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International Sericultural Commission (ISC)
Central Silk Board Complex, BTM Layout
Madiwala, Bengaluru - 560068, INDIA
Tel: +91 80 26282191, 26680162, 26681663
Fax: +91 80 26681663
E-mail: sericologia@gmail.com
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DEVELOPMENT OF EASY THREADING SLIT BUTTON FOR RAW SILK REELING

Subhas V. Naik, Sangappa N. Shillin*, K. Jaganathan and K. P. Shivakumar

Central Silk Technological Research Institute, Central Silk Board, Ministry of Textiles,
Govt. of India, B.T.M. Layout, Madiwala, Bengaluru 560068, India.

*Email: shillin_sn@yahoo.co.in

ABSTRACT

In the silk reeling process, reeling buttons play a vital role in improving the cleanness characteristic of raw silk by removing the slugs. In India, conventional reeling buttons made of porcelain and ceramic materials are commonly being used for this purpose. Nowadays, in silk reeling industry, reelers, particularly the aged ones and new reelers are finding it difficult and take more time in threading the silk through these buttons which may in turn affect silk productivity. To address this issue, CSTRI took up studies and development of slit button is one of the outcomes in this direction. This kind of a button is provided with a slit and hole of appropriate dimension depending on the denier of raw silk. Reeling experiments were carried out using the existing type and slit buttons on Multiend and Automatic silk reeling technologies by using both Multi-bivoltine and Bivoltine hybrid cocoons. The results revealed that the threading time in the case of slit button is reduced by 53 % as compared to that of conventional buttons. Further, the raw silk reeled using slit buttons has the advantage of superior grade of cleanness over that offered by the existing conventional porcelain buttons. Hence, it is envisaged that the improved productivity and quality of silk achieved, would ultimately enhance the profit earned by the reelers.

Key words: Automatic reeling, cleanness, economics, reeling, slit button, slugs.

INTRODUCTION

Silk represents luxury and royalty and these qualities are yet to be matched by any other textile fiber. In India, there are three kinds of mulberry silk cocoons produced namely, Bivoltine hybrids, Cross breed and Multivoltine races. Multivoltine cocoons are considered to be of inferior quality (Chowdhury, 1990; Rahmathulla, 2012) and are preferred by Charkha reelers for producing dupion silk yarn and to some extent by the silk sheet makers (CSTRI, 2001). Improved cross breed cocoons are reeled on cottage basin and multiend reeling machines. Whereas,

superior bivoltine hybrid cocoons are reeled on Automatic silk reeling machine (ARM). The quality of the raw silk produced on ARM is of higher grade *viz.*, 3A to 4A when compared to that of multiend reeling machine (MRM) *i.e.*, 2A to 3A. The production of superior grade raw silk (3A to 4A) is possible in ARM as the machine is fitted with denier detecting device to sense the set denier and auto cocoon casting mechanism at each end which cast the cocoons after receiving the signals by denier detector which in turn assists to produce uniform raw silk yarn.

Cleanness is one of the important characteristics of raw silk, which has significant influence on performance of silk during weaving and on fabric quality, particularly appearance of the fabric. Cleanness of raw silk is influenced by cocoon quality, cocoon drying and cocoon cooking conditions and the kind of reeling buttons (Naik *et al.*, 1995) used.

Button is an important gadget used in silk reeling for removing the slugs (thick portions) in the raw silk and to arrest waste going into the thread during the reeling operation. Appropriate hole size of the buttons depending on the denier of raw silk, circular hole shape with smooth surface and use of standardized ceramic material are important factors in determining the effectiveness of buttons. CSTRI has developed ceramic buttons with all these specifications which are already in use by the reelers (Figure 1) (CSTRI, 2002).



