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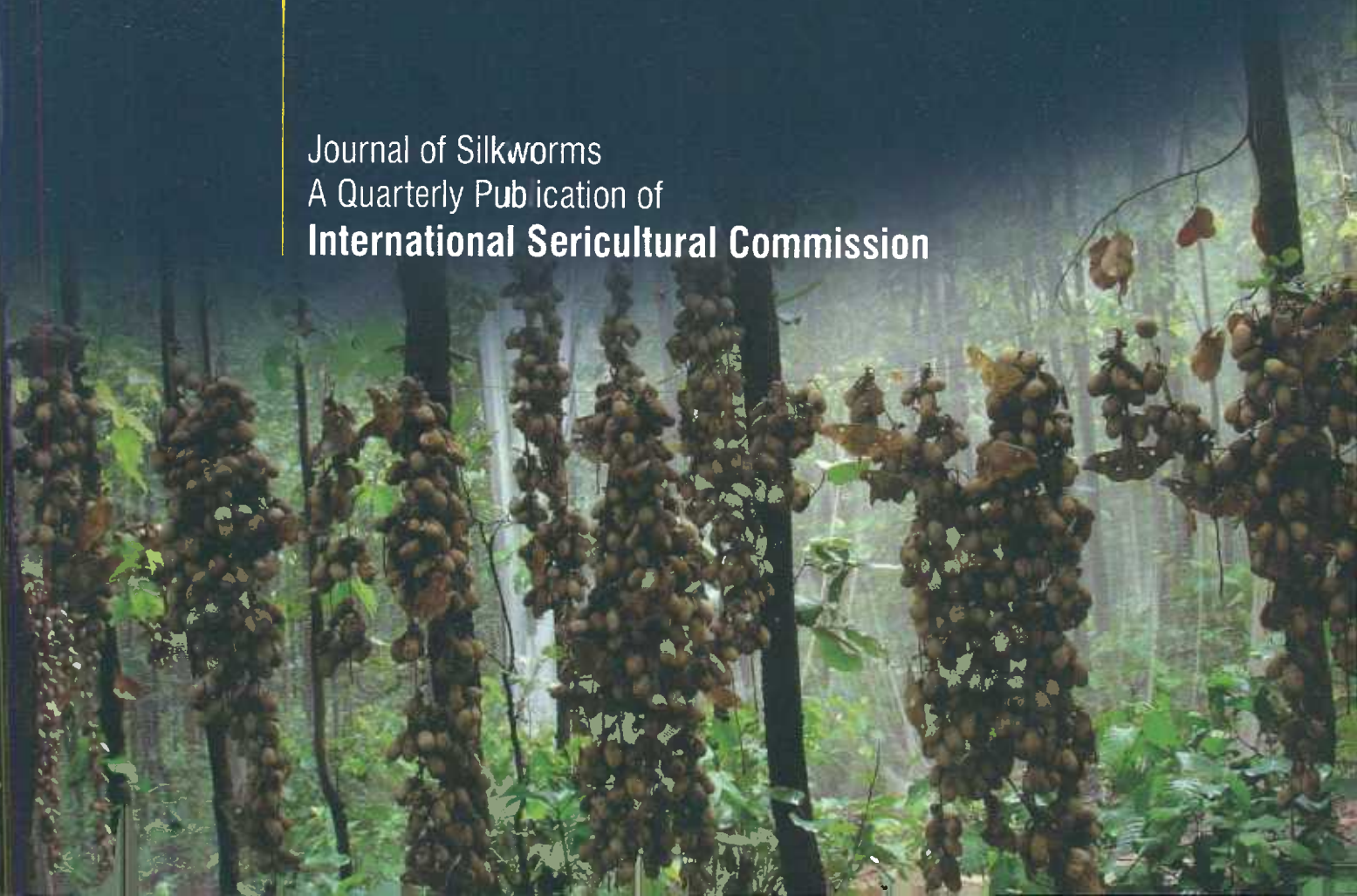
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PROCESS OPTIMIZATION FOR PREPARATION OF MULBERRY FRUIT EXTRACT TO INHIBIT ANGIOTENSIN CONVERTING ENZYME ACTIVITY

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ABSTRACT

A new processing approach to extract the bioactive components from mulberry fruit that can inhibit angiotensin converting enzyme (ACE) was explored in this study. The process conditions were optimized with Plackett-Burman experimental design, steepest ascent experiment and response surface methodology for mulberry fruit extract to have maximum ACE inhibition rate. Results indicated that the factors that influence the extraction of ACE-inhibitor were the mass concentration of mulberry fruit, extraction time and ultrasonic power. The optimized process conditions were as follows: mulberry fruit concentration of 6.17 g/l, ultrasonic power of 87 W and extraction time of 70 min. The mulberry fruit extract of ACE inhibitor obtained under the above optimal conditions was capable of bringing about an inhibition rate up to 82.77 %.

Key words: Angiotensin converting enzyme, extract, mulberry fruit, process condition.

INTRODUCTION

Angiotensin converting enzyme (ACE, EC 3.4.15.1) is a central component of the renin angiotensin aldosterone system (RAAS), which controls blood pressure, electrolyte homeostasis, renal and vascular function and myocardial remodeling (Dadzie *et al.*, 2013; Mohamad *et al.*, 2013). ACE is a zinc-containing metallic-enzyme, located mainly in the endothelial lining of the vasculature of the lung and plays an important role in the pathogenesis of various cardiovascular and renal diseases and in the regulation of blood pressure (Chaudhary *et al.*, 2013; Masuyer *et al.*, 2014). As the over expression of RAAS is associated with vascular hypertension, ACE inhibition has become a major target control for hypertension (Balasuriya and Rupasinghe, 2011). ACE inhibitors had been frequently used as anti-hypertensive agents and for an effective treatment of congestive heart failure (Magid *et al.*, 2010; Simaratnamongkol *et al.*, 2014) during the

last decade. Identification and isolation of potential ACE inhibitors has been an expanding field of research with focus on natural product derivatives such as peptides, anthocyanins, flavonols, triterpenes *etc.* (Balasuriya and Rupasinghe, 2011; Zhou *et al.*, 2013).

Natural products could be important sources of ACE inhibitors, the peptide isolated from the snake venom of the Brazilian viper *Bothrops jararaca* was the template for the development of synthetic ACE inhibitors, such as captopril, enalapril, and other synthetic antihypertensive drugs (Dadzie *et al.*, 2013; Sharifi *et al.*, 2013). These ACE inhibitors differ from each other with respect to their molecular structure, potency, bioavailability, plasma half-life and tissue affinity. Recently, many ACE-inhibitory peptides have been isolated from various food protein sources and enzymatic hydrolysates, such as milk (Majumder and Wu, 2011), rice (Chen *et al.*, 2013), egg (Yu *et al.*, 2012) and wheat germ (Jia *et al.*, 2010).

Mulberry fruit is a traditional edible fruit in China, which contains several functional bioactive compounds, such as flavonoids, anthocyanins, 1-deoxynojirimycin (DNJ), polysaccharides, *etc.* (Yang *et al.*, 2010; Kobus-Cisowska *et al.*, 2013; Sivakumar *et al.*, 2015).

Those bioactive compounds help to fight against cancer, neurological diseases, inflammation, diabetes, bacterial infections and reduce the speed of aging process as well (Wang *et al.*, 2013). Of late, the production and consumption of mulberry fruit has been increasing rapidly because of their delicacy, nutritional value and favourable biological functions (Aramwit *et al.*, 2010).

There are several statistical techniques, such as response surface methodology (RSM) (Jiang *et al.*, 2010, 2014), artificial neural network (ANN) and genetic algorithm (GA) (Sathish and Prakasham, 2010), which have been developed based on human decision-making processes and unorthodox search for determining the optimal settings for experimental factors that give the maximum (or minimum) value for response. RSM is a useful statistical technique for investigation of complex processes, particularly in the fields of chemical and engineering processes, industrial research, biological investigations and agricultural processes with emphasis on optimizing a process (Chen *et al.*, 2010; Sun *et al.*, 2010; Ye and Jiang, 2011).

To understand the ACE inhibitory activity of mulberry fruit, we have isolated the mulberry fruit extract and optimized the extraction condition in terms of single-factor experiments, Plackett-Burman design (PBD), steepest ascent method, Box-Behnken design (BBD) and response surface methodology (RSM) analysis in this study.

MATERIALS AND METHODS

Materials

Mulberry fruits (*Morus alba* L.) were harvested at the ripe stage from the plantation of National Mulberry Orchard (Zhenjiang, PR China), freeze-dried and ground to powder.

ACE (from rabbit lung) and Hippuryl-His-Leu (HHL) were purchased from Sigma-Aldrich Trading Co. (Shanghai, China). The other chemicals used for the experiment were of analytical grade.

Determination of ACE inhibitory activity

Angiotensin I-converting enzyme (ACE) inhibitory activity was measured by the spectrophotometric assay with some modifications (Guo *et al.*, 2009; Jia *et al.*, 2010). An aliquot 45 μ l of Hippuryl-His-Leu (HHL) solution (6.5 mM HHL in 0.1 M borate buffer containing 0.3 M NaCl, pH 8.3) was mixed with 10 μ l of mulberry fruit sample and pre-incubated for 5 min at 37°C. The reaction was initiated by adding 10 μ l of ACE (ACE in 0.1 M borate buffers containing 0.3 M NaCl, pH 8.3) and carried out at 37°C for 30 min. The reaction was stopped by adding 85 μ l of 1 M HCl to the samples except for the blank (85 μ l of 1 M HCl was added before the incubation). The hippuric acid formed was extracted by adding ethyl acetate (1000 μ l) to the mixture with vigorous shaking for 2 min. After centrifugation at 4000 r/min for 10 min, 800 μ l of the ethyl acetate layer was collected and then dried at 100°C for 20 min. The residue was dissolved in 800 μ l water and its absorbance was measured at 228 nm. The ACE inhibitory activity was calculated using the following equation:

$$\text{ACE inhibition rate (\%)} = \frac{C - (S - B)}{C} \times 100$$

Where *C* is the absorbance without sample (buffer for samples), *S* is the absorbance in the presence of both ACE and sample and *B* is the absorbance of blank (hydrochloric acid was added before ACE).

Plackett-Burman design

Plackett-Burman design (PBD) is a powerful and useful tool when rapidly searching for key factors in a multivariable system (Feng *et al.*, 2010). The Plackett-Burman factorial designs allow for the screening of the main factors for a large number of process variables. In PBD, twelve experiments were generated with five significant variables and two blank variables at two levels,

-1 for low level and +1 for high level, as indicated in the experimental design. Table 1 shows the coded variables under investigation as well as five significant factors of mass concentration *viz.*, (A) ultrasonic power, (B) extraction time, (C) pH, (D) extraction temperature and (E) two blank variables V_1 and V_2 used in the experimental design, whereas Table 2 represents the design matrix. In addition, 2 center points were added to the variables that could be assigned numerical values.

The path of the steepest ascent experiment

The direction of the steepest ascent was parallel to the normal contour line of the model response curve and passed through the center point of the PBD experiment (Xiao *et al.*, 2010). The path of the steepest ascent was arrived at approximately with the optimum values. According to the results of PBD, the experimental designs of the path of the steepest ascent are shown in Table 4.

Response surface analysis

Based on the results of the PBD and the steepest ascent

Table 1: Levels and codes of variables for Plackett-Burman design

Factor / Dummy variable	Symbol	Coded variable levels	
		-1	1
Mass concentration (g/l)	A	1	5
Ultrasonic power (W)	B	60	100
Extraction time (min)	C	20	60
Dummy variable 1	V_1	-	-
pH value	D	4	7
Extraction temperature (°C)	E	40	60
Dummy variable 2	V_2	-	-

experiment, three independent variables were chosen, *i.e.*, mass concentration (5-7 g/l), ultrasonic power (80-90 W) and extraction time (60-80 min), for optimization by Box-Behnken design (BBD), shown in Table 5. The complete design consisted of 15 combinations including two replicates of the center point (Table 6). Regression analysis was performed on the data obtained from the design experiments. The response function (Y) was partitioned into linear, quadratic and interactive components.

Table 2: Plackett-Burman experiment of the extraction conditions

Run	Mass concentration (g/l) (A)	Ultrasonic power (W) (B)	Extraction time (min) (C)	Dummy variable (V_1)	pH value (D)	Extraction temperature (°C) (E)	Dummy variable (V_2)	ACE inhibition rate (%)
1	-1	1	1	-1	1	-1	-1	55.32
2	1	1	-1	1	-1	-1	-1	76.92
3	1	1	-1	1	1	-1	1	62.30
4	-1	-1	-1	1	1	1	-1	51.16
5	-1	1	-1	-1	-1	1	1	64.27
6	1	-1	-1	-1	1	1	1	49.10
7	1	-1	1	-1	-1	-1	1	68.50
8	-1	-1	1	1	1	-1	1	70.31
9	-1	1	1	1	-1	1	1	58.66
10	-1	-1	-1	-1	-1	-1	-1	52.86
11	1	1	1	-1	1	1	-1	83.33
12	1	-1	1	1	-1	1	-1	72.22

Table 3: ANOVA for the evaluation of the regression model in Plackett Burman design

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Main Effects	7	734.11	734.113	104.873	0.76	0.648
<i>A</i>	1	297.9	297.904	297.904	2.16	0.215
<i>B</i>	1	111.94	111.935	111.935	0.81	0.418
<i>C</i>	1	223	222.999	222.999	1.62	0.272
<i>V₁</i>	1	27.57	27.573	27.573	0.20	0.678
<i>D</i>	1	40	40.004	40.004	0.29	0.619
<i>E</i>	1	4.65	4.65	4.65	0.03	0.863
<i>V₂</i>	1	29.05	29.047	29.047	0.21	0.67
Residual	4	551.12	551.118	137.779		
Total	11	1285.23				

The regression coefficients of individual linear, quadratic, and interaction terms were determined according to variable analysis. The model was simplified by dropping terms, which were not statistically significant ($P > 0.05$) and those which were considered statistically significant ($P < 0.05$) by analysis of variance (ANOVA). The fitted models were subjected to the lack of fit test, which was used to determine whether the models were adequate to describe the observed data. The regression coefficients were used for statistical calculation to generate 3-D surface plots and 2-D contour plots from the fitted polynomial equation (Uluko *et al.*, 2013).

Table 4: Experimental design and results of the steepest ascent experiment

Run	Mass concentration (g/l) (<i>A</i>)	Ultrasonic power (W) (<i>B</i>)	Extraction time (min) (<i>C</i>)	ACE inhibition rate (%)
1	3	70	40	63.51
2	4	75	50	65.49
3	5	80	60	68.67
4	6	85	70	71.58
5	7	90	80	69.87

Statistical analysis

All data are presented as mean $\pm$ SD. Design-expert software 8.06 (Statease Inc., Minneapolis, USA) and

Table 5 : Levels and codes of variables for Box - Behnken design

Variable	Coded variable	level		
		-1	0	1
Mass concentration (g/l)	<i>A</i>	5	6	7
Ultrasonic power (W)	<i>B</i>	80	85	90
Extraction time (min)	<i>C</i>	60	70	80

MINITAB® software 16.2.0 (Inc., USA) were used for the experimental designs and subsequent regression analysis of the experimental data.

RESULTS AND DISCUSSION

Optimization by Plackett–Burman design

Plackett-Burman design has been widely used by many researchers as a screening method to determine the significant factors in experiment design (Xiao *et al.*, 2010). Twelve runs were carried out to analyze the effects of these seven variables (including a dummy variable) on ACE

inhibitory activity. Table 2 represents the results of the screening experiments ranging from 49.10 to 83.33 %. Three variables *viz.*, mass concentration (*A*), ultrasonic power (*B*), and extraction time (*C*) were selected for further investigation. Regression analysis determined that the variables *viz.*, (*A*) mass concentration ($P=0.215$), (*B*) ultrasonic power ($P=0.418$), and (*C*) extraction time ($P=0.272$) having the lowest values among the tested variables can be selected for response surface optimization (Table 3). The ultrasonic power and extraction time played main roles in the efficient extraction of ACE inhibitor component from mulberry fruit extract. This tendency was in agreement with some of the earlier reports regarding extraction and rate of activity of ACE inhibitor (Guo *et al.*, 2009).

Table 6: Box-Behnken design for three independent variables

Run	Mass concentration (g/l) (<i>A</i>)	Ultrasonic power (W) (<i>B</i>)	Extraction time (min) (<i>C</i>)	ACE inhibition rate (%)
1	1	0	1	72.62
2	1	-1	0	70.79
3	1	1	0	78.51
4	0	0	0	81.10
5	-1	0	1	69.44
6	1	0	-1	70.07
7	-1	-1	0	71.96
8	0	1	-1	74.77
9	0	-1	1	72.84
10	0	0	0	80.87
11	-1	1	0	73.25
12	0	-1	-1	70.81
13	0	0	0	80.18
14	0	1	1	73.76
15	-1	0	-1	70.59

Optimization by the path of steepest ascent experiment

The steepest ascent experiment started from the center point of the parameters in the PBD, and the coefficients specified the proper direction of changing variables (Feng *et al.*, 2010). According to the results of PBD, the experimental design and results of the path of steepest ascent are shown in Table 4. The experiment run 4 was started from the highest value of 71.58 % of all responses and all the other runs exhibited decreased values. Therefore, it can be concluded that, (*A*) mass concentration (6 g/l), (*B*) ultrasonic power (85 W) and (*C*) extraction time (70 min) in run 4 were close to the optimum point and the combination of run 4 was selected for BBD experiment.

Box-Behnken design and response-surface method

Based on the PBD and the method of the steepest ascent, three variables (mass concentration, ultrasonic power, and extraction time) were used to determine the optimum levels of these parameters. The design matrix of the variables, including *a*, *b*, and *c* are the coded value of mass concentration, ultrasonic power, extraction time, respectively and are shown in Table 5, along with the experimental values of the response. The experiments conducted in the present study were targeted toward the construction of a quadratic model consisting of 15 trials. The results of the analysis of variance (ANOVA), goodness-of-fit and the adequacy of the models are summarized. The ACE inhibition rate varied from 69.44 to 81.10 % as shown in Table 6. To determine the optimal levels of each variable for ACE-inhibitory activity, three-dimensional response surface plots were constructed by plotting the response (ACE inhibitory activity of mulberry fruit) of three independent variables (Pan *et al.*, 2010; Kong *et al.*, 2011), while maintaining other variables at their optimal levels (Figure 1). The following quadratic model explained the experimental data:

$$Y = 80.72 + 0.84a + 1.74b + 0.30c + 1.61ab + 0.93ac - 0.76bc - 4.73a^2 - 2.36b^2 - 5.31c^2 \quad (1)$$

The regression coefficient values of Eq. (1) are listed in

Table 7: ANOVA of the response surface quadratic model

Source	SS	DF	MS	F Value	P Value Prob > F	
Model	230.08	9	25.56	44.63	0.0003	significant
<i>a-a</i>	5.7	1	5.7	9.94	0.0253	
<i>b-b</i>	24.12	1	24.12	42.1	0.0013	
<i>c-c</i>	0.73	1	0.73	1.28	0.3096	
<i>ab</i>	10.34	1	10.34	18.04	0.0081	
<i>ac</i>	3.42	1	3.42	5.97	0.0583	
<i>bc</i>	2.31	1	2.31	4.03	0.1009	
<i>a</i> ²	82.51	1	82.51	144.03	< 0.0001	
<i>b</i> ²	20.6	1	20.6	35.96	0.0019	
<i>c</i> ²	104.09	1	104.09	181.71	< 0.0001	
Residual	2.86	5	0.57			
Lack of Fit	2.41	3	0.8	2.57	0.2302	not significant
Pure Error	0.46	2	0.23			
Cor Total	232.95	14				
R-squared	0.9877					
AdjR-squared	0.9656					

SS: Sum of Squares; DF: Degree of Freedom; MS: Mean Square; P<0.05 significant.

Table 7. The *F*-value and *P*-value were used to examine the coefficient significance and the interaction strength between independent variables. The corresponding coefficient will be more significant if the absolute *F*-value becomes larger and the *P*-value becomes smaller (Guo *et al.*, 2010; Wang *et al.*, 2013). The results indicated that mass concentration, ultrasonic power and extraction time are all significantly correlated with the ACE inhibition rate. The ANOVA for response surface quadratic regression model in Table 7 showed that the model was highly significant ($P < 0.003$) with a very high *F*-value (44.63). The best fitness of the regression equation was evaluated by the coefficient of correlation (*R*) and the determination of coefficient (R^2). Guo *et al.* (2009) showed that optimal ACE inhibitions of response surface were found to be the optimal conditions to obtain the highest ACE inhibitory activity close to 92.2 % and

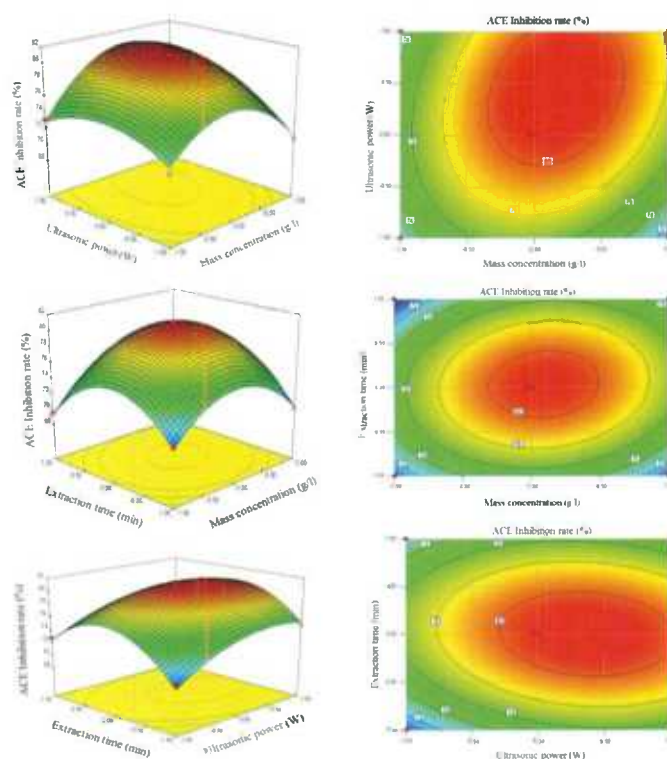


Figure 1: Three-dimensional responses (left) and Contour plot (right) of the ACE inhibition rate (Y) influenced by A: mass concentration (a) and ultrasonic power (b), B: mass concentration (a) and extraction time (c), and C: ultrasonic power (b) and extraction time (c).

degree of hydrolysis of the whey protein was 18.8 %.

In this study, the determination of coefficient R^2 (0.9877) was found in concordance with the adjusted R^2 value of 0.9656, suggesting a strong agreement between the experimental and predicted values (Kong *et al.*, 2011). The response surface could be obtained by software analysis (Figure 1). The *F*-value (2.57) and *P*-value (0.2302) of lack-of-fit implied that there was a 23.02 % chance that the lack of fit *F*-value could occur due to noise (Dadzie *et al.*, 2013). The model equation was thus appropriate to predict the yield of ACE inhibition rate extracted by any combination of values. The data showed that the ACE inhibition rate was 82.77 % as against mass concentration of 6.17 g/l, extraction time of 70.12 min and ultrasonic power of 87 W (Table 8).

Interpretation of response surface model and contour

The graphical representations of the regression Eq. (1),

called the response surfaces and the contour plots, are presented in Figure 1. These 3D response surface and contour plots provide a visual interpretation of the interactions between two variables with one variable kept at zero levels and ease the location of optimum experimental condition (Mao *et al.*, 2013). As shown in Figure 1, each 3D response surface showed a clear peak, indicating that the optimum point was well inside the

Table 8: Experimental values of the responses at optimum conditions

Condition	Mass concentration (g/l)	Ultrasonic power (W)	Extraction time (min)	ACE inhibition rate (%)
Optimum condition	6.17	87	70.12	82.77

design boundary (Sun *et al.*, 2010). As established by the above test regression equation (Eq.1), it can be seen that the response surface opens downwards, hence there are extreme points, accessible through the extraction process of regression equations to determine the best conditions (Liu and Tang, 2010). Quadratic regression equations are first-order partial derivative score as follows:

$$\begin{aligned} 0.84+1.61b+0.93c-9.46a &= 1 \\ 1.74+1.61a-0.76c-4.72b &= 2 \\ -0.30+0.93a-0.76b-10.62c &= 3 \end{aligned}$$

Solving the above equation, $a = 0.1518$, $b = 0.4219$ and $c = 0.0123$. It is desirable to test the accuracy and reliability of the model equation for predicting an optimum response, the experimental values obtained for the conditions of ACE inhibitor of mulberry fruit sample were mass concentration: 6.17 g/l, extraction time: 70.12 min and ultrasonic power: 87 W, respectively. Under the optimum conditions, the ACE inhibition rates were predicted to be 82.77 %. This set of conditions was determined to be optimal by the RSM optimization approach and used to validate experimentally and predict the values of the responses using the model equation shown in Table 8. The good correlation between these results confirmed that the response model had adequately reflected the optimization process.

