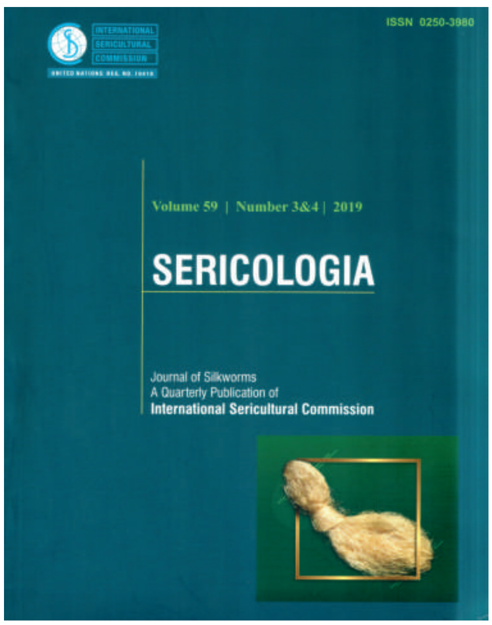

26th International Congress on Sericulture and Silk Industry scheduled during May 2022

The International Sericultural Commission (ISC) and the Ministry of Agriculture and Rural Development, Govt. of Romania are jointly organizing the 26th International Congress on Sericulture and Silk Industry at Global Centre of Advanced Research in Sericulture and Promotion of Silk Production (GCECAS-PSP), Cluj Napoca, Romania during 17-22, May, 2022. The theme of the Congress is "SERITECH - New concepts in Sericulture". An international Silk Exhibition would also be organised as a side-line event of the Congress. The Announcement of the Congress shall be released shortly.

Global Silk Production

Unit: Metric Tonnes

Country	2015	2016	2017	2018	2019
Bangladesh	44	44	41	41	41
Brazil	600	650	600	650	469
Bulgaria	8	9	10	10	10
China	170000	158400	142000	120000	68600
Colombia	1	-	-	-	1
Egypt	1	1	1	1	2
India	28523	30348	31906	35261	35820
Indonesia	8	4	3	3	3
Iran	120	125	120	110	227
Japan	30	32	20	20	16
Madagascar	5	6	7	7	8
North Korea	350	365	365	350	370
Romania	-	-	-	-	1
Philippines	1	2	2	2	2
South Korea	1	1	1	1	1
Syria	0	0	0	0	1
Thailand	698	712	680	680	700
Tunisia	3	2	2	2	2
Turkey	30	32	30	30	5
Uganda	-	-	-	-	3
Uzbekistan	1200	1256	1200	1800	2037
Vietnam	450	523	520	680	795
Total	**202073**	**192512**	**177507**	**159648**	**109114**

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Mulberry Lead paper

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Non Mulberry Lead paper

Post Cocoon Chair and Vice Chair

Post Cocoon Lead paper

Sericulture in Non- textile industries and new silk application
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Sericulture in Non- textile industries and new silk application
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Russell E. W. (1961) Soil conditions and plant growth. (9th edition), John Wiley and Sons, New York.

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