Figure 1: CSTRI Ceramic reeling buttons

During the interaction with the reelers on various forums, it was informed that, the technique for threading into the presently used buttons is a very cumbersome operation *i.e.*, buttons need to be taken out from the holder, then thread has to be formed into a loop, thread loop has to be twisted to form single straight thread, inserted into the hole, protruded thread to be plucked with fore finger on the other side of button followed by mounting on its holder (Yajima, 1998). These operations of threading require skill, bright light in the reeling unit, better eyesight and also consume a lot of time particularly for aged reelers. These constraints take their toll on quality and productivity of silk. Hence, the need for an alternate technology of easy threading associated with improved

productivity and quality of raw silk was felt. In order to mitigate the constraints faced with the presently used conventional buttons, the present study was taken up to design and develop improved buttons with slit and hole of appropriate size depending on the denier of raw silk.

MATERIALS AND METHODS

Design of slit button: The slit button has three component parts *viz.*, ceramic flat plate, ceramic flat holder and torsion spring (Figure 2). A flat plate of 1 mm thickness and 21 mm diameter made out of Al_2O_3 ceramic material was used for designing the slit button. A portion corresponding to 90° was cut off from the plate so that it appeared almost semi circular in shape (Figure 3 a). A slit of 150 micron width and 3.02 mm length was made in the ceramic flat plate for the silk thread to pass through and finally sit in a circular hole of 250 micron diameter. Buttons with varying sizes of circular holes *i.e.*, diameter of 250 micron for 20/22 denier, 300 micron for 22/24 denier and 350 micron for 24/26 denier were manufactured to suit to different denier raw silk reeling. But, the slit width (aperture) of 150 microns was kept constant irrespective of hole diameter.

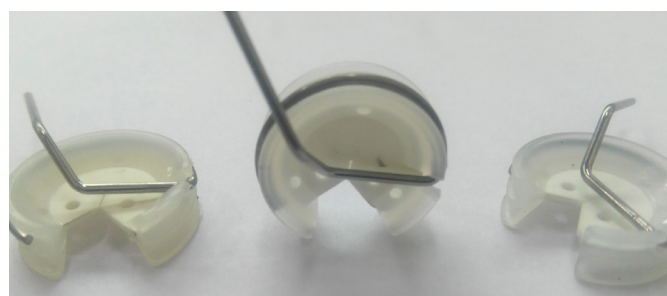


Figure 2: CSTRI Slit Button

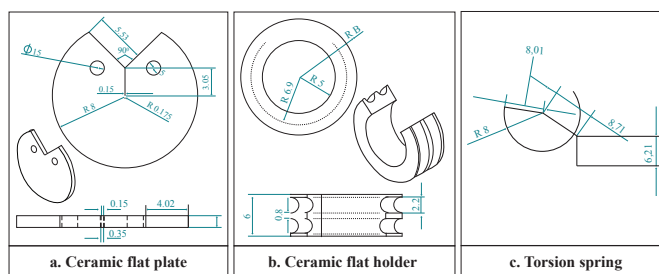


Figure 3: Design drawing of slit button

Ceramic flat holder is made up of organic polymers of HDP with 90° angle opening at one side with insert moldings for ceramic slit button. The button consists of two grooves, one for mounting on to the button holder provision made in the reeling machine and another one for mounting a torsion spring as shown in Figure 3 b. Torsion spring is made of corrosion resistance SS wire of 1 mm diameter having typical shape dimensions as shown in Figure 3 c.

In the present study, the performance of the slit button in comparison with the other buttons presently in use, *viz.*, porcelain (conventional) and CSTRI ceramic buttons, was assessed in terms of quality parameters of raw silk reeled and its economic viability.

Multi-bivoltine (CB) and Bivoltine (BV) hybrid cocoons raised by the farmers were procured from Ramanagaram and Kolar government cocoon markets for conducting experimental reeling trials. One-kilogram of cocoon per lot was assessed to determine defective cocoon percentage, cocoon weight, cocoon shell weight and shell percentage (Nakajima, 1999). The cocoon lots were dried in batch type hot air drier by following standard operating procedure. The dried cocoons lots were conditioned for a period of seven days and then subjected for test reeling and mass reeling (Naik and Somashekar, 2004). For test reeling, 300 good cocoons were used on test reeling machine, maintaining three ends by keeping eight cocoons per end for both CB & BV cocoons lots.