A number of food-derived peptides have been shown to have *in vitro* ACE inhibition activity (Inoue *et al.*,

2011). The good correlation between these results confirmed that the response model had adequately reflected the optimization process.

Conclusion

In this paper, the factors that significantly influence extraction of ACE inhibitor from mulberry fruit were screened by statistical approaches including PBD, the path of steepest ascent method and BBD. The optimal conditions obtained by RSM for ACE inhibition rate include the following parameters: mass concentration (6.17 g/l), extraction time (70.12 min) and ultrasonic power (87 W), respectively. The extraction conditions have significant effects on the ACE inhibition rate of the extract. Under the optimized conditions, the experimental data of ACE inhibition rate was close to that of the predicted value of 82.77 %.

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Article scientifique

OPTIMISATION DU PROCÉDE DE PREPARATION D'EXTRAIT DE FRUIT DE MURIER POUR INHIBER L'ACTIVITE DE L'ENZYME DE CONVERSION DE L'ANGIOTENSINE

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RÉSUMÉ

Une nouvelle approche de procédé pour extraire les composants bioactifs des fruits de mûrier qui peuvent inhiber l'enzyme de conversion de l'angiotensine (ACE) est explorée ici. Les conditions ont été optimisées avec un plan expérimental Plackett-Burman, une expérience et une méthodologie de surface de réponse de pente plus raide pour l'extrait de fruit de mûrier afin d'avoir un taux d'inhibition maximal de l'ACE. Des résultats indiquent que les facteurs qui influencent l'extraction de l'inhibiteur de l'ACE sont la concentration en masse du fruit, la durée d'extraction et la puissance des ultrasons. Les conditions du procédé optimisé sont les suivantes : concentration de fruit de 6,17 g/l, puissance des ultrasons de 87 W et durée d'extraction de 70 min. L'extrait de ACE obtenu avec les conditions optimales est capable d'atteindre un taux d'inhibition de 82,77 %.

Mots-clés: Enzyme de conversion de l'angiotensine, extrait, fruit de mûrier, conditions de procédé.



DEVELOPMENT OF MICROCONTROLLER BASED EMBEDDED SYSTEM FOR DETECTION OF MATURE MUGA LARVAE

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ABSTRACT

This paper describes a system developed for identification of mature muga larvae (*Antheraea assamensis* HELFER) based on the measurement of its optical transmissibility. Traditional methods of identification of maturity are based on intuition gathered through long experience and characterized by significant time delay in the collection process. The microcontroller based embedded system used for this purpose provides a quantitative measure of optical transmissibility of muga larvae through a potential divider circuit consisting of a light dependent resistor as a sensor unit. An inclined plastic tube containing light emitting diode as a source of light and light dependent resistor as a sensor was used where muga larvae are guided between the light source and the sensor. The power associated with the beam of light transmitted through a muga larva is proportional to the maturity level of the larva. In this system, the beam emerging out of a muga larva is captured by the sensor based potential divider circuit that produced a proportional average numerical value of optical transmissibility as 50 % for the mature samples whereas 8.34 % for the immature samples. Thus this study innovatively establishes a microcontroller based machine intelligence to distinctly identify maturity of muga larvae. The system can reduce physical labor during collection of 5th instar muga larvae and enhance productivity.

Key words: *Antheraea assamensis* Helfer, Assam silk, muga, optical transmissibility, sensor, sericigenous insect.

INTRODUCTION

Muga silkworm, *A. assamensis* (Helfer), the lone golden silk producer in nature, is a typical wild silk moth endemic to North East India (Barah, 2010). It is the prime contributor to the worldwide fame of Assam silk. Assam and its neighboring foothills of North East India are the only natural habitats of this silkworm locally known as muga and scientifically as *A. assamensis* Helfer syn. *A. assama* Westwood. Muga silkworm rearing, reeling and weaving of muga silk not only represent the tradition, culture and sentiments of the Assamese but also plays a vital role in the economy of rural Assam (Thangavelu *et al*, 1988). Muga culture activities are, by and large, confined especially to the weaker sections of the society (SC, ST and OBC) in the rural areas of the NE India

(Suryanarayana *et al.*, 2002). Like other type of silk culture, muga culture also involves plantation of food plants, rearing of silkworm, harvesting of cocoons, spinning of cocoons and weaving of yarn into different varieties of fabrics. It is an excellent form of agro based industry having potential to generate employment and contribute to the rural economy. Despite its tremendous potentialities as commercial proposition, muga culture in Assam has been continuing in a traditional way as subsidiary source of income (Nath, 2010). The role of technology thus comes into play that can change the concept of muga farming in a radical way.

Muga silkworm feeds on outdoor host plant through four moults in five instars. At the end of 5th instar, mature

muga larvae descend from their host plants in preparation to spin cocoons and at this point, they are collected by the farmers. These mature larvae are made to spin cocoons under indoor conditions within the shelter offered *i.e.*, on dry leaves of specific plants. The anatomical structure of alimentary canal of muga larvae resembles to a hollow tube from esophagus to its rectal opening (Thangavelu *et al.*, 1988). Its body is optically translucent with light green or greenish blue color measuring about 10 cm in length at the full grown period of its larval stage. In the entire process of rearing of muga, the larval stage is a crucial part as it is an outdoor activity susceptible to many adverse factors such as storms, draught, pollution, predatory birds, virus, wasp, ant *etc.* A continuous vigil for a period of 50 days in summer, make the farmers tired in the process. Above all these, the mature larvae descend from their host plants during late evening when the visibility level is significantly low. In addition to this, along with mature muga larvae, immature muga larvae may also descend from the host plant. A mature muga larva stops feeding and excretes a viscous fluid from its food canal whereas the food canal of an immature larva remains full due to continuous feeding. Hence a mature muga larva has more optical transmissibility than an immature larva. It is important to collect only the mature larvae because a mixture of mature and immature larvae hampers the production of good quality cocoons and moreover, it is to be ensured that the immature muga larvae are placed back to their feeding host plants. For this purpose, farmers usually use torch light that helps illumination and examination of maturity of larvae. Some experienced farmers use a kind of sounding technique for examining maturity. These methods are age old, laborious and needs expertise. A person new in this field cannot be expected to achieve this level of expertise easily. In this context, the optical characteristic of muga larvae during its 5th instar stage has been investigated using image processing technique (Das and Hazarika, 2014) and established that optical property of muga larvae can be used effectively to identify mature and immature muga larvae. Microcontroller based instrumentation systems were developed using optical sensing techniques (Hazarika *et al.*, 2009, Hazarika and Pegu, 2013, Laskar

and Bordoloi, 2013) in other fields of applications. This work is an innovation of embedded system to enhance productivity in muga farming process.

MATERIALS AND METHODS

The samples of mature and immature muga larvae at its 5th instar were collected from muga farm of Dwangaon of Bongaigaon district, Assam, India. The microcontroller based embedded system developed for detection of mature larvae has the following components:

Channel for guiding muga larvae and LDR based potential divider circuit with LED light source

When a muga larva descends from its host plant at the end of its 5th instar, it is required to guide it through a restricted path containing the sensor system. For this purpose, a plastic tube containing light emitting diode (LED) and light dependent resistor (LDR) based sensor system is used as shown in Figure 1. The tube inclined at 30° to x-y plane offers a slippery path for the larvae. Therefore, once a muga larva enters the inclined tube, it goes down through the cylinder quite easily within around ½ a second. Inclination of 30° has been selected after many trials as it offers optimal speed of muga larva through the tube that helps to take reading reliably. The LDR and LED are placed in the same axis on either side of the inclined tube. The space between the LED and LDR is termed as measurement zone.

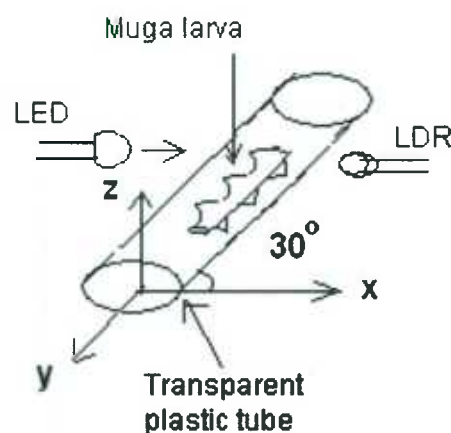


Figure 1: Schematic diagram of sensor system for measurement of optical transmissibility of muga larvae

The LDR (R_L) is connected to a resistance R to form a potential divider circuit (PDC) as shown in Figure 2. V_m is the analog voltage at the junction of the PDC, which is interfaced to the PA_0 (analog input pin 0 of the ATmega32 microcontroller) through a filter circuit consisting of $R1$ and C .

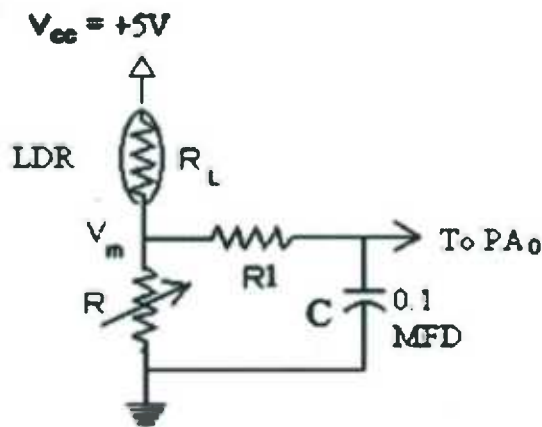


Figure 2: Diagram of Potential Divider Circuits (PDC)

The value of V_m is used – (i) to detect the entry of a muga larva in the measurement zone of the guiding tube and (ii) to read the optical transmissibility of the muga larvae after proper authentication of entry of the larvae in the measurement zone.

The power associated with the beam of light transmitted through muga larvae would depend on the transmissibility coefficient of the muga larvae and it can be represented as:

$$P(l) = P(0)e^{-0.2304\alpha} \quad (1)$$

Where $P(0)$ and $P(l)$ are the optical power of the associated light ray before entering and after leaving the muga larvae. l denotes the lateral size of the muga larvae along the direction of light path and α represents coefficient of transmissibility.

The transmissibility coefficient of mature muga larvae is considerably higher compared to immature muga larvae. Therefore, optical power transmitted through a mature larvae is also higher than an immature larvae.

Thus, the value of resistance of the LDR would be less when a mature muga larva passes through it compared to that of immature one. Again, resistance of a LDR varies inversely to the intensity of light, i.e.,

$$\frac{1}{R_L} \propto P(l) \quad (2)$$

v_m is the analog output of the potential divider circuit, which provides the measure of change in R_L due to change in coefficient of transmissibility of a muga larvae. And it can be represented as:

$$V_m = \frac{V_{cc}}{R_L + R} R \quad (3)$$

The change in $P(l)$ due to transmissibility coefficient of mature muga larvae, cause change in R_L and as result, v_m would change. Thus the value of v_m would provide the measure of maturity level of muga larvae.

Microcontroller based system for measurement of optical transmissibility of muga larvae

Figure 3 shows the scheme adopted for the measurement of optical transmissibility level of muga larvae. The display unit consists of 16×2 (i.e., two rows having 16 character provisions) LCD display. It is interfaced to the PORT-B of the ATmega32 microcontroller. The output from the LDR based PDC is interfaced to the first pin of Port A which apart from other functions can also perform analog to digital conversion. Therefore it is termed as ADC_0 when used as analog to digital converter (ADC). Four switches are interfaced to Port D, having state '1' under open condition. When a switch is pressed, the state of the switch becomes '0'. These switches are utilized to initialize threshold value for detection of entry and level of maturity of muga larvae. Depending upon the functions of these switches, they are named as - ITV (Initialization of threshold value), INRTV (Increase of threshold value), DCRTV (Decrease of threshold value), and ENTER (Enter, i.e., completion of editing process and exit). The operational details about these switches are described in the following section.

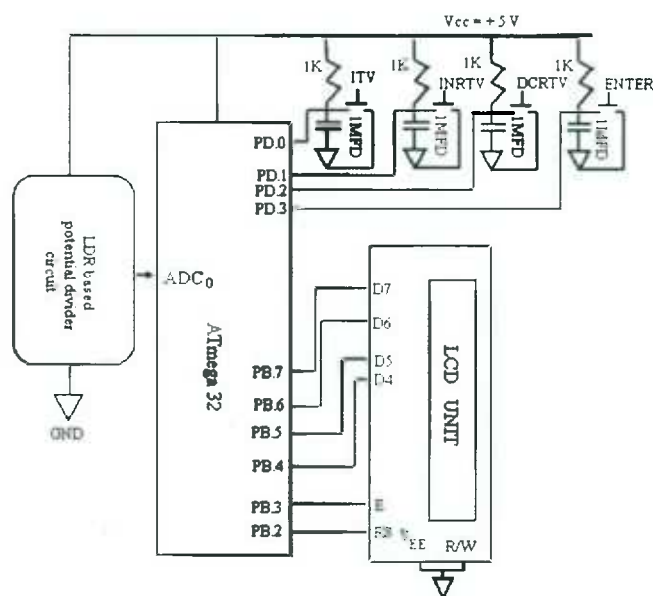


Figure 3: Schematic representation of microcontroller based system for measurement of optical transmissibility of muga larvae

Initialization and measurement procedure of the MBES

The ATmega32 microcontroller has a 10 bit ADC with 8 programmable input pins (*i.e.*, ADC₀ – ADC₇). The ADC reference voltage is set as 5 Volts. Therefore, digital equivalent corresponding to analog voltage 5 is $2^{10} = 1024_{10} = 3FF_{16}$. The resolution is $5/1024 = 0.004883$ volt per bit. To simplify the display of the measured value of optical transmissibility of muga larvae provided by the LDR based potential divider circuit, the display is calibrated as 100 % corresponding to 5 volts input at ADC₀ pin. Proper software has been developed for the MBES to display the threshold value (V_m^{TH}) and the measure of optical transmissibility of muga larvae in percentages. They are displayed in the first and second row of the 16×2 LCD display unit respectively. The threshold value is stored in the first memory location (0000H) of the EEPROM of Atmega32. As a result, it remains intact until the value is overwritten. Therefore, it is required to enter the initial threshold value after programming the microcontroller Atmega32. The MBES allows the use of the switches - ITV, INRTV, DCRTV, and ENTER for editing the threshold value, so that the user can set the threshold value based on outdoor

muga field conditions. The operations of these switches in detail are as follows

When ITV is pressed, the MBES displays a message “EDT THVL” in the first row of the 16×2 LCD display unit and keeps blinking the present threshold value to indicate that the system is ready to accept any change in threshold value by the user. The switches INRTV and DCRTV provide facility for increasing or decreasing the shown threshold value by $\pm 1\%$ every time a switch INRTV or DCRTV is pressed. Once the editing of threshold value is completed, the switch ENTER has to be pressed. On pressing ENTER, the microcontroller Atmega32 stores the modified threshold value at the first location of its EEPROM and come back to the normal measurement process.

Initialization of the MBES: When the MBES is switched on, it displays the V_m of potential divider circuit and the threshold value as percentages in the first and second row of the 16×2 LCD display unit, respectively. The variable resistor R of the potential divider circuit has to be adjusted to ensure that the V_m value displayed in the first row of the LCD display becomes (V_m^{init}) 70 – 80 % (which is the value of V_m without muga larva in the measurement zone). A mature muga larva is allowed to pass through the measurement zone of the cylindrical tube and the value of V_m is noted. This reading is used to decide and set the threshold value to identify a mature muga larva. Considering this reading as (V_m^{WML}), the threshold value is decided as:

$$V_m^{TH} = V_m^{WML} - RF \times V_m^{WML}$$

where, RF is the reduction factor that ensures a margin for measure of V_m to select a mature muga larva. This V_m^{TH} has to be set using the editing facility of the MBES.

Measurement procedure: When a muga larva enters the measurement zone, it will cast a shadow upon the LDR resulting increment in the value of resistance of the LDR and decrement in the value of V_m . If the value of $V_m < 0.9 V_m^{init}$ the measurement process for detection of mature

larva is evoked. It has been found that a muga larva requires less than $\frac{1}{2}$ sec to cross the measurement zone of the LDR based potential divider circuit. Therefore, arrangement in the software is made for reading and storing the values of V_m with a time delay (sampling delay) of 20 millisecond till it crosses the measurement zone. For this purpose, a software counter is used to keep the count of V_m values stored in the EEPROM. Once the muga larva exits from the measurement zone, the average of all these measurements are computed and displayed as the quantitative measure of the optical transmissibility of a muga larva in percentage (V_{mav}). The measurement algorithm is as follows:

1. Read V_m
2. Check if $V_m > 0.9 V_m^{init}$. If yes, go to step 1.
3. Set counter $C=0$ and address of the EEPROM starting location as $EEARH = 0x00$; (Higher byte address) and $EEARL=0x02$; (Lower byte address), i.e., the address of the starting address for the EEPROM is set as 0002H.
4. Read V_m and store in EEPROM
5. $C = C+1$, $EEARL = EEARL + 1$ and if $EEARL > FFH$ then $EEARH=EEARH+1$
6. Wait for 20 msec
7. Check if $V_m < 0.9 V_m^{init}$, go to step 4
8. $EEARH = 0x00$ and $EEARL=0x02$, $V_{av} = 0.0$ and $D = 0$;
9. Read EEPROM (i.e., the stored value of V_m^{EEPROM})
10. $V_{av} = V_{av} + V_m^{EEPROM}$
11. $EEARL = EEARL + 1$ and if $EEARL > FFH$ then $EEARH=EEARH+1$, $D=D+1$;
12. Check if $D \leq C$. If yes go to 9
13. $V_m^{av} = V_{av}/C$

RESULTS AND DISCUSSION

After proper setting of the microcontroller based system, several samples of muga larvae of varying maturity levels were tested. For testing, a muga larva was allowed to slip through the inclined tube of the system shown in Figure 1. The larva slipped through the tube in about $\frac{1}{2}$ second. The system recorded several readings set to be done during that time period and once the larva passed out, it displayed the average of the readings in the LCD display of the device. This reading provided a distinct indication on the maturity level of the larva. In a fully automated system planned for future, an appropriate mechanism would be incorporated to facilitate feeding of sample larvae to the measurement zone with minimum human intervention. The principle described in this paper can be used to design a device as the decision making engine in the detection zone.

Field measurements were taken for four different crops during our study and the results of ten samples of mature and immature muga larvae are presented in Table 1.

Table 1: Optical transmissibility

Sample	Mature			Immature		
	Optical transmissibility (%)	Mean (%)	Standard Deviation (%)	Optical transmissibility (%)	Mean (%)	Standard Deviation (%)
1	52.23			07.39		
2	51.00	50.17	3.59	06.22	8.34	1.66
3	53.26			08.25		
4	53.13			08.11		
5	49.16			07.56		
6	42.39			09.38		
7	50.33			11.91		
8	54.62			07.72		
9	47.69			09.95		
10	47.85			06.93		

Table 1 shows that the mean of optical transmissibility of mature muga larva is 50.17 % with a standard deviation of 3.59 %. Similarly, the mean of optical transmissibility of immature muga larva is 8.34 % with a standard deviation of 1.66 %. Therefore, a muga larva should exhibit minimum optical transmissibility of 50.17 % – 3.59 = 46.58 % to be considered as a mature muga larva.

On the other hand, optical transmissibility for an immature muga larva should be around $8.34\% + 1.66 = 10.00\%$. It shows that the difference of optical transmissibility between a mature and an immature muga larva is about $46.58\% - 10.00\% = 36.58\%$. Therefore, V_m^{TH} can be set within the range of 30 to 35 % to ensure a good margin of V_m to select a mature muga larva. Thus the value of RF can be selected between 0.26 and 0.36.

Conclusion

Muga silkworm cultivation is of extreme importance not only for its textile value but also for several other reasons. Muga is an intangible cultural heritage of north-east India. The livelihood of a considerable portion of the population here depends on muga silkworm cultivation. Modern investigations reveal that muga silk can be used as a protective shield against UV radiations. The market for umbrella produced using muga silk for UV protection is growing rapidly. As a result, demand and cost of muga silk is increasing day by day. But only mature muga larvae can produce good quality cocoons of good quality muga silk. Therefore, traditional muga cultivators warrant technical supports to increase their productivity and quality. The MBES described in this paper can be used effectively to separate mature muga larvae from immature muga larvae and allow them to spin cocoon. The immature larvae can be shifted back to their host plants for enhancing productivity. The system proposed here is innovative and suitable for remote muga field application as it requires very less power with cheaper electronic device.

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Article scientifique

DEVELOPPEMENT D'UN SYSTEME SCHELLE DE MICROCONTROLEUR POUR DETECTER LES LARVES MURES DE MUGA

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RÉSUMÉ

Cet article décrit un système développé pour identifier les larves mures de muga (*Antheraea assamensis* HELFER) basé sur la mesure de leur transmission optique. Les méthodes traditionnelles d'identification de la maturité sont basées sur l'intuition développée par une longue expérience et caractérisées par un délai conséquent dans le processus de collecte. Le système de microcontrôleur scellé utilisé pour cet objectif fournit une mesure quantitative de la transmission optique des larves muga par un circuit diviseur de potentiel consistant en une résistance dépendant de la lumière comme détecteur. Un tube en plastique incliné contenant une diode émettrice de lumière et une résistance dépendant de la lumière comme détecteur sont utilisés lorsque les larves muga sont placées entre la source de lumière et le détecteur. La puissance associée au rayon lumineux transmis à travers une larve muga est proportionnelle au niveau de maturité de la larve. Dans ce système, le rayon émergeant de la larve est capturé par le détecteur basé sur le circuit diviseur de potentiel qui produit une valeur numérique moyenne de transmission optique de 50 % pour les larves mures et de 8,34 pour les immatures. Ainsi cette étude établit une machine basée sur un microcontrôleur qui identifie clairement la maturité des larves. Le système peut réduire le travail physique de collecte des larves muga du 5^{ème} âge et augmenter la productivité.

Mots-clés: *Antheraea assamensis* Helfer, soie Assam, muga, transmission optique, détecteur, insecte séricigène.



CONSERVATION AND BREEDING STRATEGIES FOR LARIA SILKWORM, *ANTHRAEA MYLITTA* DRURY FOR EXPLOITATION OF SAL FLORA

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ABSTRACT

The wild ecorace population of *Antheraea mylitta* D. is declining alarmingly due to rapid deforestation and rampant human interference. This distressing stage, is consequently affecting the proliferation and sustenance of the insect. Laria is one of the important commercially exploited Sal based ecoraces of tasar silkworm, *A. mylitta*. The ecorace is notable for its small sized and robust cocoons with low denier (8-9). The characteristic voltinism behavior is uni, bi and trivoltine. Suitable strategy is required to protect and sustainably utilize the wild ecorace Laria particularly on Sal flora. With an aim to utilize the vast Sal flora and to conserve Laria ecorace, a programme was initiated to develop a module of *in situ* conservation of the ecorace. The breeding materials of Laria were augmented periodically under net cover at conservation site. This has greatly enhanced the natural proliferation and perpetuation of Laria population. The breeding possibilities of Laria was also studied with that of ruling semi-domestic Daba ecorace and Sal based Raily ecorace for the exploitation of heterosis effect for the utilization of Sal flora. A positive heterosis effect was recorded in fecundity (0.8 to 12 %), hatching (4.4 to 13.7 %) and in some cocoon characters (0.68 to 11.5 %). The present study enumerates the success of conservation of Sal based ecorace and its influence on the natural proliferation of Laria population in Sal forest. Further, Laria can be used as better breeding component along with other ecoraces of tasar silkworm to harness the heterosis potentials to enhance the tasar silk production.

Key words: *Antheraea mylitta*, breeding, conservation, Laria ecorace, Sal utilization.

INTRODUCTION

Non-mulberry sericulture is widely a forest based activity and known as wild or vanya sericulture which holds great promise for agro-forestry activities in India. The tropical tasar silkworm, *Antheraea mylitta* Drury is a wild polyphagous, holometabolous, lepidopteran saturniid insect with flexible voltine cycles. This vanya silkworm has variegated scenario of its natural existence and *in situ* propagation on naturally grown forest plants (Sinha and Srivastava, 2004; Suryanarayana *et al.*, 2005; Hansda *et al.*, 2008). Further, this wild silkworm has been

subjected to multi dimensional experimentation to enable it to thrive successfully under semi-domesticated conditions and to produce more silk. Tasar silkworms forage on wide range of food plants, being classified into primary, secondary and even tertiary. The primary food plants such as *Terminalia arjuna* (Arjun) and *T. tomentosa* (Asan) are widely utilized for the rearing and production of tasar cocoons. Many wild ecoraces forage on *Shorea robusta* (Sal) for its survivability and perpetuation. Sal flora provides the base for the collection of a large quantity of nature grown cocoons of the different ecoraces viz., Laria of Jharkhand, Modal of Orissa and Raily of

Chhattisgarh and they are regularly collected from the thickly populated Sal forests (Srivastava *et al.*, 2003, Suryanarayana and Srivastava, 2005). These ecoraces breed better and maintain their physical and genetic characters in their natural habitat (forests) which hitherto deteriorated when reared *ex-situ*.

Laria is one of the commercially exploited Sal based ecoraces and it has been found mainly distributed in Sal forests of Jharkhand State and adjoining regions. The ecorace is notable for its small and robust cocoons with long peduncle and low filament denier. In nature, the voltinism of this ecorace is not fully understood but presumed to exist as uni-, bi- and trivoltine (Suryanarana and Srivastava, 2005; Kar *et al.*, 2010). In some limited areas, farmers use *Laria* ecorace for 2nd crop (during August- September) in a small scale. Third crop (November- February) is unstable and there is loss of biomass due to unseasonal moth emergence during unfavourable seasons. The primary adaptability of this ecorace is on *S. robusta* (Sal) and this flora covers 86.9 % of the total tasar flora in India as against 13.1 % of *T. arjuna* (Arjun) and *T. tomentosa* (Asan) (Kar *et al.*, 2010). Due to rapid deforestation and rampant collection, the natural tasar silkworm population in the forest is at alarming stage. In the recent past, anthropogenic stress has resulted in shrinkage of habitat of ecoraces which in turn affect the proliferation of the insect and gradual decline in population size (Srivastava *et al.*, 2011). The efforts for the utilization of vast Sal flora have become the thrust and need of the hour to enhance the total tasar silk production in India. Concurrently, conservation of Sal based natural tasar silkworm genetic resources such as *Laria* ecorace for the posterity would ensure to achieve the prime objectives.

A strategic planning for research and development is imperative for further quantitative and qualitative improvement in tasar cocoon production and utilization. In this context, breeding prospects of *Laria* ecorace was explored through crossing between Sal based Raily ecorace as well as semi-domestic Daba for exploitation of heterosis effect and extensive utilization of vast Sal flora for commercial cocoon production.

MATERIALS AND METHODS

Conservation strategies for *Laria* ecorace in Jharkhand

Conservation studies of *Laria* ecorace was taken up at Sal forest in Bhusur, Ormanjhi block of Ranchi district as conservation site.

Description of forest at Bhusur: The conservation site is situated in the Ormanjhi block of Ranchi district near Getalsud dam with longitude of 85.528°E and latitude of 23.458°N. *S. robusta* (Sal) is the dominant food plant with distribution of about 95 % of the existing flora. Remaining flora mainly consists of *Schleichera oleosa* (Kusum), *Emblia officinalis* (Amla), *Adina cordifolia* (Karam), *Anogeissus latifolia* (Dhautha), *Butea frondosa* (Palas), *Diospyros melanoxylon* (Tendu), *Semecarpus anacardium* (Bhelwa), *T. belerica* (Bahera) and *T. tomentosa* (Asan). The soil type was red loamy. The range of the forest having continuity with forests of Gola and Peterbar of Bokaro district of Jharkhand has been identified as ecological niche for *Laria* ecorace.

Infusion of *Laria* breeding material inside conservation net: *Laria* cocoons as breeding material were collected, garlanded and hanged inside the net cover (the free fall size was 50'x50'x25' and the net covered 25 to 30 Sal plants of 15 to 20 feet height). Eight numbers of such nets were erected at the identified conservation site. In natural conditions, the hanged and infused materials were frequently attacked by rats, squirrels *etc.* To overcome this menace, open cellars in the shade were erected with the help of iron mesh and bamboos, inside the net cover at conservation site. This cellar device checked rat menace and seed cocoons were protected from predator attack. Apart from the seed cocoons as breeding materials, eggs in leaf cups and gravid female moths in *chullus* (egg laying and transferring device made of local wild Kans grass *Saccharum spontaneum*) were also hanged inside and outside of the net cover.

Grainage behavior of *Laria ecorace* at conservation site under nylon net:

After the infusion of breeding material *ie.*, *Laria* seed cocoons inside the net cover at conservation site, the moth emergence, male-female moth mating and egg laying behavior were recorded. Periodic augmentation of seed cocoons was made at the conservation site and recorded the multiplication rate for three years.

Breeding prospects of *Laria ecorace*

Breeding and compatibility with semi-domestic *Daba ecorace*: Breeding possibilities with *Daba* was analyzed through cross breeding including reciprocal cross *viz.*, *Laria* x *Daba* and *Daba* x *Laria*. The wild *Laria* cocoons collected from Peterbar Sal forest was used for the preparation of cross breed with *Daba* (semi-domestic). Parameters such as fecundity, hatching performance, cocoon yield, survivability and cocoon characters of the F1 crosses were recorded and compared with that of the parents. Rearing was conducted on *T. arjuna*.

Feasibility of F1 hybrids of *Laria* x *Raily* and its reciprocal cross on Sal utilization: Crosses of *Laria* and *Raily* including reciprocal were produced and the potential of F1 hybrids to utilize Sal foliage was studied. The parameters such as fecundity, hatching performance, rearing and survivability on Sal were recorded.

Table 2: Physical achievements of *in situ* conservation of *Laria* population during study period

Year	Month	No. of cocoons hanged	No. of cocoons collected		Cocoon to cocoon yield ratio
			Month	Number	
2010	May	20000	August – September	6000	-
2011	May	5000	November	30000	1:6
2012	May	5000	December - January	25000	1:5

RESULTS AND DISCUSSION

Infused breeding material and *in situ* multiplication of *Laria* population: The observations on *in situ* grainage performance of *Laria ecorace* at the conservation site is presented in Table 1. During the first year, about 20000 cocoons of *Laria ecorace* were infused inside the conservation net in the month of May for natural emergence and multiplication. A total of 6000 cocoons were harvested from net cover and nearby area during the month of August – September. During the second year, 5000 cocoons were infused and 30000 cocoons were estimated at conservation site with yield of 1:6. During the third year, again 5000 cocoons were infused in the month of May and about 25000 (24841) cocoons were collected from the natural forest.

These observations revealed that in the first year, no significant result for multiplication of *Laria ecorace* in conservation site was observed as with input of 20000 cocoons in May, only 6000 cocoons could be collected by

Table 1: Grainage performance of the *Laria* seed cocoons infused inside the net at the conservation site, Ormanjhi (Ranchi)

Period of preservation	No. of cocoons preserved	Moths emerged		Pairing obtained	Total moths emerged	Total cocoons with no emergence	Pupal mortality	Rat cut cocoons	Cocoons with live pupae*
		Female	Male						
10.5.2010 to 23.7.2010	20000	5239 (37.68)	8665 (62.32)	4334 (82.72)	13904 (69.62)	6096 (30.48)	1934 (9.67)	3618 (18.09)	546 (2.723)
14.8.2010 to 10.10.2010	6000	2122 (45.47)	2545 (54.53)	1931 (91.00)	4667 (77.78)	1333 (22.22)	220 (3.67)	557 (9.28)	556 (9.27)
6.11.2010 to 12.1.2011	5000	792 (37.72)	1308 (62.28)	159 (20.08)	2100* (42.00)	2900 (58.00)	0	0	2900* (58.06)
19.3.2011 to 25.7.2011	5000	1576 (40.75)	2291 (59.25)	1261 (80.01)	3867 (77.52)	1133 (22.66)	683 (13.66)	0	450 (9.00)
9.5.2012 to 21.7.2012	5000	1606 (39.55)	2455 (60.45)	1369 (85.24)	4061 (81.23)	939 (18.78)	521 (10.42)	0	418 (9.36)

Figures in parentheses indicate the percentages; * - winter emergence; Mode of preservation: Hanging of cocoons inside net; * No. of live cocoons remained (diapause) until next season.

the end of September. During the second and third year, 30000 and 25000 cocoons were collected, respectively with infusion of only 5000 cocoons each year. The multiplication ratio observed was 1: 5 to 1:6 (Table 2). This is because of the fact that though the breeding material released during first year was not immediately discernable, it is believed to be perpetuated in the forest by its own as it contributed to multiplication of stock even

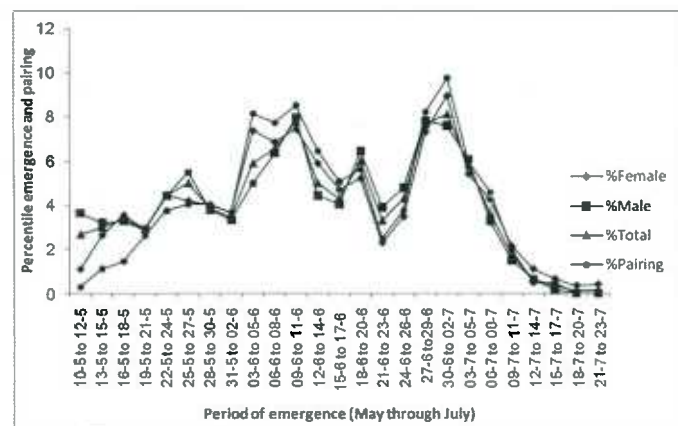


Figure 1: Emergence and coupling percentile from May to July 2011

when a small quantity of seed cocoons was released during the subsequent years. The process of natural multiplication of race is slow but there might be gradual increase in the population of *Larisa* over subsequent generations if there is no rampant collection of cocoons and menace of pests and predators. Although the process is slow, the conservation strategy is effective in increasing the population of depleting race on a long term basis.

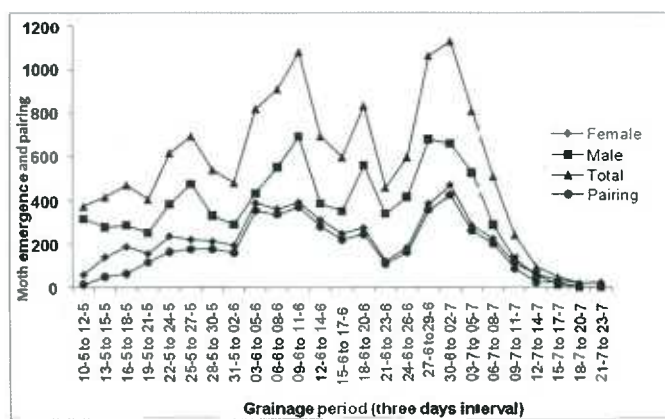


Figure 2: Emergence and coupling from May to July 2011 (by number)

***In situ* grainage behavior of *Larisa ecorace* at conservation site under nylon net:** The moth emergence behaviour in *Larisa* seed cocoons was recorded *in situ* at the conservation site under the net cover throughout the year (Figures 1-8). However, the peak emergence was recorded from last week of June to first week of July (Figure 2). During this period, the average emergence was 59.25 to 62.31 % and 37.68 to 40.75 %, respectively for male and female (Figure 1). The peak period of II grainage (male 54.53 % and female 45.47 %) was observed during last week of August to second week of September (Figure 4). During the month of December, about 14 % of *Larisa* silk moths emerged out (Figure 5) and was recorded with very low rate of coupling (16 %). This indicates the weak trivoltine behaviour of *Larisa*.

In the natural conditions, pairing was 80 to 85 % in June-July and 88 to 91 % in August-September. This trend showed the bi as well as trivoltine behaviour. The moth emergence in semi-domestic Daba (TV) starts during middle of June and for bivoltine, it is scheduled during first or second week of July, in concert with the onset of monsoon. Univoltine cocoons were also recorded to the tune of 2.72 to 9.36 %.

The egg laying behaviour was studied thoroughly and it was noticed that the female silk moths laid eggs in patches not only on bark, leaf and stem of Sal trees but also on different non-food plants. The egg laying was in a scattered way, with clump size of 9 to 16 eggs. Life cycle was allowed to continue in natural condition without

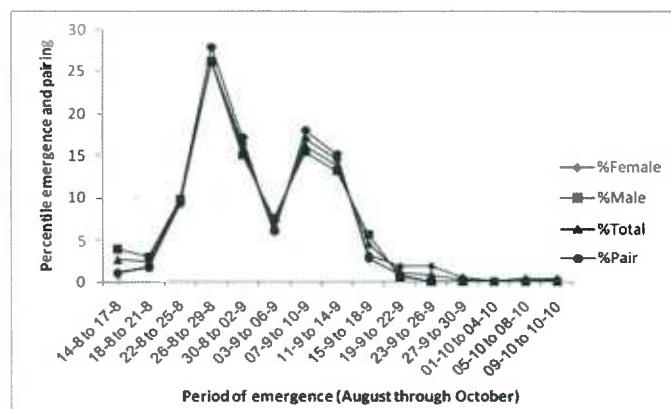


Figure 3: Emergence and coupling percentile from August to October 2011

human interference, from June–July onwards.

Breeding prospects of Laria ecorace combination with semi-domestic Daba

Fecundity and egg hatching: The performance of F_1 and reciprocal crosses of Laria x Daba was recorded with significant improvement in the fecundity ($P < 0.05$) over its parental lines (Table 3). The fecundity was 245 ± 8 in F_1 cross of Laria x Daba and 238 ± 10 in the reciprocal cross. Compared to the parental lines, Daba (231 ± 5) and Laria (205 ± 9), there was a genetic gain of about 12.5 % over the mid parent value for the fecundity. Higher hatching was recorded in the F_1 cross Laria x Daba (86 %) compared to the parental lines, Daba (83 %), Laria (72 %) and F_1 of Daba x Laria (79%).

Fecundity is considered as one of the most desired quantitative traits of commercial importance in silkworms (Reddy *et al.*, 2010). The genotype-environment interaction has highly significant influence

on the fecundity of the silkworms, the differential performance with reference to fecundity attributed to the genetic endowment of the two ecoraces (Omana and Gopinathan, 1995). Similarly, the egg hatching depends on the fertilization of eggs and proper development of embryo inside the egg (Saheb *et al.*, 2009).

Cocoon yield and cocoon characters: The cocoons harvested out of 2nd crop were analysed for the

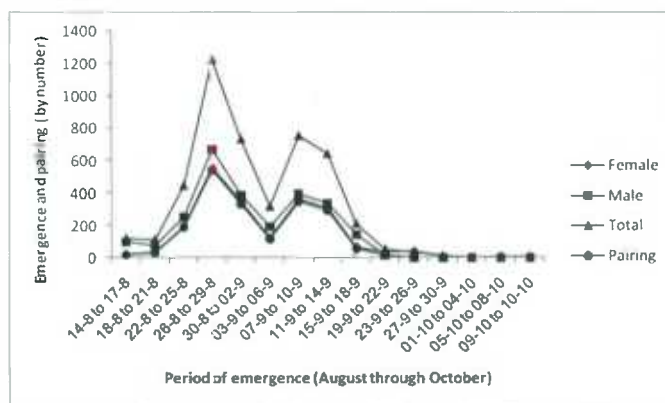


Figure 4: Emergence and coupling from August to October 2011 (by number)

Table 3: Comparative assessment of quantitative characters and heterosis values of different cross combination of Laria with Daba and Raily ecoraces of *A. mylitta*

Ecorace/Combination	Fecundity (No.)	Hatching (%)	Cocoon yield/df	Cocoon weight (g)	Shell percentage
Daba	231 ±	87 ± 3%	58 ± 6 (Arjun)	12.59 ± 1.95	15.80 ± 1.33
Laria	205 ± 9	70 ± 4%	18 ± 5 (Arjun) 19 ± 7 (Sal)	10.63 ± 2.0 110.01 ± 2.10	16.08 ± 1.28 17.08 ± 2.20
Raily	278 ± 10	68 ± 6%	23 ± 8 (Arjun) 19 ± 8 (Sal)	12.83 ± 3.50 12.78 ± 3.33	16.36 ± 2.45 17.21 ± 2.50
Laria x Daba	245 ± 8 (+12.00)* (+06.06)**	82 ± 5% (+4.45)* (-05.74)**	53 ± 5 (Arjun) (+39.47)* (-08.62)**	12.65 ± 2.01 (+8.96)* (+0.47)**	15.88 ± 1.27 (-0.30)* (-01.24)**
Daba x Laria	238 ± 10 (+6.00)* (+03.03)**	79 ± 2% (+0.06)* (-09.20)**	52 ± 8 (Arjun) (+36.84)* (-10.10)**	12.61 ± 1.85 (+8.61)*	16.25 ± 1.20 (+01.94)* (+01.05)**
Raily x Laria	238 ± 12 (+0.80)* (-14.38)**	73 ± 8% (+5.79)* (+04.30)**	20 ± 5 (Sal) (+05.26)* (+05.26)**	12.45 ± 2.85 (+9.30)* (-02.58)**	16.9 ± 2.76 (-01.40)* (-01.80)**
Laria x Raily	235 ± 11 (-1.20)* (-15.46)**	78 ± 9% (+13.10)* (+11.43)**	23 ± 4 (Sal) (+21.05)* (+21.05)**	12.66 ± 3.08 (+11.15)* (-0.93)**	18.00 ± 2.11 (+05.02)* (+04.60)**

* Heterosis value (in %) over mid parent value, ** heterosis over better parent value; +/- : positive/ negative heterosis effect for particular character.

comparative performance of each combination. Daba yielded 58 ± 6 cocoons per dfl brushed whereas, in Laria x Daba, it was 53 ± 5 , in Daba x Laria, it was 48 ± 8 and 18 ± 5 in Laria. The heterosis percentage estimated over mid parent value is presented in Table 3. The higher values of the quantitative characters of the F_1 crosses might be due to the epistatic and dominant effects of the genes resulted from the crossing of the ecoraces (Falconer, 1985; Aruga, 1994; Verma *et al.*, 2005; Reddy *et al.*, 2008; Reddy *et al.*, 2010).

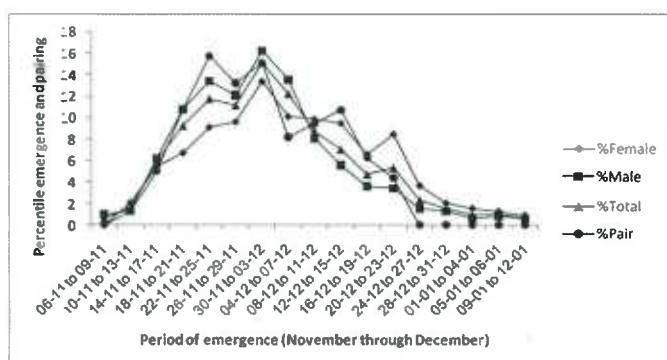


Figure 5: Emergence and coupling percentile from November to January 2011 - 12

Feasibility of F_1 hybrids of Laria x Raily and its reciprocal cross on Sal utilization: The performance of reciprocal cross of Laria and Raily showed a mixed response in relation to some grainage and rearing parameters when reared on Sal foliage. Higher fecundity (238 ± 12) was recorded with over +0.80 % of heterosis value in Raily x Laria. Similarly, better heterosis values

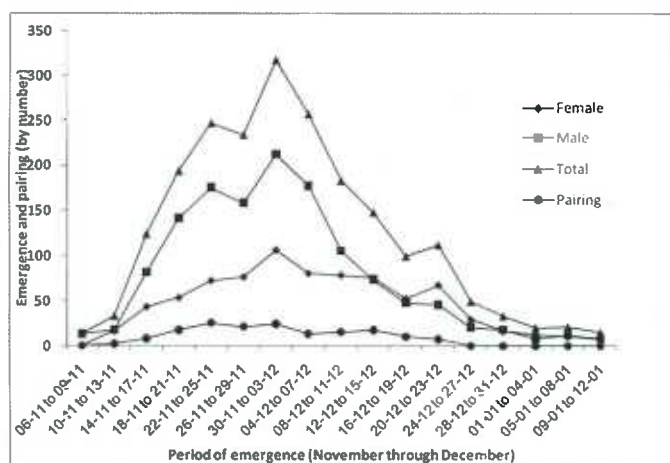


Figure 6: Emergence and coupling from November to January 2011 - 12 (by number)

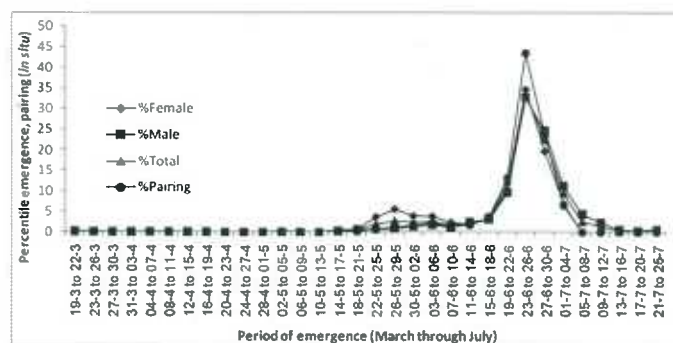


Figure 7: Emergence and coupling percentile (*in situ*) from March to July 2011

with improvement in cocoon yield (+ 21 %), cocoon weight (+ 11 %) and shell percentage (+ 5 %) were observed in the F_1 crosses of Laria x Raily (Table 3).

Conservation of wild tasar silkworm genetic resources is the prime need of the hour. Due to various anthropogenic activities and in consequent to climate change, the invaluable populations of this species are under the threat of extinction. A suitable strategy is required to be adopted to protect and sustainably utilize the wild ecorace particularly Laria on Sal flora. As evident from the present study, *in situ* conservation strategies adopted to augment the breeding materials of Laria ecorace at the designated conservation site consisting of Sal flora has given encouraging results. A significant increase in the proliferation of Laria ecorace was noticed in and around the conservation site. Similar module was adopted by the Sericulture Department of Jharkhand state and successfully implemented in about five Sal forest patches in different locations of Jharkhand. This has resulted in high rate of natural proliferation of Laria

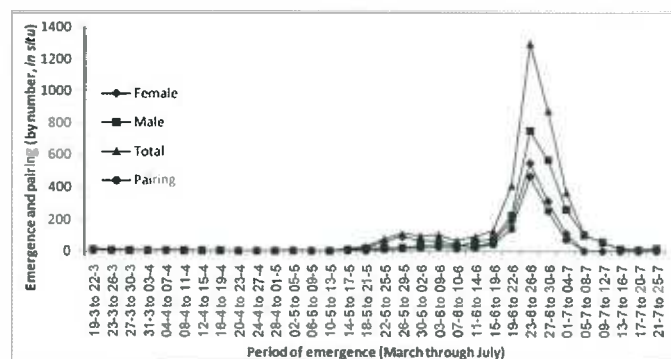


Figure 8: Emergence and coupling (*in situ*, by number) from March to July 2011

ecorace and natural collection of cocoons recorded up to the tune of 50-60 lakhs. The study also reiterates based on the present results that the potentialities of wild ecorace Laria as a breeding component along with other ecoraces of tasar silkworm could be exploited to harness the heterosis potentials to enhance the tasar silk production simultaneously, utilizing the vast Sal flora.

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Article scientifique

STRATEGIES DE CONSERVATION ET DE CROISEMENTS DU VER A SOIE LARIA, *ANTHRAEA MYLITTA* DRURY, POUR L'EXPLOITATION DE LA FLORE DE SAL

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RÉSUMÉ

Les populations sauvages des éco-races de *Antheraea mylitta* D. déclinent de manière alarmante en raison de la déforestation rapide et des interférences humaines. Cet état douloureux affecte évidemment la prolifération de l'insecte ce qui entraîne le déclin progressif de sa population. Laria est l'une des éco-races de ver à soie tasar (*Antheraea mylitta*) commercialement importante vivant sur Sal. Laria est connue pour ses cocons robustes de petite taille donnant un filament de faible titre (8-9 deniers). Il peut être mono, bi et trivoltin. Une stratégie adéquate est nécessaire pour protéger et utiliser de manière durable l'éco-race sauvage Laria particulièrement sur la flore Sal. Un programme a été initié pour développer un module de conservation *in situ* de l'éco-race. Les matériels de croisement de Laria ont été accrus périodiquement sur un site de conservation sous filets. Ceci a grandement augmenté la prolifération et la pérennité de la population Laria. Nous avons également étudié les possibilités de croisements avec la race semi-domestique Daba et l'éco-race Raily vivant sur Sal. Une hétérosis positive a été observée pour la fécondité (0,8 à 12 %), l'éclosion (4,4 à 13,7 %) et pour quelques caractères du cocon (0,68 à 11,5 %). Notre étude énumère les succès de la conservation de l'éco-race se nourrissant de Sal et de son influence sur la prolifération naturelle de la population de Laria dans la forêt de Sal. De plus, Laria peut être utilisée comme un meilleur composant de croisement avec d'autres éco-races de ver à soie tasar afin de fixer les potentiels d'hétérosis pour augmenter la production de soie tasar.

Mots-clés: *Antheraea mylitta*, croisement, conservation, éco-race Laria, utilisation de Sal.



INFLUENCE OF ENZYMATIC FINISHING ON TASAR SILK FABRICS

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ABSTRACT

Tasar silk is one of the most sought after wild silk for its natural fawn colour, unique rustic appearance and texture. Major drawback of tasar silk is its rough feel and low dimensional stability issues when subjected to normal washing, which restricts its mass utilization. Chemical treatments to overcome such shortfall have adverse effects on its natural color, surface properties, fabric strength and it even pollutes the environment. Hence, this article attempts to study the influence of eco-friendly protease enzymatic treatment on the dimensional stability, tensile strength, tear strength, bending, drape and comfort properties of tasar silk fabrics. It was obvious that the enzymatic finishing could impart improved aesthetic properties to tasar silk fabric such as fabric feel, drape and fabric bending properties along with decreased shrinkage.

Key words: Comfort properties, dimensional stability, enzyme finish, tasar silk.

INTRODUCTION

Silk fiber is known as the “Queen of Textiles”, due to its attractive luster, royal feel and elegant look. Tasar is a variety of vanya silk, famous for its natural fawn color and rich texture. But the drawback is its rough feel and dimensional stability issues related to normal washing, which restricts its mass utilization. Bio-finishing is a finishing process applied to textiles that produces permanent effects by the use of enzymes. Enzymes are biological catalysts usually derived from a fungal or a bacterial source. The enzyme and substrate form a 'lock and key' complex that requires the enzyme to have a specific molecular alignment in order to act as a catalyst. In an enzyme – catalysis reaction, the substrate first binds to the active site of the enzyme to form an enzyme – substrate complex, then the substrate is converted into product whilst attached to the enzyme, and finally the product is released, thus allowing the enzyme to start all over again.

Proteases are hydrolase class of enzymes which acts upon the protein substrate at optimum pH and

temperature. Proteases precisely act on peptide bonds formed by specific amino acids to hydrolyze them. The degumming process in silk industry involves the removal of sericin and natural impurities from the silk filaments, which is being done usually by soap-soda boiling method. Application of 1-2 % dosages of alkaline protease at pH 9 and temperature 60 °C provides controlled, uniform degumming and enhanced handle besides being an eco-friendly process (Gowda *et al.*, 2007; Das *et al.*, 2011). Studies on acidic, neutral, and alkaline proteases to carry-out silk degumming have been conducted and it has been found that alkaline and neutral proteases performed better than acidic proteases in terms of complete sericin removal (Gulrajani *et al.*, 1998; Gulrajani *et al.*, 2000; Freddi *et al.*, 2003). Nakpathom *et al.* (2009) have studied the degumming of Thai *Bombyx mori* silk fibers with papain enzyme and alkaline soap. Bio-finishing of silk to obtain the required aesthetic characteristics being an essential processing component of the industry, an attempt has been made to evaluate the effect of enzymatic treatment on the dimensional stability, tensile strength, tear strength, bending, drape and comfort properties of tasar silk fabrics.

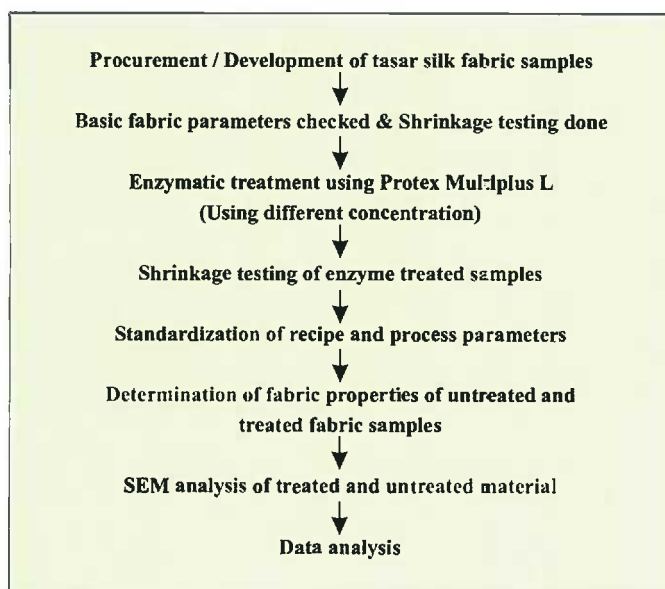
MATERIALS AND METHODS

Tasar fabric samples (four types) prepared from reeled tasar silk yarn were used for the present study. Sample I and II were commercial varieties while sample III and IV were developed in-house. Details of the tasar silk fabric samples used for the test are presented in Table 1.

Table 1: Tasar silk fabric particulars

Fabric parameter	Sample			
	I	II	III	IV
Ends/cm	34	33	39	39.1
Picks/cm	35	33	32	31.7
Denier	Warp	35	72	71.8
	Weft	175	69	70.5
Weave	Plain	Plain	Plain	Plain
GSM	74	72	57	56.8
Thickness (mm)	0.18	0.13	0.11	0.11

Alkaline protease (Protex Multiplus L) provided by M/s Dupont India Ltd. were used for the trials. Experimental process steps adopted for the present study in the form of flow chart is illustrated below.



Testing methods

Fabric constructional parameters were determined as per the standard testing methods (EPI/PPI - IS 1963, Warp and Weft denier - IS 3442, GSM - IS 1964, Thickness - ASTM D 1777). In order to evaluate the effect of enzyme treatment, both the treated and untreated tasar silk fabric

samples were subjected to dimensional stability test, i.e., shrinkage testing (IS 3561: 1989), comfort properties evaluation by drape-ability (IS 8357:1977), bending length /flexural rigidity (IS 6490:1971), moisture regain (IS 199), wicking (DIN 53924, 1978) and air permeability (IS 11056:1984) tests and strength evaluation by tensile strength, elongation % (IS 1969:1985) and tearing strength (IS 6489:1993) tests.

Enzyme was applied at different concentrations, time duration and temperature. Four different concentrations of enzyme (0.5, 1.0, 1.5 and 2.0 g/l) were used. The biofinishing treatment to the tasar silk fabric using protease enzyme was carried-out in a winch. Two-step treatment was adopted for the process. Wetting pre-treatment for 30 minutes was carried-out as first step with 1 gpl (gram/litre) non-ionic wetting agent with material to liquor ratio of 1:20 at room temperature. Second step of the treatment comprised of application of the enzymes (different dosages as indicated above) at temperature of 50-55 °C with 8.5 pH in the same bath for 1 hour. After enzyme treatment, the bath temperature was raised to near boiling (about 90 °C) for enzyme breakdown. Later, the treated tasar silk fabric was washed once in hot water and twice in cold water and dried under shade. Sample I was treated with four different enzyme concentrations for optimizing the recipe and process parameters. Other three samples were treated with the optimized recipe and the effect of the enzyme treatment on the fabric properties was determined.

RESULTS AND DISCUSSION

The impact of enzyme treatment at different concentrations on the fabric parameters of sample I is presented in Table 2.

Weight loss of the fabric was observed to increase after the enzyme treatment with the increase in enzyme concentration. In spite of the weight loss, fabric aerial density (GSM) and thickness were noticed to be increased with the increase in enzyme concentration. This is due to the shrinkage occurred due to the enzyme treatment. The fabric sample also shrunk in warp direction to a quite extent compared to weft direction, during the enzyme

Table 2: Change in fabric* parameters after enzyme treatment

Sample type	Weight loss %	Ends/cm	Ficks/cm	GSM	Thickness (mm)	Denier warp	Denier Weft
Control sample		35	35	74	0.18	39	175
0.5 % Treated Sample	0.18	31	32	75	0.27	37	120
1 % Treated Sample	0.43	35	31	75	0.32	36	101
1.5 % Treated Sample	1.1	31	31	75	0.3	36	176
2 % Treated Sample	1.75	31	31	80	0.32	38	172

* Fabric used for the test is Sample I

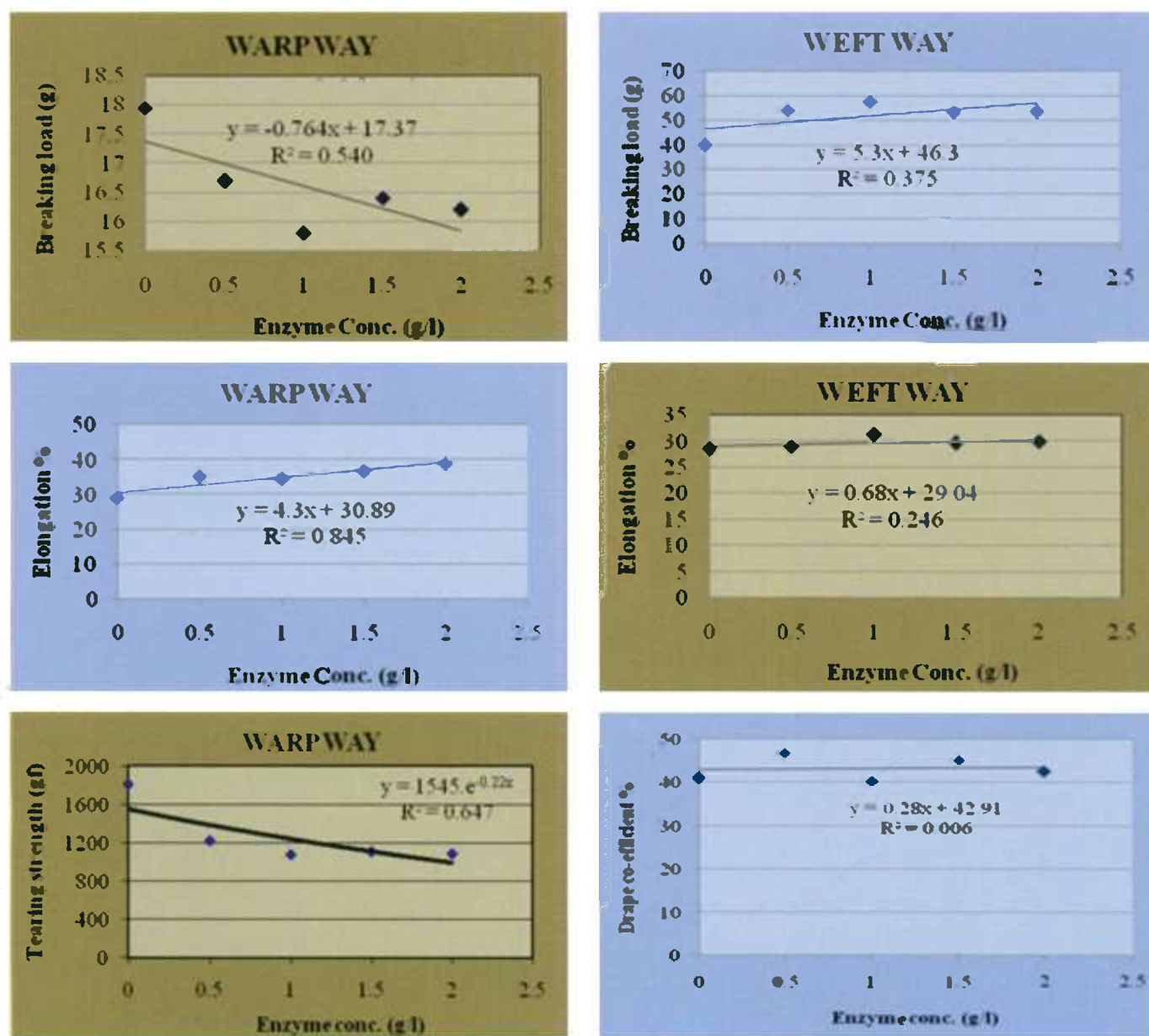


Figure 1: Effect of enzyme treatment on tensile and tearing strength of tasar fabric

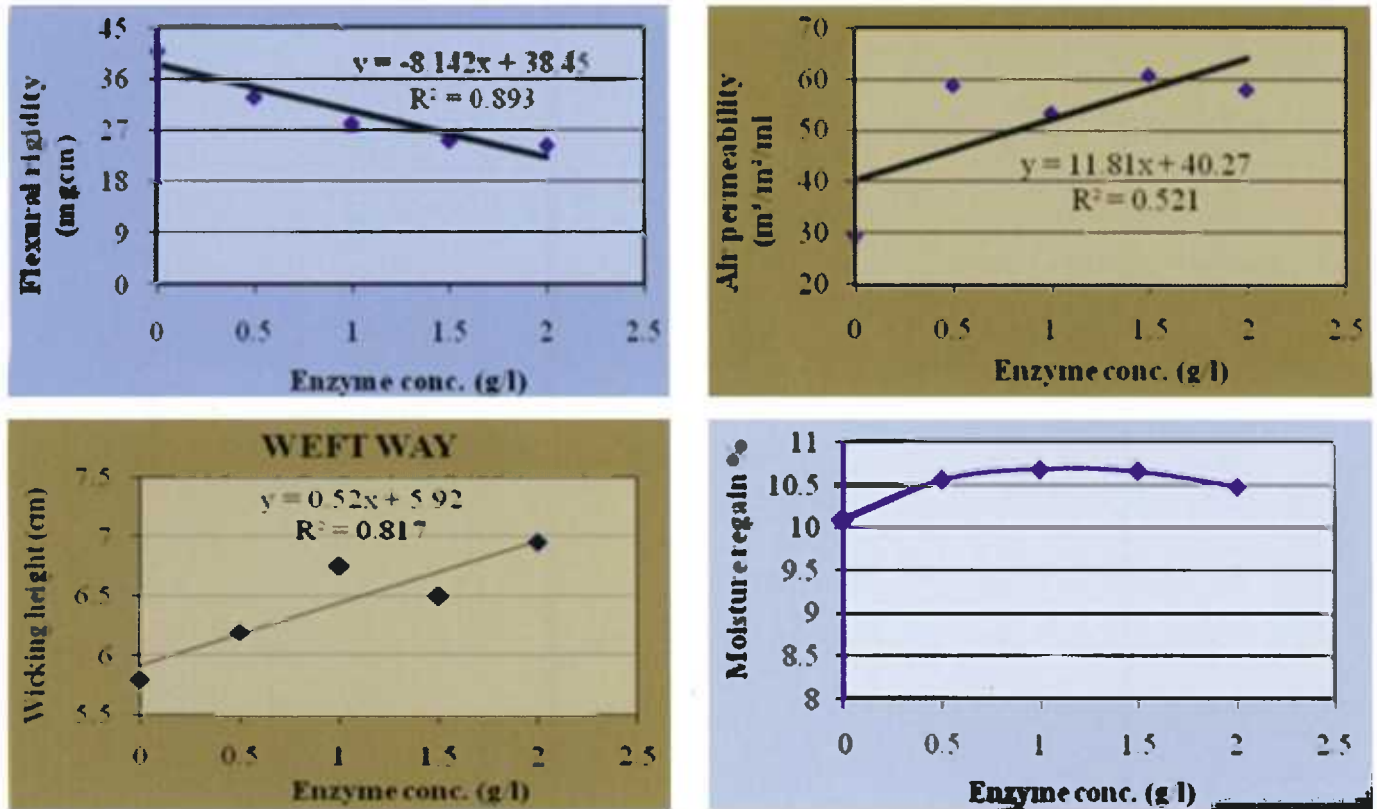


Figure 2: Effect of enzyme treatment on comfort properties of tasar fabric

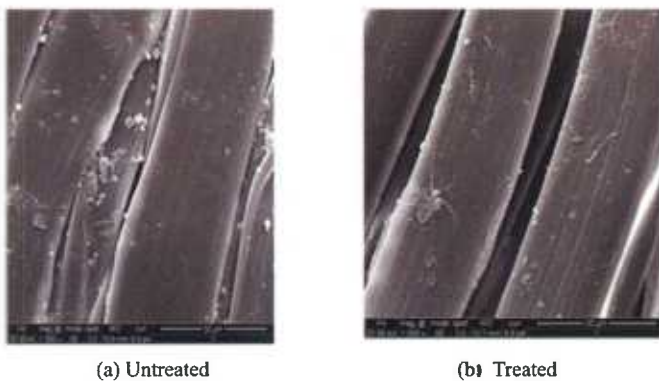


Figure 3: Surface morphology of tasar fabric

treatment. The phenomenon may be due to the difference in yarn denier. During this enzyme treatment, fabric samples were relaxed to the maximum and hence, negligible shrinkages were observed in subsequent washing.

The changes occurred in the fabric properties due to the application of enzyme at different concentrations are plotted in Figures 1 and 2. Further, the surface

morphology of the tasar fabric before and after the treatment was characterized using SEM, the images of which are given in Figure 3. The images illustrate that after the treatment, the fabric surface was much smoother than the untreated one. From the results it is obvious that elongation % of the fabric samples increased after the enzyme treatment and showed an increasing trend along with enhanced enzyme concentration. Breaking load and tearing strength were observed to decrease linearly with rising enzyme concentration. The loss in strength may be attributed to the breakage of polypeptide bonds in the long chain molecules inducing weak spots along the silk fibre. Increased elongation of the fabric samples after enzyme treatment could be due to release of stress induced in the fabric while weaving. A slight decrease was noticed in the tearing strength of the enzyme treated tasar silk fabrics. Flexural rigidity was found to decrease after enzymatic finishing, which represents the improvement in comfort properties. The drape co-efficient was found reduced in treated samples over control sample. Air permeability and wickability were on the higher side with increase in enzyme concentration. In the case of drape ability and

Table 3: Effect of enzyme treatment on different properties of fabric

Fabric property	Sample							
	I		II		III		IV	
	UT	Treated	UT	Treated	UT	Treated	UT	Treated
Breaking load, warp (g)	17.96	15.8	18.2	14.4	16.1	13.3	18.5	14.9
Breaking load, weft (g)	39.8	57.6	58.1	38.1	25.1	21.6	22.9	21.9
Elongation %, warp	29.25	35	18.2	28.2	22.2	24.4	24.6	23.9
Elongation %, weft	28.6	31.4	28.8	25.6	29.1	27.2	28.4	24.3
Tearing strength, warp (g)	1811	1081	1107.2	1235.2	2124	1779	1792	1241.6
Tearing strength, weft (g)	Jaw slippage	Jaw slippage	2348.8	Jaw slippage	1574	1536	1728	1139.2
Moisture regain (%)	10.09	10.68	10.25	10.66	11.85	12.07	11.9	12.1
Flexural rigidity, warp (mg cm)	16.77	15.84	23.36	11.38	38.41	27.91	42.12	40.22
Flexural rigidity, weft (mg cm)	100.57	50.18	114.23	106.67	44.80	19.17	27.74	36.85
Drape co-efficient (%)	41.08	40.49	49.25	40.39	42.9	38.1	41.44	35.2
Air permeability (m ³ /m ² /min)	29.47	53.44	40.0125	73.425	195.03	198.21	325.88	320.67
Wicking height (cm), Warp*	2.92	4.1	3.1	5.2	10.8	11.9	9.2	11
Wicking height (cm), Weft*	5.8	6.76	6.8	7.15	11.5	13.4	9.9	11.4

UT-Untreated; * Wicking height in 10 min

Table 4: Shrinkage % of different tasar samples before and after enzyme treatment

Status	Sample I		Sample II		Sample III		Sample IV	
	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
Untreated	5.22	3.1	4.75	2.75	6.94	8.9	7.17	9.41
Treated	0	0.5	0.5	0	1	1 % stretch	0.5	1

moisture regain, no significant changes were observed at different enzyme concentrations. Based on the experimental findings, the optimized dose which has been finalized for the treatment of tasar fabric is 1 g/l, 50-60 °C, 1 h, 8.5 - 9 pH.

With the optimized recipe, fabric sample II, III and IV were treated. Effect of enzyme treatment on different properties of tasar fabric samples are given in Table 3. The result of the shrinkage testing is presented in Table 4. After the treatment with 1 g/l enzyme conc., it was observed that tensile and tearing strength was reduced to a little extent, whereas the fabric stiffness had reduced making it more drape able. Though air permeability was observed to increase after the enzyme treatment in the case of sample I and II, no significant change was observed in the case of other two fabric samples. Wickability and moisture regain of the fabric was

increased, which will offer more comfort to the wearer. After the treatment, negligible shrinkage % was observed in the fabric, *i.e.*, dimensional stability of the fabric was improved.

Conclusion

Application of enzyme on tasar silk has shown significant improvement on the comfort properties of fabric with optimal protease dosage of 1 gpl and treatment duration of 1 hour. Fabric luster and surface properties were also noticed as improved. The finishing treatment on tasar has also brought about significant improvement in the dimensional stability. Enzymatic treatment provides promising finish to the tasar silk fabric and it could potentially enhance the use of tasar silk for mass apparels and dress materials, even with the green approach.

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Article scientifique

INFLUENCE DE LA FINITION ENZYMATIQUE SUR LES TISSUS DE SOIE TASAR

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RÉSUMÉ

La soie tasar est l'une des plus recherchées parmi les soies sauvages en raison de sa couleur fauve naturelle, son apparence rustique et sa texture. Les principaux refus de la soie tasar proviennent de son toucher rugueux et de sa faible stabilité dimensionnelle après un lavage normal, ce qui réduit son utilisation de masse. Les traitements chimiques pour éliminer ces obstacles ont des effets contraires sur sa couleur naturelle, les propriétés de surface, la résistance des tissus et ils polluent l'environnement. Aussi, cette étude examine l'influence des traitements écologiques enzymatiques à la protéase sur la stabilité dimensionnelle, la résistance à la tension et à la déchirure, la pliure, le drapé et les propriétés de confort des tissus de soie tasar. Il est apparu évident que la finition enzymatique transmet des propriétés esthétiques améliorées aux tissus de soie tasar telles que le toucher, le drapé et la déchirure ainsi qu'une diminution du rétrécissement.

Mots-clés: Propriétés de confort, stabilité dimensionnelle, finition enzymatique, soie tasar.



DISCRIMINANT FUNCTION ANALYSIS OF FACTORS ASSOCIATED WITH THE OUTBREAK OF ROOT ROT DISEASE IN MULBERRY (*MORUS* SPP.)

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ABSTRACT

Cultivation of mulberry is the most crucial factor in establishing a sericultural enterprise. Maintenance of soil health and management of diseases become an integral part of mulberry raising as in any other crop cultivation practice. In mulberry, diseases of the root system pose serious problems and management of soil borne diseases in mulberry plantation has been a more difficult task than the foliar diseases. This is because of the complex nature of edaphic factors. Among all soil borne diseases, root rot disease has become more alarming due to its epidemic nature and propensity to kill the plant completely. Eleven discriminating variables [type of soil, mulberry variety, disease incidence, hydrogen ion concentration (pH), electrical conductivity (EC), organic carbon (OC), soil moisture, phosphorus, potassium, iron and zinc] were considered in the present study to be the strong discriminators for the predisposition of root rot disease in mulberry gardens. The data on these variables were analysed by using the computer software SPSS for windows version 10.0 (SPSS Inc., 1999). The results of discriminant function analysis for root rot affected and healthy gardens revealed that the variables viz., phosphorus, potassium, soil moisture, iron, disease incidence, hydrogen ion concentration, zinc and organic carbon contributed 45.6, 21.6, 17.7, 7.4, 6.4, 0.9, 0.3 and 0.1 %, respectively for the outbreak of root rot disease in mulberry, whereas it was found that there was no role of EC, variety and soil type in predisposing mulberry for root rot disease. The Mahalanobis D^2 for the fitted function was 29.68 and found to be statistically significant ($P \leq 0.05$). The Eigen value was 71.815, percentage of variance and cumulative percentage were 100 % each and the canonical correlation was 0.993. In this analysis, Wilks' lambda showed that the group means were different and value of χ^2 was 996.942 and found to be significant ($P \leq 0.05$).

Key words: Discriminant function, edaphic factors, mulberry, root rot.

INTRODUCTION

Mulberry leaves of selected maturity and quality are repeatedly harvested for feeding the silkworms in accordance with the requirements at different instars of the silkworm larvae. More than 60 % of the cost of silk production is attributed to mulberry cultivation alone (Yokoyama, 1962; Anonymous, 1997). Hence,

cultivation of mulberry is the most crucial factor in sericulture for the production of lustrous silk. Mulberry is prone to a number of soil borne diseases. This category of diseases or in particular that affect the root system are dreadful from the management point of view because of the complex nature of soil. Among all soil borne diseases, root rot was reported to cause extensive damage to mulberry plant and has become more alarming

particularly in south India because of its epidemic nature and propensity to kill the plant completely. Hence, the present study was undertaken to identify the edaphic factors associated with the outbreak of root rot disease in mulberry. Discriminant function analysis is one of the tools of statistical analysis to discriminate between two or more groups of individuals on the basis of variables, which are selected to be the relevant variables in group discrimination. In the analysis, the multivariate problem is actually reduced to a single univariate problem by assigning appropriate weighting coefficients to the discriminating variables. The assignment of individuals between different groups depends upon the value of a single variable.

In order to find out the critical predisposing edaphic factors responsible for the outbreak of root rot disease in healthy mulberry gardens, to compare the predisposing factors responsible for diseased and healthy gardens and to compare the soil chemical parameters in root rot affected and healthy gardens in peninsular south India, the linear discriminant function analysis was employed.

The linear discriminant process was used to analyze the relative importance of the differentiating variables considered as discriminators for the predisposition of root rot disease in mulberry gardens.

MATERIALS AND METHODS

The soil samples collected from the healthy and root rot affected mulberry gardens ($n = 120$ each) in the states of Andhra Pradesh, Karnataka and Tamil Nadu were analyzed for hydrogen ion concentration (pH), electrical conductivity (EC), contents of organic carbon (OC), soil moisture, available potassium (K), available phosphorus (P), zinc (Zn) and iron (Fe).

Soil reaction (pH) and electrical conductivity (EC) were estimated as per the method of Jackson (1973). The soil moisture was determined by the gravimetric method (Piper, 1966). The modified Walkley and Black (1934) rapid titration method was adopted to estimate Organic

carbon (OC) content. Available phosphorus was estimated by the method of Olsen *et al.* (1954). Potassium was extracted from the soil with the help of saturated ammonium acetate solution, by shaking, followed by filtration. The extract was determined by using a flame photometer as described by Rao (1993). The available micronutrient contents *viz.*, Fe and Zn were extracted by reagents, diluted acids, salt solutions and chelating agents. Diethylene triamine pentaacetic acid (DTPA) was used to extract available micronutrient cations from soils by adopting the method of Lindsay and Norvell (1978).

Eleven discriminating variables (type of soil, mulberry variety, disease incidence, hydrogen ion concentration (pH), electrical conductivity (EC), organic carbon (OC), soil moisture, phosphorus, potassium, Iron and zinc) were considered in the present study to be the strong discriminators for the predisposition of root rot disease in mulberry gardens. The results obtained were analyzed by using the computer software SPSS for windows version 10.0 (SPSS Inc., 1999).

Disease incidence

In each area, 5 - 8 villages at a distance of 10 - 15 km from each other were selected for the roving survey. In each village, 8 - 10 farmers' gardens were observed. The disease incidence was determined on the basis of the number of infected/dead plants in the mulberry garden due to root rot disease by careful examination. Five rows of a patch containing 100 plants were selected at random in different locations in a field and the number of infected/dead plants in each row was counted and disease incidence percentage was calculated by using the following formula.

$$\text{Disease incidence (\%)} = \frac{\text{Number of infected plants}}{\text{Total number of plants}} \times 100$$

Statistical methods

The data generated were subjected to frequency distribution analysis by adopting standard statistical

methods (Fisher, 1936).

The linear discriminate function of the following form was employed

$$Z = \sum_{i=1}^p b_i X_i \dots\dots\dots (1)$$

where, Z = composite discriminate score

X_i = variable selected to discriminate between the groups and

b_i = linear discriminant coefficients

The function was constructed by choosing values of b_i 's in such a way that the resulting composite score would have maximum utility in distinguishing between the two groups. The optimal values for the weighting coefficients were determined, so that the difference between the mean score for the two groups would be maximized relative to the variation within the group. The function to be maximized was first defined by Fisher (1936). This is the ratio of the in between groups' variance to the within groups' variance.

$$f(b_1, b_2, \dots, b_p) = \frac{n_1 n_2 (b_1 d_1 + b_2 d_2 + \dots + b_p d_p)^2}{p n \sum_{i=1}^{n_1+n_2} \sum_{j=1}^p S_{bi} b_j} \quad (2)$$

$$= (n_1 n_2 / n_1 + n_2) + (b_1 d d' b / b' S b) \dots\dots\dots (3)$$

Where, d' = the vector of mean difference on 'p' measures

S = within group covariance matrix

b_i = unknown weighting coefficients and

n_1 and n_2 = the sample size in each group

Maximizing the above function (2) with regard to b_i yields a set of P equations in P unknowns viz.,

$$\begin{aligned} b_1 s_{11} + b_2 s_{12} + \dots + b_p s_{1p} &= d_1 \\ b_1 s_{12} + b_2 s_{22} + \dots + b_p s_{2p} &= d_2 \text{ and} \\ &\vdots \\ &\vdots \end{aligned}$$

$$b_1 s_{n1} + b_2 s_{n2} + \dots + b_p s_{np} = d_n$$

which can be solved by using simultaneous equation model.

The discriminant function was tested for significance to examine whether or not the variables considered together were strong enough to discriminate between two groups. This was done by using the following statistic.

$$F = \frac{n_1 n_2 (n_1 + n_2 - p - 1)}{p (n_1 + n_2) (n_1 + n_2 - 2)} \times D^2$$

Where, D^2 = Mahalanobis statistic given by

$$d' S^{-1} d = d' b,$$

p = Number of variables,

n_1 = Number of soil samples in diseased

category and

n_2 = Number of soil samples in healthy category

This follows the F distribution with (p) and $(n_1 + n_2 - p - 1)$ degrees of freedom. If the discriminant function is significant, we may conclude that the function is capable of effective discrimination between the healthy and diseased groups.

RESULTS AND DISCUSSION

The frequency analysis and primary statistical data of soil chemical analysis of both diseased and healthy gardens are presented in Tables 1 - 9.

The results of discriminant function analysis for root rot and healthy gardens revealed that the variables viz., phosphorus, potassium, soil moisture, iron, disease incidence, hydrogen ion concentration, zinc and organic carbon contributed 45.6, 21.6, 17.7, 7.4, 6.4, 0.9, 0.3 and 0.1 %, respectively for the outbreak of root rot disease in mulberry, whereas it was found that there was no role of EC, variety and soil type in predisposing mulberry for root rot disease (Table 10). The Mahalanobis D^2 for the fitted function was 29.68 and found to be statistically significant ($P \leq 0.05$). The Eigen value was 71.815, percentage of variance and cumulative percentage were 100 % and the canonical correlation was 0.993 (Table 11).

Table 1: Frequency distribution of hydrogen ion concentration (pH) in healthy and diseased mulberry gardens

pH range	Healthy gardens*		pH range	Diseased gardens*	
	No.	Frequency (%)		No.	Frequency (%)
5.90 - 6.10	4	3.33	7.90 - 8.10	2	1.67
6.50 - 6.70	6	5.00	8.11 - 8.30	9	7.50
6.71 - 6.90	7	5.83	8.31 - 8.50	30	25.00
6.91 - 7.10	6	5.00	8.51 - 8.70	33	27.50
7.11 - 7.30	12	10.00	8.71 - 8.90	25	20.83
7.31 - 7.50	12	10.00	8.91 - 9.10	19	15.83
7.51 - 7.70	21	17.50	9.30 - 9.50	1	0.83
7.71 - 7.90	20	16.67	9.70 - 9.90	1	0.83
7.91 - 8.10	32	27.67			

* n = 120

In this analysis, Wilks' lambda showed that the group means were different and value of χ^2 was 996.942 and found to be significant ($P \leq 0.05$) (Table 12).

In hot spot areas of Andhra Pradesh, 78.4 % of mulberry gardens were infected with root rot disease

Table 2: Frequency distribution of EC (mmohs/cm) in healthy and diseased mulberry gardens

EC (mmohs/cm) range	Healthy gardens*		EC (mmohs/cm) range	Diseased gardens*	
	No.	Frequency (%)		No.	Frequency (%)
0.070 - 0.120	6	5.00	0.10 - 0.30	33	27.50
0.121 - 0.170	22	18.33	0.31 - 0.50	65	54.17
0.171 - 0.220	14	11.67	0.51 - 0.70	17	14.17
0.221 - 0.270	19	15.83	0.71 - 0.90	2	1.67
0.271 - 0.320	19	15.83	0.91 - 1.10	1	0.83
0.321 - 0.370	23	19.17	1.11 - 1.30	2	1.67
0.371 - 0.420	2	1.67	-	-	-
0.421 - 0.470	5	4.17	-	-	-
0.471 - 0.520	7	5.83	-	-	-
0.720 - 0.770	3	2.50	-	-	-

* n = 120

Table 3: Frequency distribution of organic carbon (%) in healthy and diseased mulberry gardens

OC (%) range	Healthy gardens*		OC (%) range	Diseased gardens*	
	No.	Frequency (%)		No.	Frequency (%)
0.550 - 0.650	11	9.17	0.070 - 0.120	16	13.33
0.651 - 0.750	12	10.00	0.121 - 0.170	12	10.00
0.751 - 0.850	15	12.50	0.171 - 0.220	23	19.17
0.851 - 0.950	53	44.17	0.221 - 0.270	31	25.83
0.951 - 1.050	27	22.50	0.271 - 0.320	10	8.33
1.050 - 1.150	2	1.67	0.321 - 0.370	13	10.83
-	-	-	0.371 - 0.420	5	4.17
-	-	-	0.421 - 0.470	10	8.33

* n = 120

caused by *M. phaseolina* with 22.6 - 73.3 % disease incidence. In Tamil Nadu, 76.1 % gardens were infected and the disease incidence was recorded as 14 - 71 %. In Karnataka, 54.1 % of gardens were infected with the disease incidence being in the range of 12.3 - 39.3 % (Table 13).

Out of 400 mulberry gardens surveyed in various hot spot places (Andhra Pradesh, Karnataka and Tamil Nadu),

Table 4: Frequency distribution of phosphorus (kg/ha) in healthy and diseased mulberry gardens

Phosphorus (kg/ha)	Healthy gardens*		Phosphorus (kg/ha)	Diseased gardens*	
	No.	Frequency (%)		No.	Frequency (%)
18.0 - 23.0	5	4.17	6.0 - 7.0	4	3.33
23.1 - 28.0	6	5.00	7.1 - 8.0	1	0.83
28.1 - 33.0	42	35.00	8.1 - 9.0	8	6.67
33.1 - 38.0	33	27.50	9.1 - 10.0	21	17.50
38.1 - 43.0	24	20.00	10.1 - 11.0	43	35.83
43.1 - 48.0	9	7.50	11.1 - 12.0	32	26.67
48.1 - 53.0	1	0.83	12.1 - 13.0	9	7.50
-	-	-	13.1 - 14.0	2	1.67

* n = 120

Table 5: Frequency distribution of potash (kg/ha) in healthy and diseased mulberry gardens

Potash (kg/ha)	Healthy gardens*		Potash (kg/ha)	Diseased gardens*	
	No.	Frequency (%)		No.	Frequency (%)
150.0 – 250.0	10	8.33	150.0 – 250.0	13	10.83
250.1 – 350.0	26	21.67	250.1 – 350.0	44	36.67
350.1 – 450.0	23	19.17	350.1 – 450.0	35	29.17
450.1 – 550.0	41	34.17	450.1 – 550.0	22	18.33
550.1 – 650.0	14	11.67	550.1 – 650.0	6	5.00
650.1 – 750.0	4	3.33	-	-	-
750.1 – 850.0	2	1.67	-	-	-

* n = 120

235 gardens were with V-1 variety, followed by K-2 variety in 82 gardens, MR-2 in 43 gardens, S-13 in 18 gardens, S-36 in 13 gardens and RFS -175 in 9 gardens (Table 14).

The discriminant function analysis results clearly revealed that variety and soil type have no role to play in

Table 6: Frequency distribution of soil moisture (%) in healthy and diseased mulberry gardens

Soil moisture (%)	Healthy gardens*		Soil moisture (%)	Diseased gardens*	
	No.	Frequency (%)		No.	Frequency (%)
12.250 – 12.750	5	4.17	5.90 – 6.10	4	3.33
12.751 – 13.250	3	2.50	6.11 – 6.30	1	0.83
13.251 – 13.750	7	5.83	6.50 – 6.70	1	0.83
13.751 – 14.250	12	10.00	6.90 – 7.10	10	8.33
14.251 – 14.750	11	9.17	7.11 – 7.30	4	3.33
14.751 – 15.250	25	20.83	7.31 – 7.50	2	1.67
15.251 – 15.750	18	15.00	7.51 – 7.70	21	17.50
15.751 – 16.250	38	31.67	7.71 – 7.90	24	20.00
16.251 – 16.750	1	0.83	7.91 – 8.10	24	20.00
-	-	-	8.11 – 8.30	23	19.17
-	-	-	8.31 – 8.50	6	5.00

* n = 120

Table 7: Frequency distribution of zinc (ppm) in healthy and diseased mulberry gardens

Zn (ppm)	Healthy gardens*		Zn (ppm)	Diseased gardens*	
	No.	Frequency (%)		No.	Frequency (%)
0.47 – 0.52	4	3.33	0.17 – 0.22	37	30.83
0.57 – 0.62	20	16.67	0.27 – 0.32	47	39.17
0.67 – 0.72	11	9.17	0.37 – 0.42	21	17.50
0.77 – 0.82	23	19.17	0.47 – 0.52	15	12.50
0.87 – 0.92	33	27.50	-	-	-
0.97 – 1.02	29	24.17	-	-	-

* n = 120

predisposing mulberry for outbreak of root rot disease. The discriminant function analysis was utilized in the current study to elicit the factors responsible for discriminating the healthy gardens with that of root rot affected gardens, which was found to be more contributing. In the present analysis, the Eigen value recorded was 71.815 % of variance, cumulative percentage was 100 % and the canonical correlation was 0.993 indicating a strong association between the discriminant scores and the groups, which implies that the

Table 8: Frequency distribution of iron (ppm) in healthy and diseased mulberry gardens

Fe (ppm)	Healthy gardens*		Fe (ppm)	Diseased gardens*	
	No.	Frequency (%)		No.	Frequency (%)
9.0 – 11.0	1	0.83	3.0 – 4.0	1	0.83
11.1 – 13.0	22	18.33	4.1 – 5.0	4	3.33
13.1 – 15.0	41	34.17	5.1 – 6.0	11	9.17
15.1 – 17.0	40	33.33	6.1 – 7.0	17	14.17
17.1 – 19.0	13	10.83	7.1 – 8.0	16	13.33
19.1 – 21.0	2	1.67	8.1 – 9.0	21	17.50
21.1 – 23.0	1	0.83	9.1 – 10.0	28	23.33
-	-	-	10.1 – 11.0	21	17.50
-	-	-	11.1 – 12.0	1	0.83

* n = 120

Table 9: Soil chemical analysis of healthy and diseased mulberry gardens in south India

Parameter	Primary statistics						t [†] test
	Healthy gardens*			Diseased gardens*			
	Mean	S.D.	CV%	Mean	S.D.	CV%	
pH	7.47	0.50	6.74	8.62	0.26	3.06	**
EC (mmohs/cm)	0.28	0.12	44.51	0.40	0.17	43.39	**
OC (%)	0.92	0.20	22.43	0.24	0.10	41.27	**
P (kg/ha)	33.98	5.80	17.08	9.71	1.37	14.10	**
K (kg/ha)	438.62	137.23	31.28	361.02	176.95	45.99	**
Soil moisture (%)	15.00	0.98	6.56	7.72	0.51	6.65	**
Zn (ppm)	0.82	0.15	18.27	0.31	0.09	31.72	**
Fe (ppm)	15.01	2.02	13.51	7.57	1.75	23.14	**

* n = 120, ** CD ($P \leq 0.01$).

variables under consideration could effectively discriminate the healthy and diseased condition of the mulberry gardens. Wilks' lambda is the proportion of the total variance in the discriminant scores not explained by differences among the groups. In this analysis, Wilks'

Table 10: Discriminant function for 'diseased' and 'healthy' gardens

Discriminating factor	Coefficient (b _i s)	Group mean difference (d ¹ -d ²)	b _i d ¹ -d ²	Percentage contribution
Disease incidence	- 0.53	-3.57	1.90	6.4
Electrical conductivity	- 0.04	- 0.12	0.00	0.0
Iron	0.30	7.43	2.20	7.4
Potassium	- 0.08	76.65	6.40	21.6
Organic carbon	0.06	0.67	0.04	0.1
Phosphorus	0.56	24.27	13.53	45.6
pH	- 0.24	- 1.15	0.27	0.9
Soil moisture	0.72	7.28	5.25	17.7
Soil type	- 0.09	- 0.09	0.01	0.0
Variety	0.14	0.02	0.00	0.0
Zinc	0.16	0.51	0.08	0.3

F value significant at ($P \leq 0.05$); $D^2 = 29.68$.**Mean Z score for**

Healthy gardens	Cut off point	Diseased gardens
2.902	11.5	20.109

Table 11: Eigen values of the discriminant functions for 'diseased' and 'healthy' gardens

Function	Eigen value	% of variance	Cumulative %	Canonical correlation
1	71.815	100.0	100.0	0.993

Table 12: Wilks' lambda of discriminant functions for 'diseased' and 'healthy' gardens

Test of function(s)	Wilks' Lambda	Chi-square	d.f.	Sig.
1	0.014	996.942	11	0.000

lambda indicated that the group means were different and value of χ^2 was 996.942, which shows differences in the group means. Therefore, the variables considered in the function were found to be effective in discriminating the diseased and healthy status of the mulberry gardens.

The results of present study revealed that there was no contribution of soil type (red/black) for the outbreak of root rot disease caused by *M. phaseolina* in mulberry. This is in conformity with the results of Ledingham *et al.* (1973), who reported that, there is no difference of common root rot disease severity of wheat in Canada caused by *Bipolaris sorokiniana*. However, the variety does not differ strongly and group differences are not

Table 13: Prevalence of root rot disease in south India

State	District	No. of gardens surveyed	No. of gardens infected	% of infected gardens	% of disease incidence
Andhra Pradesh	Anantapur	50	40	80.0	25 – 85
	Chittoor	40	29	72.5	18 – 60
	Cuddapah	40	33	82.5	25 – 75
Total/Average		130	102	78.4	22.6 – 73.3
Karnataka	Bangalore Rural	45	29	64.4	12 – 40
	Mandya	55	32	58.1	20 – 50
	Kolar	60	24	40.0	5 – 28
Total/Average		160	85	54.1	12.3 – 39.3
Tamil Nadu	Dharmapuri	30	25	83.3	22 – 68
	Coimbatore	40	30	75.0	8 – 84
	Erode	40	28	70.0	12 – 61
Total/Average		110	83	76.1	14 – 71
Grand Total/Average		400	270	67.5	16.3 – 61.2

Table 14: Variety-wise number and percentage of root rot infected mulberry gardens (2002 - 04)

State	District	No. of gardens surveyed	V - 1		S - 13		S - 36		K - 2		MR - 2		RFS -175	
			No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Andhra Pradesh	Anantapur	50	25	96.1	2	20.0	7	77.7	3	75.0	-	-	0	0.0
	Chittoor	40	23	92.0	-	-	1	50.0	7	87.5	-	-	5	100.0
	Cuddapah	40	19	86.3	1	12.5	2	100	5	83.33	-	-	2	100.0
Total/Average		130	67	91.46	3	16.25	10	75.9	15	81.94	-	-	7	66.66
Karnataka	Bangalore Rural	45	24	80.0	-	-	-	-	5	33.3	-	-	-	-
	Mandya	55	29	69.0	-	-	-	-	3	23.0	-	-	-	-
	Kolar	60	18	64.2	-	-	-	-	6	18.7	-	-	-	-
Total/Average		160	71	71.0	-	-	-	-	14	23.3	-	-	-	-
Tamil Nadu	Dharmapuri	30	13	86.6	-	-	-	-	1	50.0	11	91.6	-	-
	Coimbatore	40	18	81.8	-	-	-	-	-	-	12	66.6	-	-
	Erode	40	21	84.0	-	-	-	-	1	50.0	6	46.1	-	-
Total/Average		110	52	84.8	-	-	-	-	2	50.0	29	67.4	-	-
Grand Total/Average		400	190	80.85	3	16.66	10	76.92	31	37.80	29	67.44	7	77.77

significant. Thus, it can be concluded that group means differ strongly and group differences are significant for most of the edaphic variables studied except the variety and soil type. Waller (1986) reported that the moisture and nutrient stresses are so common in tropical soils, which predispose roots of annual crops to a range of pathogens.

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Article scientifique

ANALYSE DE LA FONCTION DISCRIMINANTE DES FACTEURS ASSOCIES AU DECLENCHEMENT DE LA POURRITURE DE LA RACINE CHEZ LE MURIER (*MORUS* SPP.)

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R É S U M É

La culture du mûrier est le facteur le plus important pour établir une activité séricicole. La maintenance de la santé du sol et la gestion des maladies deviennent une part intégrale de la culture du mûrier comme pour n'importe quelle autre culture. Chez le mûrier, les maladies de la racine posent des problèmes sérieux et la gestion des maladies issues du sol dans les plantations de mûriers représente une tâche bien plus difficile que celle des maladies foliaires. Ceci est dû à la nature complexe des facteurs édaphiques. Parmi les maladies issues du sol, la pourriture des racines est devenue plus alarmante en raison de sa nature épidémique et sa propension à tuer la plante totalement. Onze variables discriminantes telles le type de sol, la variété de mûrier, l'incidence de la maladie, la concentration en ions hydrogène (pH), la conductivité électrique (EC), le carbone organique (OC), l'humidité du sol, le phosphore, le potassium, le fer et le zinc ont été prises en compte dans cette étude pour être les discriminants forts quant à la prédisposition à la pourriture de la racine dans les mûraies. Les données de ces variables ont été analysées en utilisant le logiciel SPSS pour la version 10.0 de windows (SPSS Inc, 1999). Les résultats de l'analyse de la fonction discriminante des mûraies affectées et saines révèlent que le phosphore, le potassium, l'humidité du sol, le fer, l'incidence de la maladie, la concentration en ions hydrogène, le zinc et le carbone organique contribuent pour 45,6 ; 21,6 ; 17,7 ; 7,4 ; 6,4 ; 0,9 ; 0,3 et 0,1 % respectivement au déclenchement de la pourriture de la racine chez le mûrier, alors que l'EC, la variété et le type de sol n'ont pas de rôle dans la prédisposition à la maladie. Le D^2 Mahalanobis est de 29,68 et est significatif à $P \leq 0,005$. La valeur Eigen est de 71,815, le pourcentage de variance et le pourcentage cumulé sont de 100 % chacun et la corrélation canonique est de 0,993. Dans cette analyse, Le lambda de Wilks indique que les moyennes de groupe sont différentes et que la valeur de χ^2 est 996,942 ce qui est significatif au seuil de $P \leq 0,05$.

Mots-clés: Fonction discriminante, facteurs édaphiques, mûrier, pourriture de la racine.



APPLICATION OF LAC DYE BY SCREEN-PRINTING ON MULBERRY AND TASAR SILK

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ABSTRACT

Environmental awareness throughout the world now seems to rescue the total 'fall' of natural dyes. Hazards of chemical industries and dyes in particular have forced environmentalists to think in terms of natural products. Hence, the trends of greater use of synthetic substitutes of natural substances have been reserved. This actually started when people throughout the world in general and west in particular preferred pure cotton clothes and dress material in place of clothes made from synthetic yarn. After the restoration of the cotton, natural dyes including lac dye await their turn. Studies on application of lac dye on mulberry and non-mulberry silk have been extensive. As natural dyes are less practiced in screen-printing units, an attempt was made here to print mulberry and non mulberry silk fabric using lac dye and screen-printing method. Using a few mordants along with lac dye, an appropriate printing recipe was formulated for the printing process. Wash, light, rubbing and perspiration fastness properties of the printed fabrics were tested using standard methods. Physical properties such as tensile strength, bending, and drape were also tested before and after processing. Techno economics of printed fabric was optimized and the process package for printing on non mulberry silk fabric with lac dye and by screen-printing method was finalised. Further, the effect of Mordanting on depth of shade and colourfastness was also studied. It was observed that most of the post mordanted fabrics possessed better wash and light fastness properties. The lac dye printed silk fabrics had acceptable performance in pre and post mordanted conditions. The colour fastness properties of mulberry and tasar silk fabric samples were within acceptable range.

Key words: Lac dye, mulberry, screen printing, tasar silk fabric.

INTRODUCTION

Lac is one of the insect dyes. India is the premier country to produce lac and its by-products, followed by China and Thailand. Nearly 250 MT of lac dye is obtained annually from 2500 MT of sticklac. The composition of the shellac is Carminic acid, Kermesic acid and Laccic acid. These compounds are hydro soluble and non-toxic in nature. Lac dye is a by-product generated during the production of sticklac. Lac dye being an acid dye can be directly dyed on protein fibers such as wool and silk. Indian lac dye has high potentiality through the world for

its use as textile colouring material as well as food colouring substance.

There have been quite a few interesting research works in this field. Ghosh and Sengupta (1977) could highlight the major areas covered during twenty-five years of research in lac. Prasad and Agarwal (1989) described the industrial perspectives of insect dyes. Paul *et al.* (1996) conducted a study on different natural dyes, their classification, ways of extraction and fastness properties. They could extract lac dye up to a purity level of 50 to 98 % Montra Chairat *et al.* (2008) had given an insight into the

adsorption and kinetic properties of lac dyeing on silk. Lac dye in general is applied on mulberry silk, but an altogether new attempt on tasar silk was made by Sreenivasa *et al.* (2001). Rao and Singh (1990) concluded in a survey on "Lac cultivation and marketing" that These insects are commonly cultivated on host plants viz., kusum, ber and palas. The average yield of stick lac per tree of kusum, ber and palas is 10, 6 and 4 kg, respectively.

But in screen-printing units, natural dyes are less practiced even today. Present work is an attempt to screen print mulberry and tasar silk fabric with lac dye. Appropriate recipe was formulated using a few mordants along with lac dye for printing on tasar and mulberry silk. Performance of the mulberry and tasar silk fabrics before and after printing with lac dye for colour change to wash, light, rubbing and perspiration were evaluated as per the standard test methods. Effect of the lac dye prints on physical properties of the fabric, i.e., tensile strength, bending, drape and air permeability were also evaluated in this study.

MATERIALS AND METHODS

Loom finished plain woven fabric of mulberry soft silk (50 GSM) and tasar silk plain woven fabric (48 GSM) were used for this study. Constructional parameters of the experimental fabrics are furnished in Table 1. The samples were treated with soap (1gpl) and soda (0.5 gpl) in order to remove the traces of the finishes and pre-treatment given at yarn/fabric stage.

Table 1: Constructional parameters of the silk fabrics

Fabric particulars	Mulberry	Tasar
Ends/cm	49	33
Picks/cm	49	24
Thickness (mm)	0.11	0.23
GSM 50		48

Lac dye sample was tested for purity and original

representation. UV spectra characteristic peak at 489 nm represents the presence of lac dye (Figure 1, Table 2).

Table 2: UV Visible spectral peak of lac dye

Type of the sample	Characteristic peak of dye solution extraction	Characteristic peak of dye fabric extraction
Standard lac dye	488.8	488.8
Lac dye extracted from dyed silk	487	489

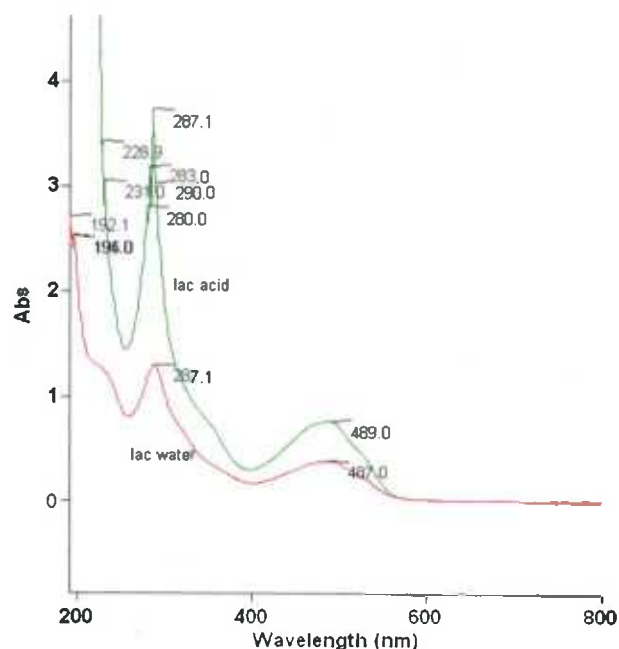


Figure 1: UV spectra analysis graph

The following methodology was adopted for the printing purpose:

Printing paste preparation

Printing gum was prepared using 80 g of gum powder (AGBV) dissolved in 1000 ml of water and a homogeneous paste made using mechanical stirrer. The paste was kept overnight for proper swelling. The swollen paste was added with appropriate ingredients as given in the following recipe to prepare the printing paste. Viscosity of printing paste was adjusted to suit screen-printing method.

Printing recipe

Content	Parts
Dye	2 or 5
Urea	5
Diethylene Glycol	5
Thickener (Gum)	60
Formic acid	6
Water	Remaining parts to make 100

Mordanting

Effect of mordanting during printing the silk fabrics with lac dye was also observed in the present study. Two types of mordant *i.e.*, Alum and Hardha were used for pre, post and simultaneous mordanting. A flow chart depicting the different steps of mordanting procedure is presented below. Sample codes and the treatment details are indicated in Table 3.

Printing and fixing: Fabric was spread properly over a printing table and the impression formed using suitable screen. Subsequently, the printed fabric was subjected to drying and curing in steamager followed by thorough washing and drying under shade.

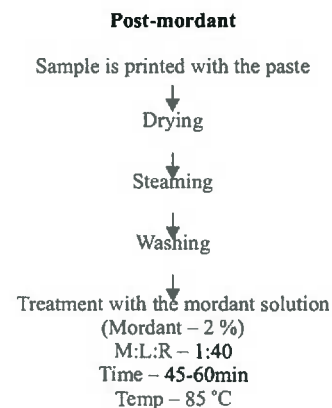
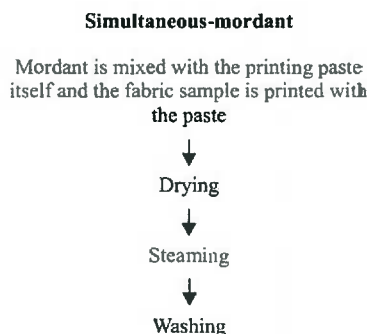
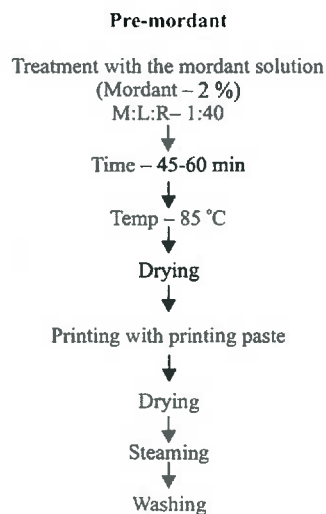
TESTING METHODS

Measurement of colour fastness: Colour fastness to washing, rubbing, perspiration and light were determined according to standard test methods: (IS 687:1979), (IS 766:1988), (IS 971:1983) and (IS 2454:1985), respectively.

Light fastness: The light fastness of the dyed sample was tested on "digital light fastness tester, Model PSC-707A" and the fastness was graded for the colour change when the samples were partially exposed to the arc lamp for 8 hours. The standard gray scale for colour change was referred from AATCC manual.

Washing fastness: Washing fastness test was conducted at 50 ± 2 °C for 45 mins in 5 gpl nonionic detergent as per ISO 9001:2000 group specifications in Launderometer. Grey scale rating was assigned to the washed samples.

Rubbing fastness: Dry and wet rubbing fastness properties of dyed samples were determined by using automatic crockmeter, 50 strokes were given under the load of 1 kg and the undyed stained fabric rubbed against the sample was assessed on the grey scale.

PRINTING METHOD

M - Material; L - Liquor; R - Ratio

Table 3: Sample code vs. treatment details

Sample code	Treatment details
Mul-1 / Tas- 1	1% lac (control sample)
Mul-5 / Tas- 5	5% lac (control sample)
Mul-Pre-Al-1 / Tas- Pre-Al-1	Pre-treated with 2% Alum and printed with 1% lac
Mul-Pre-Al-5 / Tas- Pre-Al-5	Pre-treated with 2% Alum and printed with 5% lac
Mul-Pre-Hr-1 / Tas- Pre-Hr-1	Pre-treated with 2% Hardha and printed with 1% lac
Mul-Pre-Hr-5 / Tas- Pre-Hr-5	Pre-treated with 2% Hardha and printed with 5% lac
Post treated samples	
Mul-Sim-Al-1 / Tas- Sim -Al-1	Printed with 1% lac with 2% Alum in the print paste
Mul-Sim-Al-5 / Tas- Sim -Al-5	Printed with 5% lac with 2% Alum in the print paste
Mul-Sim-Hr-1 / Tas- Sim -Hr-1	Printed with 1% lac with 2% Hardha in the print paste
Mul-Sim-Hr-5 / Tas- Sim -Hr-5	Printed with 5% lac with 5% Hardha in the print paste
Mul-Post-Al-1 / Tas- Post-Al-1	Printed with 1% lac and post treated with 2% Alum
Mul-Post-Hr-5 / Tas- Post-Hr-5	Printed with 5% lac and post-treated with 2% Hardha

Mul- and Tas- represent mulberry and tasar silk fabric, respectively

Perspiration fastness: Perspiration fastness was determined both in alkaline and acidic condition in perspirometer.

Alkaline test: The reagent was prepared by dissolving 0.5 g of L-histidine mono hydrochloride mono hydrate, 5 g of sodium chloride and 5 g of sodium hydrogen orthophosphate dodecahydrate in 1000 ml of water and adjusted the pH of the solution to 8.0 by adding 0.1 N sodium hydroxide solution.

Acidic test: For acidic test, 0.5 g of L-histidine mono hydrochloride mono hydrate, 5 g of sodium chloride and 2.20 g of sodium hydrogen orthophosphate dodecahydrate were dissolved in 1000 ml of water and adjusted the pH of the solution to 5.50 by adding 0.1 N of acetic acid solution.

Physical properties

Tearing strength: Fabric tearing strength was tested using Elmendorf Tearing strength tester as per IS 6489:1993 test method.

Drape coefficient: Drape coefficient determination of the fabric samples was carried out in Prolific Drape meter as per IS 8357:1977 test methods.

Fabric stiffness: Fabric stiffness was tested using prolific bending tester as per IS 6490:1971 test method. By using values of bending length, flexural rigidity of the fabric was calculated.

RESULTS AND DISCUSSION

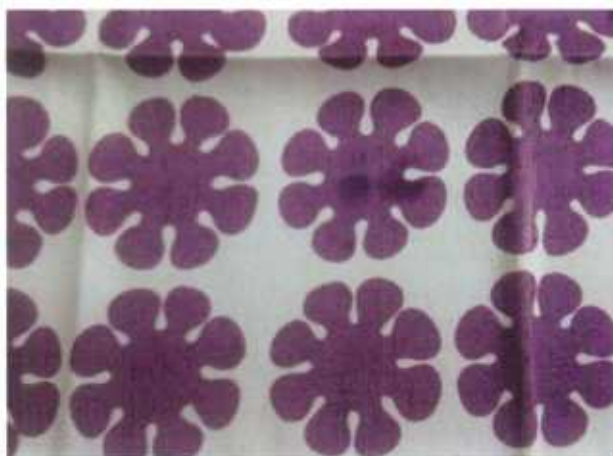
Performance of printed fabrics as evident through test results of standard testing methods has registered acceptable results in pre, post and simultaneous mordanting conditions. Tables 4 and 5, respectively presents the data on the colour fastness properties of mulberry silk and tasar silk fabric samples printed with lac dye. All fastness properties were within acceptable range, whereas, deviation was observed with wash and perspiration fastness properties of control sample.

Light fastness was noticed to be poor for the lac printed samples.

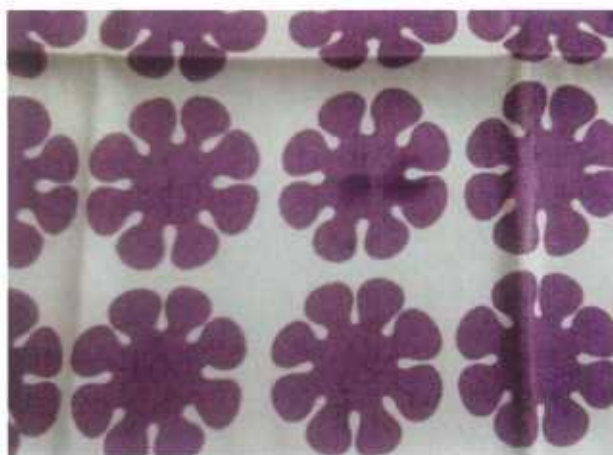
Mulberry silk printed with lac dye has shown better luster than the tasar fabric. This class of dye can also be adopted for different printing methods to bring in versatility in designs. In the case of pre-mordanting, depth of shade (k/s value) was found significantly higher. Generally, poor light fastness is observed in the samples having lower percentage (below 1 %) of colour. This is true in the case of samples that have undergone pre and simultaneous mordanting whereas, all post mordanting samples have shown better light fastness. Mulberry silk sample pre mordanted with alum has shown poor rubbing (wet) and light fastness properties whereas, in the case of post mordanting with both shade % (1 and 5), all fastness properties have fallen in a good range. In general, lac dye

sample printed on mulberry has shown better luster than that on tasar fabric. Wash fastness of printed fabrics was found unaltered till 6th wash under normal home laundry process. Figure 2 depicts photographs of mulberry and tasar silk fabric samples, printed with lac dye.

Physical properties of mulberry and tasar silk fabric samples printed with lac dye are presented in Table 5, Figures 3, 4, 5 and 6. Tearing strength of mulberry fabrics printed under different conditions along with that of the unprinted sample are shown in Figure 4. It can be observed that no significant changes occurred in the tearing strength of the mulberry fabric after printing under different conditions. On the other hand, certain changes were noticed in bursting strength of the mulberry silk fabric



Mulberry



Tasar

Figure 2: Silk fabric printed using lac dye

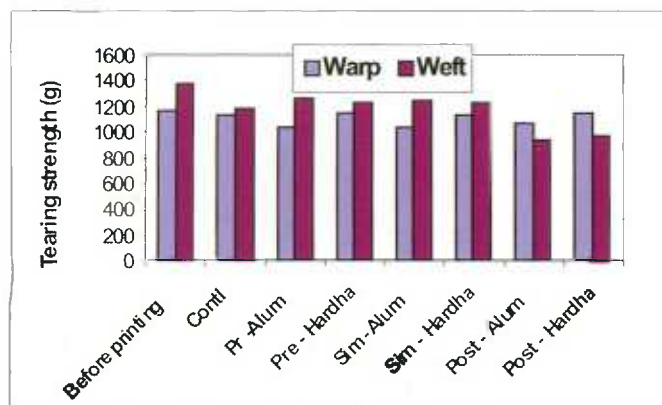


Figure 3: Tearing strength of mulberry silk fabrics printed with lac dye

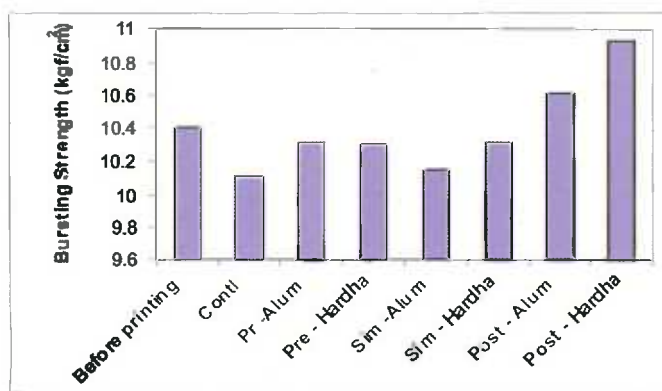


Figure 4: Bursting strength of mulberry silk fabric printed with lac dye

after printing as shown in Figure 5, which indicates the least variations (about 5 %) among the printed samples compared to that of unprinted sample. The results also indicate no significant changes in the physical properties of mulberry silk fabrics after the printing process even with the mordant treatments.

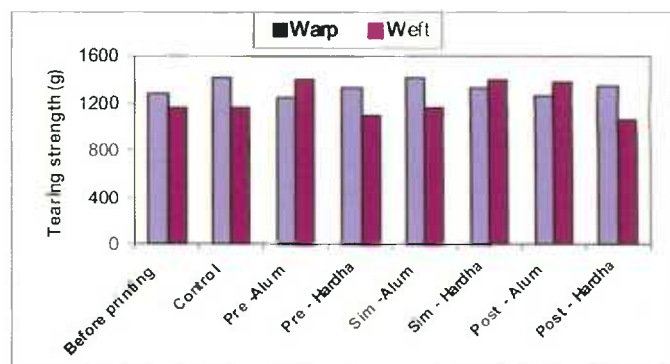


Figure 5: Tearing strength of tasar silk fabric printed with lac dye

Figures 5 and 6 display the changes in tearing strength and bursting strength of tasar silk fabric after printing with lac dye. The bar graphs show that changes observed in the samples are the least significant for both tearing and bursting strength properties after printing the tasar silk fabrics with lac dye.

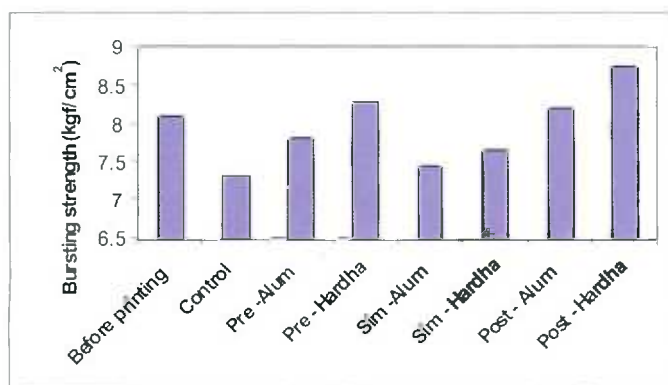
Table 4: Colour fastness properties of mulberry silk fabric samples printed with lac dye

Sample code	Washing			Perspiration - Acid			Perspiration - Alkali			Rubbing		Light (CC)
	CC	SS	SC	CC	SS	SC	CC	SS	SC	Dry	Wet	
Mul-1	3/4	4/5	4/5	4	4	4/5	4/5	4/5	4/5	4/5	4/5	3
Mul-5	4	4/5	4/5	4	4/5	4/5	4	4/5	4/5	4/5	4	3
Mul-Pre-Al-1	4	4/5	4/5	4/5	4	4/5	4	4	3/4	4		2/3
Mul-Pre-Al-5	4	4/5	4/5	4	3	3/4	4	3	3/4	3	1/2	3
Mul-Pre-Hr-1	4	4/5	4/5	4/5	4/5	4/5	4	4/5	4/5	4/5	4/5	3/4
Mul-Pre-Hr-5	3/4	4/5	4/5	4/5	4	4/5	4/5	4/5	4/5	4/5	3/4	4
Mul-Sim-Al-1	4/5	4/5	4/5	4	4/5	4/5	4	4/5	4/5	4/5	4/5	3/4
Mul-Sim-Al-5	3/4	4/5	4/5	4/5	4/5	4/5	4	4/5	4/5	4	4	4
Mul-Sim-Hr-1	4	4/5	4/5	4	4/5	4/5	4	4/5	4/5	4/5	4	3
Mul-Sim-Hr-5	4	4/5	4/5	3/4	4/5	4/5	3/4	4/5	4/5	4	3/4	4
Mul-Post-Al-1	4/5	4/5	4/5	4	4	4/5	4	4/5	4/5	5	4/5	4
Mul-Post-Hr-5	4	4/5	4/5	4	4/5	4/5	4	4/5	4/5	4	3/4	4/5

CC - Change in colour; SS - Stain on Silk; SE - Stain on cotton.

Table 5: Colour fastness properties of tasar silk fabric printed with lac dye

Sample code	Washing			Perspiration Acid			Perspiration - Alkali			Rubbing		Light (CC)
	CC	SC	SS	CC	SS	SC	CC	SS	SC	Dry	Wet	
Tas- 1	3	4/5	4/5	3	4/5	4/5	3/4	4/5	4/5	4/5	4	3
Tas- 5	3/4	4/5	4/5	4	4/5	4/5	4	4/5	4/5	4/5	3/4	3
Tas- Pre-Al-1	3	4/5	4/5	3/4	4/5	4/5	3/4	4/5	4/5	4/5	3	3
Tas- Pre-Al-5	3/4	4/5	4/5	3/4	3/4	4	3/4	3/4	3/4	4	3	4
Tas- Pre-Hr-1	3/4	4/5	4/5	3	4/5	4/5	3	4/5	4/5	4/5	4	2/3
Tas- Pre-Hr-5	3/4	4/5	4/5	3/4	4/5	4/5	3/4	4/5	4/5	4	3	3
Tas- Sim -Al-1	3/4	4/5	4/5	3/4	4/5	4/5	3/4	4/5	4/5	4/5	3/4	3
Tas- Sim -Al-5	3/4	4/5	4/5	3/4	4/5	4/5	3/4	4/5	4/5	4	3	3
Tas- Sim - Hr-1	3/4	4/5	4/5	3/4	4/5	4/5	3	4/5	4/5	4/5	3/4	2/3
Tas- Sim - Hr-5	3/4	4/5	4/5	3/4	4/5	4/5	3	4/5	4/5	4	3	4
Tas- Post-Al-1	3	4/5	4/5	3/4	4/5	4/5	3/4	4/5	4/5	4	3/4	3
Tas- Post-Hr-5	3	4/5	4/5	3/4	4/5	4/5	3/4	4/5	4/5	4	3	3/4

**Figure 6: Bursting strength of tasar silk fabric printed with lac dye**

Conclusion

Lac dye has been successfully used for printing mulberry and tasar silk fabrics by screen printing and the performance of lac dye printed silk fabrics has been observed to be well accepted as well. Lac dye can be adopted very well for different printing methods to bring in versatility in design. Lac dyed and printed fabrics are found suitable for children garments, casual wear dress and party wear (crepe chiffon) fabrics.

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Article scientifique

APPLICATION DE LAQUE PAR IMPRESSION AU CADRE SUR LES SOIES MURIER ET TASAR

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R É S U M É

La sensibilisation à l'environnement à travers le monde semble réduire la chute des colorants naturels. Les risques des industries et des colorants chimiques en particulier ont obligé des environnementalistes à penser en termes de produits naturels. Ainsi, les tendances à une utilisation plus grande de substituts synthétiques que de produits naturels ont été réduites. Ceci a réellement commencé lorsque les gens à travers le monde en général et à l'ouest en particulier ont préféré les vêtements en pur coton au lieu de vêtements réalisés avec des fibres synthétiques. Après la restauration du coton, les colorants naturels incluant la laque attendent leur tour. Des études importantes sur l'application de laque sur les soies mûrier et non-mûrier ont été réalisées. Alors que les colorants naturels sont peu utilisés dans les unités d'impression au cadre, une tentative a été réalisée ici pour imprimer des tissus de soies mûrier et non-mûrier avec de la laque. Utilisant peu de mordants, une recette adéquate d'impression a été formulée. Les propriétés de résistance au lavage, à la lumière, à la perspiration et au frottement des tissus imprimés ont été testées selon les méthodes standard. Des propriétés physiques telles que la résistance, le pliage et le draper ont été également testées avant et après le processus. Les données technico-économiques des tissus imprimés ont été optimisées et le paquet du procédé pour l'impression au cadre des tissus de soie non-mûrier avec la laque a été défini. De plus, nous avons étudié l'effet du mordantage sur la profondeur de la teinte et la solidité de la couleur. Nous avons observé que la plupart des tissus après mordantage avaient une meilleure résistance au lavage et à la lumière. Les tissus de soie imprimés présentent des performances acceptables en conditions pré-, post- et de mordantage. La solidité de la couleur des tissus de soie mûrier et de soie tassar est dans une fourchette acceptable.

Mots-clés: Laque, mûrier, impression au cadre, tissu de soie tassar.



EFFECT OF DYEING METHODS ON MECHANICAL PROPERTIES OF SILK FABRICS

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ABSTRACT

The effect of dye-fibre interaction in respect of acid, metal complex and reactive dyes on the mechanical properties of the degummed silk material was studied in detail. For this, the mulberry bivoltine raw silk fabric was woven and subjected to optimum degumming process. The degummed silk fabric was then dyed using acid, metal complex and reactive dyes in three different concentrations viz., 0.3, 1 and 3 %. Simultaneously, control samples were treated under conditions identical to those of dyeing except that the dye was omitted (blank) for comparison to study the dye-fibre interaction in respect of all three different processes of dyeing. The effect of reaction of different types of dye molecules with silk fibre in the dye bath, salt concentration, fixing agent and combination of all these factors on their mechanical properties was studied. Finally, the dyed and control samples were conditioned and analysed for mechanical properties. The test results were compared and analysed statistically. It was found that reactive colour dyed silk fabrics exhibited a substantial difference between warp and weft in tensile strength and also the lowest flexural rigidity and higher drape values implying that the drape is poor compared to either acid or metal complex dyed samples.

Key words: Bivoltine silk fabric, dye-fibre interaction, flexural rigidity, mechanical properties, tensile properties.

INTRODUCTION

Natural silk has good affinity for a large number of dyes by virtue of its chemical and physical composition. The selection of suitable dye depends on various factors such as fastness properties, intensity of shades, input cost and end use. The dye fibre interaction has been found to influence fastness of dye with respect to light, rubbing and washing (Archana, 1997). The reaction of different types of dye molecules with silk fibre in the dye bath, salt concentration, fixing agent and combination of all these factors may also affect the mechanical properties of silk fabric (Gulrajani, 1975). Though several studies have focused on degumming, dyeing, printing and finishing

separately to optimize the conditions, the effect of these processes on all the mechanical properties were not studied and a very little information was available on the loss of mechanical properties due to various dyeing treatments of silk fabrics (Sivasankaran, 1998). As each process leads to addition of new characteristics to silk and loss of some properties, the understanding of the influence of each process to optimize each method to get maximum comfort properties and minimum strength loss is essential (Gulrajani, 2004). Therefore, an effort was made to study the changes in the mechanical properties of the silk fabrics that occur during different dyeing processes and in specific, the effect of dye fibre interaction in respect of acid, metal complex and reactive dyes on the mechanical properties of silk fabric.

MATERIALS AND METHODS

In this study, the bivoltine raw silk fabric of mass: 49 g/m², thickness: 0.19 mm, EPI: 122 and PPI: 80 was woven. The raw silk fabric was degummed by soap and soda method. The material was treated in the liquor ratio of 1: 30 using Marcellis soap of 5 gpl and 0.5 gpl of sodium carbonate for 60 minutes at 85–90 °C. The pH of the bath was maintained at a range of 9.5 to 10. The degummed fabric samples were dyed using acid, metal complex and reactive dyes. The following dyes with corresponding C.I. number were selected for the purpose: C.I. Acid blue: 113-26360, C.I. Acid blue: 158-14880 & Reactive black: 5 - 20505. Initially, the degummed fabric samples were subjected to blank dyeing process for considering them as control samples to compare with the dyed samples to study the dye - fiber interaction in respect of acid, metal complex and reactive dyes on the degummed silk fabric. The treatment samples of degummed silk fabrics were dyed using acid dyes, reactive dyes and metal complex dyes (Gulrajani, 1993) in three shades viz., 0.3, 1 and 3 %. The dyeing recipe is as follows:

bursting strength as per IS 1966 – 1975, tearing strength as per IS 6489 – 1993, tensile strength as per ASTM D 5034 – 95, drape as per IS 8357 – 1977, abrasion resistance as per IS 12673 – 1989, crease recovery as per IS 4681 – 1981, bending length and flexural rigidity as per IS 6490 – 1971 and the test results were compared with those of control samples (blank). The data on mechanical properties were analyzed statistically using Analysis of variance and the significant variation between the control and the dyed samples were studied.

RESULTS AND DISCUSSION

Dye-fiber interaction in respect of acid, metal complex, and reactive dyes on the degummed silk material: The reactive dyes differ fundamentally from the acid and metal complex dyes in fact that the former group combines chemically with silk while those of the latter are adsorbed only physically. The fabrics dyed with reactive dyes showed a distinct difference from that dyed with metal complex or acid dyes. Thus, there is more loss in bursting and tearing strength in reactive dyeing. The per cent elongation at break has decreased in the two principal

Acid dye	Metal complex dye	Reactive dye
Material to liquor ratio: 1 : 30	Material to liquor ratio: 1 : 30	Material to liquor ratio: 1 : 30
Glauber's salt: 10 %	Glauber's salt : 10%	1st stage-Glauber's salt: 20 %
		Soda ash: 5 % Duration: 45 min.
		Temperature: 50-55°C
Acetic Acid: 5 % (40 % strength)	Duration : 30 to 45 minutes	2nd stage-Glauber's salt: 20 %
		Soda ash: 5 % Duration: 45 min.
		Temperature: 65-70°C
Duration: 30 to 45 minutes	Temperature : 85 to 90°C	
Temperature: 85 to 90 °C		
pH: 4 to 6		

All the dyed samples were conditioned and analysed for the mechanical properties viz., fabric weight per square metre as per IS 1964 – 2001, thickness as per IS 7702– 1975, air permeability as per IS 11056 – 1984,

directions in the case of reactive dyed silk fabrics as distinct in Figures 1 and 2. The crease recoveries of the dyed silk fabrics are not different from those of the undyed fabric. These changes point to the introduction of cross-

links on silk. The loss in bursting strength ranged between 15.67 and 23.24 %. Per cent loss in tear strength in respect of reactive dyed silk fabrics ranged between 13 and 23 % in warp and from 43 to 48 % in weft. The loss in tensile strength ranged between 5.76 and 9.61 % in warp while in weft, the values ranged between 34 and 45 %.

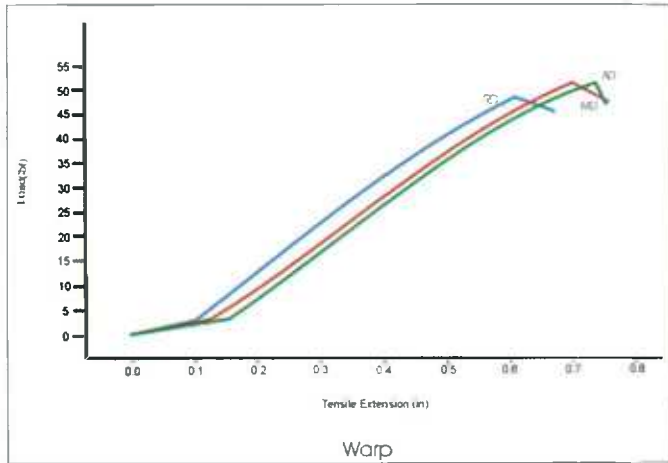


Figure 1: The load extension curves of dyed samples (warp way)

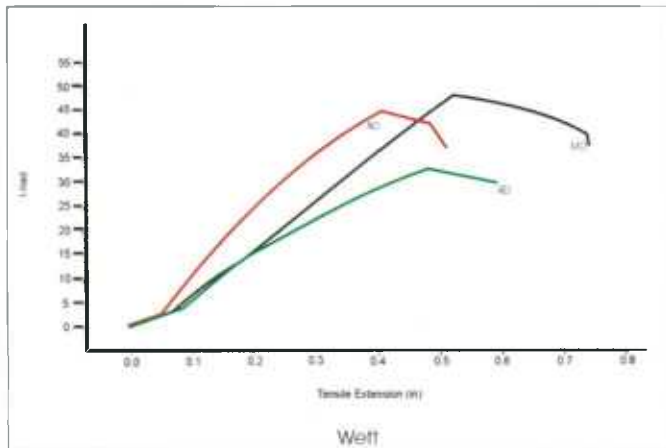


Figure 2: The load extension curves of dyed samples (weft way)

The acid dyed silk fabrics showed higher losses in tensile strength in warp way whilst in weft way, the values were lower as shown in Figures 3 and 4. Values of bursting strength of metal complex dyed silk fabrics showed no consistent trend while these in respect of reactive dyed silk fabrics have shown the lowest values (Figure 6). The per cent elongation at break has increased for acid and metal complex dyed silk fabrics (Figures 7 and 8) which is likely to be due to some shrinkage during dyeing. The

crease recoveries of acid and metal complex dyed fabrics have shown higher values compared to their blank counterparts while in this regard, reactive dyed samples were not very different from those of control samples. The fabrics dyed with reactive dyes showed lower tensile

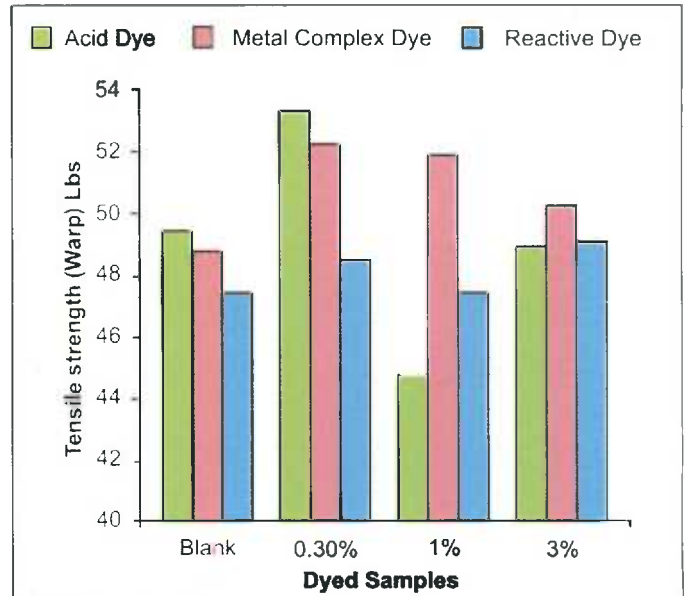


Figure 3: Effect of different dyes on tensile strength (warp)

strength in weft way (Figure 4) and lower bursting strength (Figure 6). Tear strength of reactive dyed silk fabric showed a lower value compared to acid or metal complex

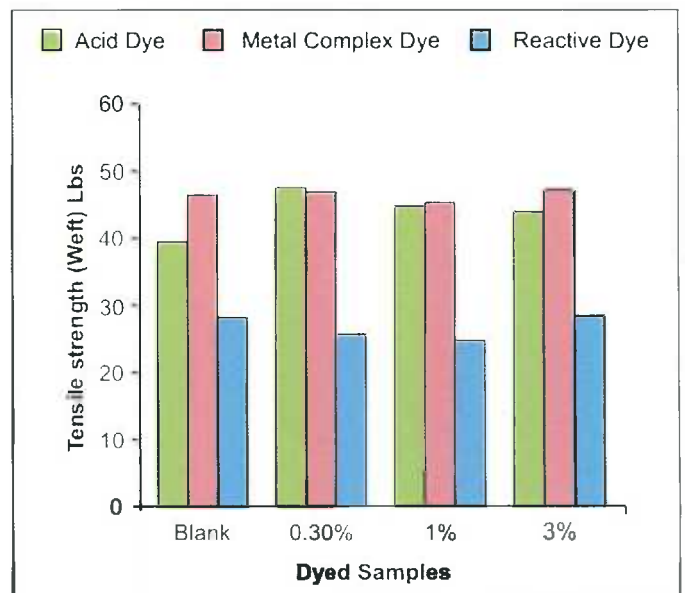


Figure 4: Effect of different dyes on tensile strength (weft)

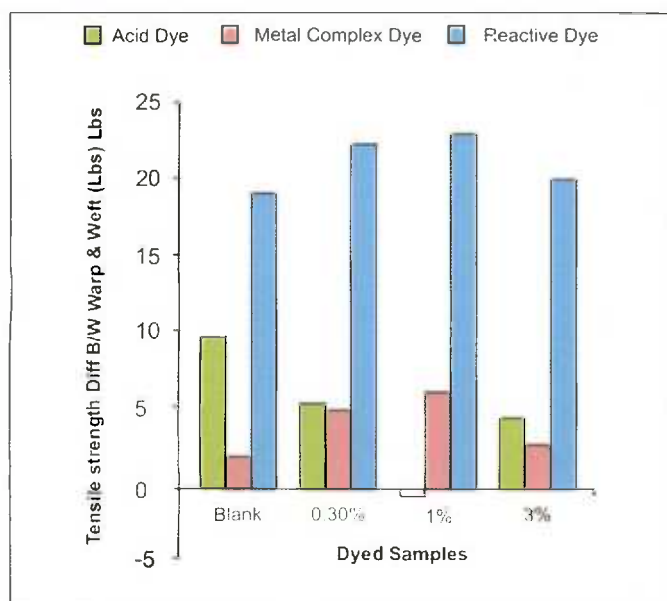


Figure 5: The difference between the tensile strength of warp and weft way due to different dyes

dyed one. By far, the lowest elongation in warp way is noticed in this class of dyes. Tear strength did not show any consistent trend with the dye concentration. The differences between warp and weft way tensile strength were much more for reactive dyed silk fabrics compared to those dyed with acid or metal complex dyes. The loss in tear strength was more marked in reactive dyeing (Gulrajani, 1993)

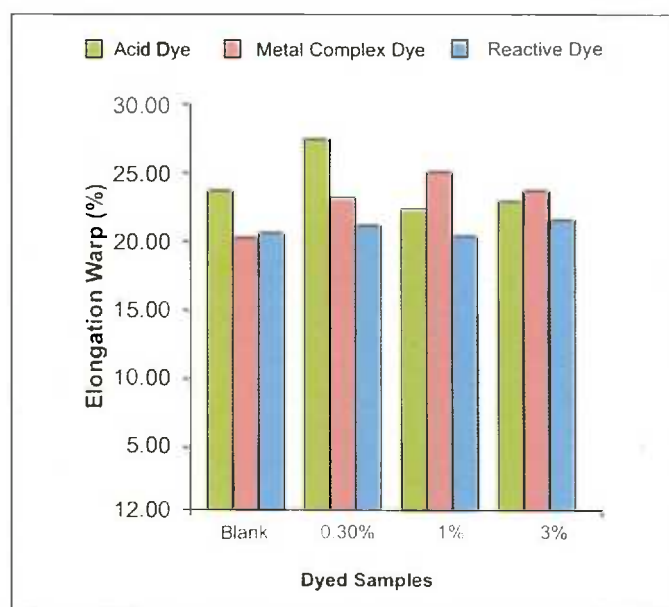


Figure 7: Effect of different dyes on elongation (warp)

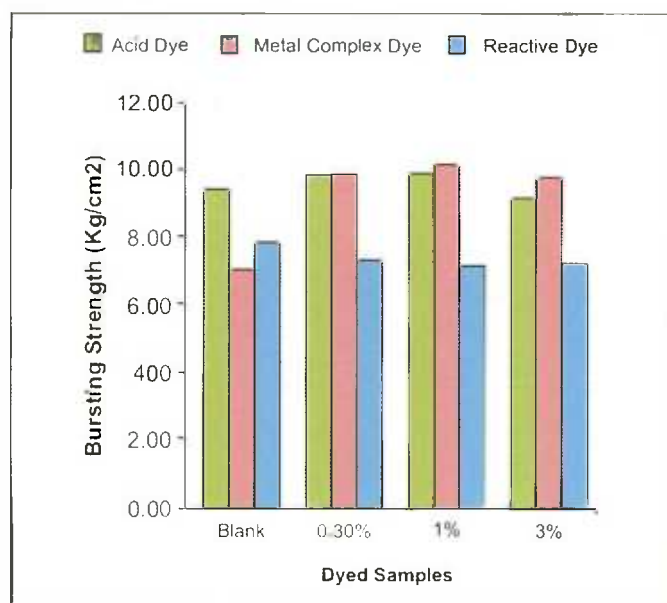


Figure 6: Effect of different dyes on bursting strength

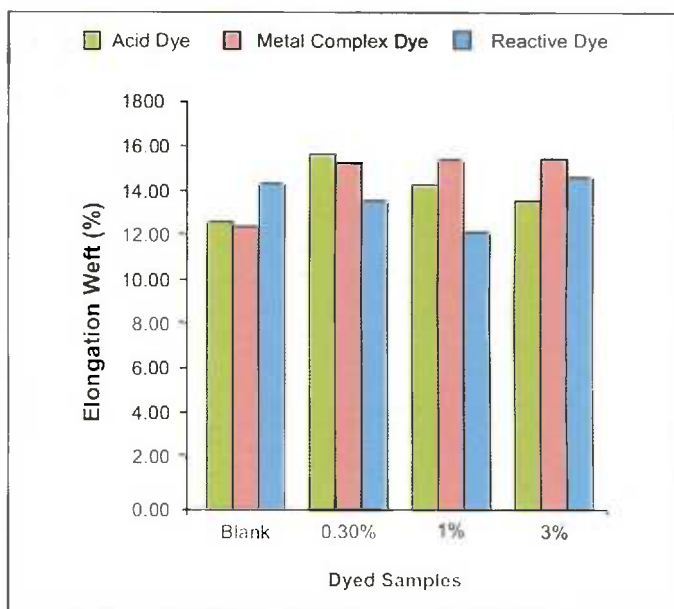


Figure 8: Effect of different dyes on elongation (weft)

Reactive dyed samples showed the lowest flexural rigidity values compared with either acid or metal complex dyed samples (Figure 9). Drapé values reflected the same trend that the values of reactive dyed samples are higher implying that the drapé is poor compared to metal complex and acid dyed samples (Figure 10).

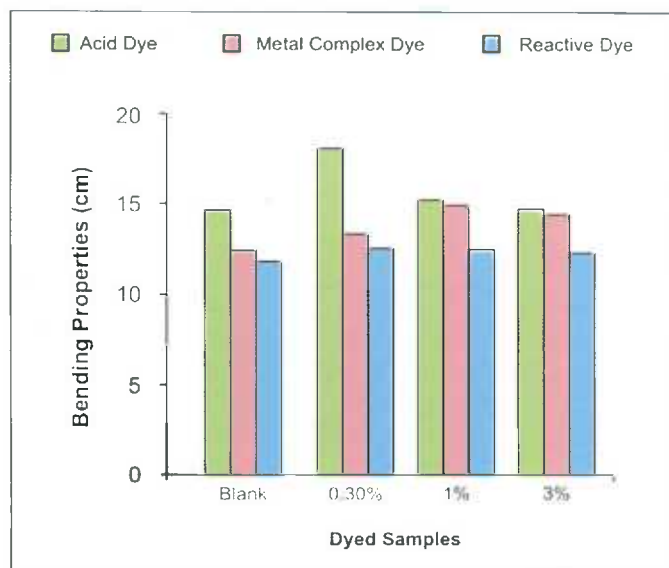


Figure 9: Effect of different dyes on flexural rigidity

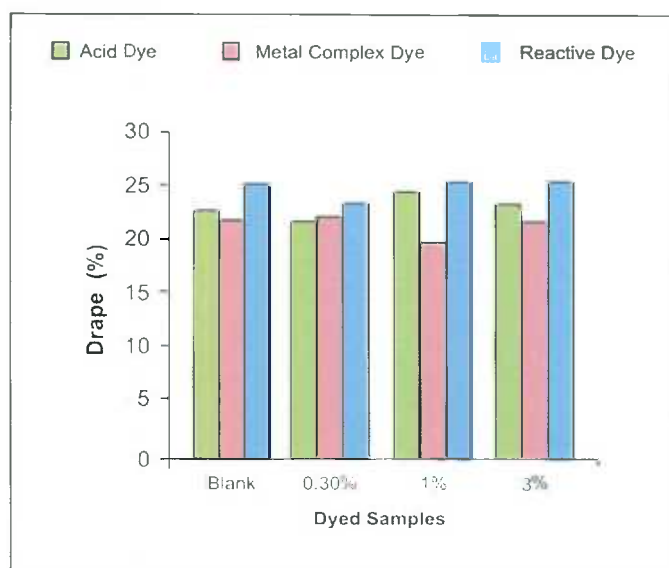


Figure 10: Effect of different dyes on drape

Table 1: Acid dye treatment in different concentrations

Property	Acid dye (Blank)		Acid dye (%)		
			0.1	1	3
	Mean	CD at 5 %	Mean	Mean	Mean
Fabric mass	38.33	0.81	40.73*	40.85*	40.88*
Thickness	0.13	0.01	0.15*	0.15*	0.15*
Air permeability	141.94	13.13	131.12	134.88	142.99
Bursting strength	9.40	0.83	9.90	9.85	9.10
Tearing strength (Warp)	1993.50	152.75	1568.00*	1523.50*	1817.50*
Tearing strength (Weft)	1884.75	91.68	2120.00*	2011.00*	2302.50*
Tensile strength (Warp)	49.45	3.75	53.33*	44.75*	48.90*
Tensile strength (Weft)	39.80	3.80	47.93*	45.30*	44.45*
Elongation (Warp)	23.58	3.08	27.53*	22.28	22.85
Elongation (Weft)	12.55	1.05	15.60*	14.35*	13.65*
Drape co-efficient	22.55	1.44	21.73	24.35*	23.20
Abrasion resistance	222.50	33.84	107.50*	205.00	200.00
Crease recovery Angle (Warp)	98.50	10.42	122.50*	107.00	116.50*
Crease recovery Angle (Weft)	99.50	5.95	131.00*	117.50*	115.50*
Bending length (Warp)	1.51	0.13	1.44	1.50	1.47
Bending length (Weft)	1.63	0.16	1.88*	1.60	1.61
Flexural rigidity (Warp)	13.18	3.44	1.20	13.93	13.00
Flexural rigidity (Weft)	16.78	5.84	27.45*	17.05	17.18
Flexural rigidity (Overall)	14.83	3.73	18.23*	15.33	14.90

* Significant at 5 %.

Table 2: Metal complex dye treatment in different concentrations

Property	Metal complex dye (Blank)		Metal complex dye (%)		
			0.1	1	3
	Mean	CD at 5 %	Mean	Mean	Mean
Fabric mass	32.40	0.81	37.05*	40.88*	40.53*
Thickness	0.13	0.00	0.15*	0.15*	0.15*
Air permeability	149.43	16.12	174.83*	151.72	152.35*
Bursting strength	7.05	0.52	9.90*	10.10*	9.75*
Tearing strength (Warp)	1464.00	151.94	1624.00*	1681.50*	1560.00
Tearing strength (Weft)	1206.50	53.81	1926.50*	1968.00*	2052.75*
Tensile strength (Warp)	48.78	4.92	52.23	51.93	50.30
Tensile strength (Weft)	27.08	4.22	47.30*	46.05*	47.63*
Elongation (Warp)	20.40	2.71	23.43*	25.13*	23.68*
Elongation (Weft)	42.43	41.10	15.23	15.38	15.53
Drape co-efficient	21.70	2.77	22.10	19.58	21.53
Abrasion resistance	145.00	35.83	177.50	167.50	175.00
Crease recovery angle (Warp)	97.50	5.50	122.50*	118.00*	120.00*
Crease recovery angle (Weft)	98.50	9.40	118.50*	124.00*	117.00*
Bending length (Warp)	1.47	0.13	1.50	1.45	1.45
Bending length (Weft)	1.69	0.11	1.62	1.64	1.61
Flexural rigidity (Warp)	10.20	3.35	12.64	12.43	12.35
Flexural rigidity (Weft)	15.53	3.60	16.01	18.08	16.88
Flexural rigidity (Overall)	12.53	3.18	13.46	14.98	14.53

* Significant at 5 %.

Metal complex dyes led to lower values of abrasion resistance, while crease recovery seemed to be good in reactive dyed samples.

Statistical analysis

The data of mechanical properties of all dyed and control samples were analysed statistically using analysis of variance and the significant differences found out. The summary of ANOVA results are provided in Tables 1, 2 and 3.

The significant differences among the data of respective mechanical properties confirm that the dyeing process improves some of the properties and deteriorate the other properties.

Conclusion

The changes in tensile properties of the dyed silk fabrics were found to be more marked in respect of reactive dyed material and the tensile strength of warp and weft and fabric extensibility were quite sensitive to the

reactive dyes. The acid and metal complex dyes resulted only in minor differences in the tensile properties. Reactive dyed samples showed the lowest flexural rigidity and higher drape values implying that the drape is poor compared to either acid or metal complex dyed samples. It is concluded that the dyeing process is vital since each method of dyeing improves some of the

important characteristics. Hence, further optimization of each method to get minimum strength loss and maximum comfort properties, techniques to minimise usage & wastage of chemicals, use of economic processing methods and satisfaction in terms of eco-friendliness should be the essential targeted areas.

Table 3: Reactive dye treatment in different concentrations

Property	Reactive dye (Blank)		Reactive dye (%)		
			0.1	1	3
	Mean	CD at 5 %	Mean	Mean	Mean
Fabric mass	32.55	1.02	33.13*	33.13*	33.28*
Thickness	0.13	0.01	0.13	0.13	0.14*
Air permeability	132.38	13.43	138.61	154.85*	134.85
Bursting strength	7.80	0.65	7.25	7.10*	7.20*
Tearing strength (Warp)	1422.50	133.82	1312.00	1422.50	1494.50
Tearing strength (Weft)	1094.50	3812.63	1155.25	1068.75	3999.50
Tensile strength (Warp)	47.38	2.13	48.43	47.43	49.13
Tensile strength (Weft)	28.38	2.94	26.20*	24.70*	29.13
Elongation (Warp)	20.65	1.03	21.18	20.18	21.43
Elongation (Weft)	14.30	1.62	13.15	12.20	14.53
Drape co-efficient	24.98	1.88	23.20	25.30	25.23
Abrasion resistance	202.50	48.45	197.50	205.00	197.50
Crease recovery angle (Warp)	124.50	10.68	119.00	114.50	116.00
Crease recovery angle (Weft)	119.00	8.51	122.50	118.50	118.50
Bending length (Warp)	1.50	0.16	1.51	1.55	1.46
Bending length (Weft)	1.58	0.14	1.59	1.57	1.63
Flexural rigidity (Warp)	1.50	3.84	1.51	1.55	1.46
Flexural rigidity (Weft)	1.58	40.91	1.59	1.57	1.63
Flexural rigidity (Overall)	12.08	3.77	12.55	12.65	12.38

* Significant at 5 %.

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Article scientifique

EFFET DES METHODES DE TEINTURE SUR LES PROPRIETES MECANQUES DES TISSUS DE SOIE

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RÉSUMÉ

L'effet de l'interaction colorant-fibre selon les colorants acides, métalliques, ou réactifs sur les propriétés mécaniques des matériels en soie décreusée a été étudié en détail. Pour cela, les tissus en soie grège bivoltine ont été soumis à un décreusage optimum. Le tissu de soie décreusée est ensuite teint en utilisant des colorants acides, métalliques ou réactifs à trois concentrations différentes, 0,3 ; 1 ; et 3 %. Des échantillons témoin sont traités dans des conditions identiques mais sans teinture afin d'étudier l'interaction fibre-colorant dans les trois procédés de teinture différents. L'effet de la réaction des molécules des différents types de colorant avec la fibre de soie dans les bains de teinture, la concentration en sel, l'agent de fixation, et la combinaison de tous ces facteurs sur les propriétés mécaniques ont été étudiés ici. Finalement, les échantillons teints et témoins sont conditionnés et leurs propriétés mécaniques analysées. On observe que les tissus de soie teints avec un colorant réactif montrent une différence substantielle de résistance à la tension entre la chaîne et la trame, la plus faible rigidité à la flexion et une plus forte valeur de drapé ce qui signifie que le drapé est pauvre comparé à celui des autres échantillons teints.

Mots-clés: Tissu de soie bivoltine, interaction colorant-fibre, rigidité de flexion, propriétés mécaniques, propriétés de tension.



ANALYSIS OF WORKING CAPITAL OF MULTIEND REELING AND MULTIEND REELING CUM TWISTING UNITS

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ABSTRACT

A scheme to support multiend reeling units with twisting facility was implemented in the XI five-year plan of Govt. of India for value addition and consequently more than 50 multiend reeling cum twisting units were established. But most of the units have been facing problems of working capital availability, since the requirement is quite high due to low value addition in the activity and high material cost. Hence, it was proposed to study the working capital of multiend reeling and reeling cum twisting units. The study indicated that the units do not have adequate working capital at their disposal. The working capital requirement was found to be significantly higher in multiend reeling cum twisting units as compared to only multiend reeling units due to larger working capital cycle. The availability of working capital was found to be significantly lower than the requirement in both the cases. The net profit per kg silk of units with adequate working capital was found to be significantly higher than that of units with inadequate working capital. From the study, it is suggested that the reeling sector needs support on easier terms by financial institutions to raise working capital.

Key words: Components, cycle, holding period, net profit, working capital.

INTRODUCTION

The multiend reeling technology developed by Central Silk Technological Research Institute, Bengaluru, India keeping in view the field requirements to deal with the cocoons presently being produced has provided the right impetus for the quality improvement. Under the Catalytic Development Programme in the IX, X & XI Plans, more than 500 multiend reeling units were established in the country.

Most of the silk reeling units are micro enterprises having low capacity to invest. They operate on very thin margins (Nagaraj *et al.*, 2011) which get erased by occasional input / output price fluctuations. In view of

this, the Govt. has been supporting the reeling industry during the plan periods in terms of investment subsidy on the cost of the machinery for establishment of multiend reeling units. Further during XI Plan, it was proposed to support the existing multiend reeling units and new units to be established during the plan periods with 400 spindles twisting capacity for value addition. More than 50 multiend reeling cum twisting units were established and many multiend reelers have applied for the scheme. In spite of the Govt. support to the silk reeling sector for establishment of multiend reeling units by subsidizing the machinery cost, the reeling units do not have sufficient working capital at their disposal and the support from financial institutions are not forthcoming (Nagaraj *et al.*, 2012).

Silk reeling needs working capital to stock cocoons for processing, to pay for labour & utilities periodically, to create a stock of raw / twisted silk for supplying to the market demand regularly and to grant credit to the customers.

The various components of working capital in silk reeling are (i) stock of cocoons (ii) stock of work in process (iii) stock of raw / twisted silk (iv) stock of debtors / bills receivables and (v) stock of cash / working expenses.

Adequate working capital is crucial for any business in terms of optimum capacity utilization, opportunity raw material purchases, stock of finished goods to market the required quantity and quality, ability to provide credit to customers, *etc.*, and thereby improving the profitability. It is more so in silk reeling activity since the value addition is very low and the raw material cost forms the major portion of the total cost of production.

In view of the above, it was proposed to take up this work to study the working capital of multiend reeling and multiend reeling cum twisting units with the following specific objectives.

- To study the availability of working capital with the multiend reeling and multiend reeling cum twisting units.
- To study the adequacy of working capital by assessing requirements and gap of multiend reeling and multiend reeling cum twisting units.
- To study the profitability of units with inadequate and adequate working capital.

METHODOLOGY

Study area

The states of Karnataka and Andhra Pradesh were selected for this study since more than 90 % of the multiend reeling cum twisting units in the country have been established in these states. Important reeling clusters were selected as mentioned below:

- Karnataka: Siddlaghatta, Kolar and Ramnagaram
- Andhra Pradesh: Hindupur and Dharmavaram

Data collection

A sample survey was conducted during 2011-12 in the above-mentioned reeling clusters. A questionnaire was prepared to collect all relevant data to achieve the set objectives. Random sampling was adopted covering more than 50 % of the reeling cum twisting units (34 units) and simultaneously data were collected from 20 multiend reeling units at random for comparison. The collected data were compiled and subjected to verification and various analyses.

Analytical tools

Working capital availability was arrived at based on the information collected from the reelers during the survey. The requirement of working capital for smooth operation of a reeling unit was assessed based on the feed back from the reelers and experts in the field. The working capital was calculated as mentioned below.

Table 1: Basis of valuation for working capital

Components of working capital	Basis for valuation
Stock of raw materials	Purchase cost of raw materials
Stock of work in process	Prime (direct) cost
Stock of finished goods	Cost of production
Bills receivables	Cost of sales
Cash	Working expenses

One way ANOVA was used to compare the per basin working capital availability with requirement for multiend reeling and multiend reeling cum twisting units separately.

RESULTS AND DISCUSSION

The details of working capital for multiend reeling and multiend reeling cum twisting units were calculated based on the information provided by the reelers during the survey.

Availability of working capital

The availability of working capital was worked out based on the various components of working capital provided by the units and presented in Table 2.

Table 2: Availability of working capital per basin

Particulars	Multiend reeling unit		Multiend reeling cum twisting unit	
	Holding period (days)	Amount (₹)	Holding period (days)	Amount (₹)
Raw material	4	9065	5	11327
Work in process	2	5484	5	13623
Finished goods	4	11859	7	19808
Bills receivables	3	7749	13	36714
Working expenses	13	4318	13	5790
Working capital cycle	13		30	
Total working capital		38475		87262

From Table 2, it can be seen that the working capital cycle of multiend reeling is only 13 days and hence the availability of working capital per basin is quite low at ₹38475/-. While in the case of multiend reeling cum twisting units, the working capital cycle is 30 days and availability of working capital is ₹87262/- per basin. The larger working capital cycle in the case of reeling cum twisting units as compared to only reeling units is mainly due to longer holding period of bills receivables *i.e.*, 13 days as compared to only 3 days. It implies that reeling cum twisting units have higher credit sales as compared to only reeling units. Hence the working capital availability for a 10 basin multiend reeling and reeling cum twisting unit was to be around ₹3.80 lakhs and ₹8.70 lakhs, respectively.

Adequacy of working capital

The requirement of working capital for smooth operation of a reeling unit was assessed based on the feed back from the reelers and experts in the field. The gap in working capital was calculated from the requirement and availability which indicated the adequacy of working capital.

Table 3: Requirement of working capital per basin

Particulars	Multiend reeling unit		Multiend reeling cum twisting unit	
	Holding period (days)	Amount (₹)	Holding period (days)	Amount (₹)
Raw material	7	16772	7	15954
Work in process	2	5484	5	13623
Finished goods	10	27924	10	27922
Bills receivables	15	42094	21	58900
Working expenses	26	8636	26	11581
Working capital cycle	34		43	
Total working capital		100910		127980

Table 3 shows the requirement of working capital for smooth functioning of a reeling / reeling cum twisting unit calculated based on the information collected during the survey. It can be seen that the ideal working capital cycle was found to be 34 days in the case of reeling units which works out to ₹100910/- working capital per basin with the holding period of working expenses (cash in hand) being 26 days. While in the case of reeling cum twisting units, the ideal working capital cycle was found to be 43 days and the working capital being ₹127980/- per basin with 26 days period of working expenses.

From the above, it can be seen that for smooth functioning of a 10 basin multiend and multiend reeling cum twisting unit, the working capital requirement would be around ₹10.00 lakhs and ₹12.50 lakhs, respectively.

Comparison between working capital availability and requirement

One way ANOVA was used to compare the mean values of available and required working capital per basin of multiend reeling and multiend reeling cum twisting units.

Table 4 indicates that working capital availability per basin is far lower than what is required in the case of multiend reeling units and significant at 1 % level.

Table 4: Comparison between available and required working capital in multiend reeling units (One way ANOVA)

Descriptive Statistics

Particulars	N	Mean	Std. Deviation	Minimum	Maximum
WC available	20	38788.55	16872.513	15695	83280
WC required	20	99740.95	14377.929	79684	132452
Total	40	69264.75	34525.604	15695	132452

WC: Working capital

ANOVA

Particulars	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.715E10	1	3.715E10	151.207	.000**
Within Groups	9.337E9	38	2.457E8		
Total	4.649E10	39			

**Significant at 1% level

Table 5: Comparison between available and required working capital in multiend reeling cum twisting units (One way ANOVA)

Descriptive Statistics

Particulars	N	Mean	Std. Deviation	Minimum	Maximum
WC available	34	87595.76	34644.049	46004	197291
WC required	34	128389.85	15017.211	104180	155238
Total	68	107992.81	33533.157	46004	197291

WC: Working capital

ANOVA

Particulars	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.829E10	1	2.829E10	39.686	.000**
Within Groups	4.705E10	66	7.129E8		
Total	7.534E10	67			

**Significant at 1% level

In the case of multiend reeling cum twisting units also, the working capital availability per basin is far lower than what is required and significant at 1 % level (Table 5).

The gap in working capital was calculated based on the availability and requirement in the case of multiend reeling and multiend reeling cum twisting units, which is presented below.

Table 6: Gap in working capital

Particulars	Multiend reeling unit	Multiend reeling cum twisting unit
Availability of working capital per basin (₹)	38475	87262
Requirement of working capital per basin (₹)	100909	127979
Gap in working capital per basin (₹)	62434	40717
Gap in working capital (%)	61.87	31.82

Table 6 shows the availability, requirement and gap in working capital per basin for multiend reeling and multiend reeling cum twisting units. The gap in working capital per basin was found to be ₹62434/- in the case of multiend reeling units, while it was ₹40717/- in the case of multiend reeling cum twisting units, the percentage in gap being 61.87 and 31.82, respectively. The working capital availability was found to be significantly lower (at 1% level) than the requirement in both the cases as seen from Tables 4 and 5.

Comparison between profitability of units with adequate and inadequate working capital

It was found that all the multiend reeling units were working with inadequate working capital (₹0.38 lakh per basin), when compared to the required working capital of around ₹1.00 lakh per basin. In the case of multiend reeling cum twisting units, 7 of them had higher working capital (₹1.44 lakhs per basin) than the required amount of around ₹1.25 lakhs per basin while 27 units were working with inadequate working capital (₹0.73 lakh per basin). Hence, only reeling cum twisting units were considered for the above analysis. One way ANOVA was used to compare the mean values of net profit per kg of silk between units with adequate and inadequate working capital.

Table 7 indicates that the net profit per kg silk in the case of units with adequate working capital is higher than that of units with inadequate working capital and found to be significant at 1 % level.

Table 7: Comparison between net profit per kg silk of multiend reeling cum twisting units with inadequate and adequate working capital (one way ANOVA)

Descriptive Statistics

Particulars	N	Mean	Std. Deviation	Minimum	Maximum
NP Inadequate WC	27	176.18	33.052	80.02	234.57
NPAdequate WC	7	216.65	20.919	188.69	247.30
Total	34	184.51	34.873	80.02	247.30

NP: Net Profit; WC: Working capital

ANOVA

Particulars	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	9102.973	1	9102.973	9.388	.004**
Within Groups	31029.256	32	969.664		
Total	40132.229	33			

**Significant at 1% level

Conclusion

From the analysis on working capital of multiend reeling and multiend reeling cum twisting units, it is clear that units do not have adequate working capital at their disposal. The working capital availability of both the units was found to be significantly lower than the requirement for smooth operations due to smaller working capital cycle. It indicates that units do not have optimum holding periods of raw material and finished goods / credit, hence affecting their cost of production and sales realization adversely, respectively.

The significantly higher net profit per kg silk in reeling cum twisting units with adequate working capital as compared to those with inadequate working capital indicates that adequacy of working capital is one of the factors affecting the profitability.

Working capital availability is crucial for the silk reeling sector and the working capital requirements of multiend reeling units are high and more so in the case of multiend reeling cum twisting units due to larger working capital cycle. Hence the reeling sector needs support on easier terms by financial institutions to raise working capital. This would also help the multiend reeling units to avail the benefit of working capital interest subsidy scheme included in the XII Plan CDP scheme of Govt. of India.

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Rapport technique

ANALYSE DU FONDS DE ROULEMENT DES UNITES DE FILATURE MULTIBOUTS ET DES UNITES MULTIBOUTS COUPLEES AU MOULINAGE

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RÉSUMÉ

Un schéma pour supporter des unités de filature multibouts avec des équipements de moulinage a été élaboré dans le plan quinquennal XI du gouvernement indien pour ajouter de la valeur et plus de 50 unités de filature avec moulinage couplé ont été établies. Mais la plupart des unités font face à des problèmes de disponibilité de fonds de roulement alors que leur nécessité est très élevée en raison de la faible valeur ajoutée de l'activité et du coût élevé du matériel. Ainsi il a été proposé d'étudier le fonds de roulement des unités de filature multibouts et des unités couplées au moulinage. L'étude montre que les unités n'ont pas un fonds de roulement adéquat à leur disposition. Les fonds de roulement requis sont significativement plus importants pour les unités de filature avec moulinage couplé que pour les autres en raison d'un cycle plus large du fonds de roulement. La disponibilité de ce fonds est significativement plus faible que sa nécessité dans les deux cas. Le bénéfice net par kg de soie des unités ayant un fonds de roulement adéquat est significativement plus élevé que celui des unités qui n'ont pas un tel fonds de roulement. L'étude suggère que le secteur de la filature nécessite des aides plus faciles de la part des institutions financières pour relever les fonds de roulement.

Mots-clés: Composants, cycle, période d'emprise, bénéfice net, fonds de roulement.



DEVELOPMENT OF CREATIVE AND DESIGN THAI SILK PRODUCTS

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ABSTRACT

A collaborative project on 'Creative and Design Thai Silk Products' was conducted in 2013 in the northeastern province of Thailand aiming to design and develop products to publicize and support the image of Thai silk products in International market and streamline the process pattern development of Thai silk products. The concept of this project was based on the deliberations of a brainstorming event of various experts related to the field of Thai silk products and market. The issues of design brief and market direction were addressed. A survey on farmers from pilot provinces (Nakhon Ratchasima, Buriram, Khonkaen) who make Thai silk products and new Thai silk products entrepreneurs was conducted and a selected few were allowed to participate in the project. The participants were trained in a workshop organized on design and development of Thai silk products from the local wisdom. Finally, participants who proved to possess the best potential were chosen to develop their concept designs and sketch for making the prototype for five new Ikat patterns of Thai silk fabric and one collection of Thai silk bags.

INTRODUCTION

Development of Thai silk fabric and Thai silk products are value creation which support Thai silk product to have high potential in order to compete in the international market and face high trading competition due to free ASEAN trade area influence. This is also to cope with the changing consumers' behavior and lifestyle and fluctuation of economic scenario at present and in the future.

In the development process, designing is an important factor because it is a value creation step that plays an important role in consumer's need and satisfaction. Therefore, silk which is of premium material should be developed through an appropriate design process to add more value and support image to Thai silk. This project witnessed collaboration of many sectors such as government, private sector, university, designers and expert entrepreneurs to improve the capability of farmers and new entrepreneurs to develop their silk products through a strong and sustainable business. Furthermore, it

also promotes the new image of Thai silk as more interesting among the new generation. The project coincided with the mission of The Queen Sirikit Department of Sericulture *i.e.*, to develop high quality Thai silk products to international market.

The project envisaged the following objectives:

- To study and develop Thai silk products to increase business potential and conform with present day need of consumers.
- To publicize and promote Thai silk products to be known in worldwide market.
- To create the development process pattern for Thai silk products from local Thai wisdom.

METHODOLOGY

1. The committee constituted by officers of The Queen Sirikit Department of Sericulture, professors from Faculty

of Fine Arts Srinakharinwirot University, senior designers and experts of Thai silk entrepreneurs consulted and decided on the issues of design brief and market direction.

2. A survey was conducted to screen the farmers who make Thai silk products and the new Thai silk products entrepreneurs in order to select the group that have potential to participate in this project.

3. Training courses and workshops were set up on designing and development of Thai silk products from the local wisdom as following:

- Theory part: designing and development of Thai silk products from local Thai wisdom and study on market opportunity.
- Workshop part: consultation on in-depth issues for defining the method to design Thai silk products and practical activities on idea development and sketch design.

4. Selected 4 groups out of 12 groups of participants from 3 pilot provinces viz., Nakhon Ratchasima, Buriram and Khonkaen who have the best potential to continuously develop their sketch design into prototypes as following:

- 3 collections of Thai silk fabric
- 1 collection of product from Thai silk fabric

5. Follow up done on prototype production.

6. Publicized the knowledge and prototypes from this project in related events and exhibition.

7. Evaluated the result.

RESULTS AND DISCUSSION

The main issue of design brief and market direction was resolved that the expansion of Thai silk market should focus on the new generation or younger people living in urban areas with new lifestyle. Thai silk products can add value by designing being of contemporary style which can be of use in daily life. This will help to enhance the image of Thai silk product and increase demand of consuming

materials from Thai wisdom as well.

Under the training and workshop courses, the participants not only studied how to create their products step by step, but also practiced to present the inspiration, concept, mood board and sketch design in order to generate / transform ideas to visual images translated as unique prototypes with the suggestions from the professors (Visual art, Faculty of Fine Arts) and the expert designers.

The creativity works undertaken by the participants who passed the standard on working attitude and with high potential to make the prototype products are as following:

1. Mai Thong Suranaree cluster, Pak-Thong-Chai district, Nakhon-Ratchasima province

Product: Coconut fruit and leaves patterns of Ikat Thai silk fabric.

This cluster had an inspiration to produce Thai silk pattern and their symbol cluster from coconut trees growing around the district which is in accordance with their lifestyle and work in community.



Coconut fruit and leaves patterns of Ikat Thai silk fabric



Fashion item from fabric prototypes

2. Ban NongKo cluster, Na-Pho district, Buriram province

Product: Peacock tail patterns of Ikat Thai silk fabric with 2 color schemes.

This cluster had ideas to develop new pattern from the existing signature peacock pattern to be more modern and contemporary.



Peacock tail patterns of Ikat Thai silk fabric with 2 color schemes



Mood board and sketch design from the workshop

3. Ban Nongbua cluster, Phon district, Khon-Kaen province

Product: 2 Rice field pattern of Ikat Thai silk fabric.

They were inspired from the rice fields in the bird's eye view. The patterns showed the repeated rhythmic lines and shapes of the edges of the field.



Rice field pattern of Ikat Thai silk fabric



Fashion item from fabric prototypes

4. Ban Huafai cluster, Chonnabot District, Khon-Kaen province

Product: One of the bag collections was created from hand-woven fabric with 3 designs.

The cluster had an idea to develop hand-woven Thai silk fabric into another product of more commercial value.



Thai silk bags collection

Experts from the field of textile and fashion designing in their telecast programmes addressed to both local and international market expressed that there is enormous potential to promote Thai silk in the markets, especially from contemporary view. However, it is important that they should improve quality of the products in line with the ever-changing consumers' need. This in a way will also conserve Thai wisdom and knowledge for future. The development process model and knowledge generated out of this project can be applied for other product development too.

This project prototype was exhibited in "Royal Peacock Logo Upholding The Petitionary Thai Silk 2014" during 8-12 August 2014 at IMPACT Exhibition & Convention Center, Muang Thong Thani Nonthaburi province organized by The Queen Sirikit Department of sericulture, Ministry of Agriculture and Cooperatives, Thailand. Farmers and the new entrepreneurs engaged in Thai silk production were interested and impressed upon by the exhibition, especially with the patterns of silk fabric displayed. Moreover, this can be an applied knowledge for value addition of commercial products.

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Rapport technique

DEVELOPPEMENT DE PRODUITS CREATIFS ET DE DESSINS EN SOIE THAÏ

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RÉSUMÉ

Un projet collaboratif sur « des produits en soie Thaï créatifs et design » a été conduit en 2013 dans le nord-est de la Thaïlande afin de développer des produits pour promouvoir et supporter l'image des produits en soie Thaï sur le marché international et de dynamiser le développement des produits en soie Thaï. Le concept de ce projet est issu des délibérations d'un aréopage de divers experts liés aux produits et au marché de la soie Thaï. Une évaluation de fermiers de provinces pilote (Nakhon Ratchasima, Buriram, Khon kaen) qui fabriquent des produits en soie Thaï et des nouveaux entrepreneurs en soie Thaï a été menée et quelques uns d'entre eux ont été sélectionnés pour participer au projet. Les participants ont été formés lors d'un atelier organisé sur le design et le développement de produits en soie Thaï à partir de la sagesse locale. Finalement, les participants qui ont montré le meilleur potentiel ont été choisis pour développer leurs concepts et pour produire le prototype de cinq nouveaux dessins Ikat de tissus de soie Thaï et une collection de sacs en soie Thaï.

Mots-clés : Produits de soie Thaï créatifs et design, design, direction du marché.

Regional Consultation Meeting on "Sericulture scenario in SAARC region – a re-emerging industry for poverty alleviation in SAARC Region", Mysore-India, 24-28 August, 2015



International Sericultural Commission, Bangalore, India and SAARC Agriculture Centre, Dhaka, Bangladesh have jointly organized a Regional Consultation Meeting on "Sericulture scenario in SAARC region – a re-emerging industry for poverty alleviation in SAARC Region", at Mysore-India, on 24-28 August, 2015. The meeting was inaugurated by Prof. K. S. Rangappa, Hon'ble Vice Chancellor, University of Mysore on 25th August, 2015. Representatives from 8 SAARC Member Countries attended the meeting. Subject experts from Central Silk Board presented technical papers on different aspects of silk industry for the benefit of country delegates. While the first 2 days (i.e., 25th & 26th August, 2015) were devoted for meetings, the delegates were taken for a guided tour to sericulture facilities, farmers' fields, silk factory, and other infrastructure facilities associated with the industry for the remaining three days. The major resolutions adopted taken during the meeting were;

- 1) The SAARC Member Countries would replicate the successful model of sericulture practice developed in India by taking up a Joint Sericulture Project by sourcing fund under Multilateral Assistance Programme.
- 2) The ISC and SAC would enter into a MoU of collaboration for the benefit of SAARC Member Countries.
- 3) The Indian Sericulture establishment would support SAARC countries to introduce and develop sericulture as a viable occupation for employment generation and poverty alleviation in their respective countries.
- 4) The SAARC Member Countries; Bhutan, Maldives, Nepal, Pakistan and Sri Lanka would enroll as Member Countries of ISC to avail the facilities offered under the global developmental programmes of ISC



Visit of SAARC delegates to Central Silk Technological Research Institute, Bangalore

Visit of a Chinese delegation headed by Dr. Li Long, Director, Sericultural Research Institute, Chinese Academy of Agricultural Sciences, Zhenjiang 212018, Jiangsu, China



A five member delegation led by Dr. Li Long, Director, Sericultural Research Institute, Chinese Academy of Agricultural Sciences, Zhenjiang 212018, Jiangsu, China visited the sericulture areas of India from 27th Aug, to 1st September, 2015. The main purpose of the visit was to explore the possibility of collaborating with Indian seed producers to produce and supply highly productive silkworm seeds of Chinese origin to Indian sericulture farmers. Apart from meeting the ISC and CSB officials, the delegation had also met and interacted with State Sericulture Department officials of Karnataka and Private Seed Producers.

The discussion with Central Silk Board (CSB) culminated in broadly agreeing for collaborating between India and China for developing robust silkworm hybrids suitable to Indian conditions. The Chinese have agreed to provide training to the candidates deputed from India.

Visit of Swaziland delegation



A two member Swaziland delegation comprising Mr. Marcel Bruck and Ms. Michelle Hu, Linne Trading visited the ISC Office on 13th August, 2015. The ISC facilitated the visit of the delegation to the sericulture areas of Tamilnadu and organized a meeting with Dr. H. Nagesh Prabhu, Chief Executive Officer, Central Silk Board, Bangalore. The Swaziland sought Indian assistance for developing an Sericulture Farm in Swaziland in about 600 hectares of land. A collaboration in this direction is likely to be finalized soon.

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