The cocoons were cooked by using two pan cooking method and mass reeling was carried out on Multiend and Automatic reeling machines. Re-reeling was carried out on closed type re-reeling machine. The reeling

characteristics *viz.*, filament length, non-broken filament length, filament denier, renditta, raw silk percentage, raw silk recovery, reelability, and cookers' and reelers' waste were determined. Raw silk testing was conducted as per Indian Standard IS 15090 (Parts 1-11): 2002 (BIS, 2002).

Mass reeling experiments were carried out with multiend and automatic reeling technology package. Multi-bivoltine and Bivoltine hybrid cocoons were reeled on Multiend machine and reeling on Automatic machine was carried out with only Bivoltine cocoons.

The threading time consumed by the silk reeler for ceramic and CSTRI slit buttons was recorded. Based on the observations, a rating factor in percentage was allotted. Normal time is the product of observed time and rating factor. Whereas, allowance period of 5 percentage of normal time as per the standard permissible allowance was calculated. The standard time was calculated as per the norms, which is the summation of normal time and allowance time.

RESULTS AND DISCUSSION

Cocoon parameters: The results of cocoon assessment are presented in Table 1. The defective cocoon per cent (10.9 %) was recorded more for Multi-bivoltine than Bivoltine hybrid cocoons (7.1 %). The other important cocoon parameter *i.e.*, shell percentage of 22.93 and 20.16 were registered for Bivoltine hybrid and Multi-bivoltine cocoons, respectively.

Test reeling: The reeling characteristics, such as filament length, non-broken filament length, filament denier and reelability percentage were analyzed and displayed in Table 1.

Table 1: Test & mass reeling results of cocoons

Cocoons	Defective cocoon (%)	Cocoon weight (g)	Shell weight (g)	Shell %	Filament length (m)	Non- broken filament length (m)	Filament denier (d)	Reelability (%)	Renditta	Raw silk (%)	Raw silk recovery (%)
Multi-bivoltine	10.9	1.974	0.398	20.16	893	810	2.78	90.8	7.2	16.3	69.4
Bivoltine hybrid	7.1	2.089	0.479	22.93	1031	934	2.71	90.6	6.5	17.6	69.9

The raw silk samples reeled were tested for quality characteristics (following ISA method) viz., denier (d), size deviation, evenness variation I, II & III (count), cleanness (%), neatness (%), low neatness (%), maximum deviation, winding (breaks), tenacity (g/denier),

elongation (%) and cohesion (strokes). The results of quality parameters of raw silk reeled on Multiend and Automatic reeling machines are provided in Tables 2 and 3, respectively.

Table 2: Quality characteristics of Multi-bivoltine raw silk reeled with different buttons on Multiend reeling machine

Parameter	Conventional				CSTRI slit button	
	Porcelain button		CSTRI ceramic button			
	Value	Grade	Value	Grade	Value	Grade
Average denier (d)	21.7		20.4		21.2	
Size deviation	1.49	2A	1.55	2A	1.42	2A
Evenness variation I (Count)	165	3A	160	3A	160	3A
Evenness variation II (Count)	16	3A	17	3A	15	3A
Cleanness (%)	89	A	95	3A	96	3A
Average neatness (%)	90	2A	90	2A	92	3A
Low neatness (%)	84	2A	85	2A	87	3A
	Value	Class	Value	Class	Value	Class
Maximum deviation (Denier)	2.9	1	1.9	1	2.1	1
Evenness variation III (count)	0	1	0	1	0	1
Winding (breaks)	3	1	1	1	1	1
Tenacity (g / denier)	3.7	1	3.7	1	3.9	1
Elongation (%)	19	1	18	1	20	1
Cohesion (strokes)	55	2	69	1	71	1
Overall Grade		B		2A		2A

Table 3: Quality characteristics of Bivoltine raw silk reeled with different buttons on Automatic reeling machine

Parameter	Conventional				CSTRI slit button	
	Porcelain button		CSTRI ceramic button			
	Value	Grade	Value	Grade	Value	Grade
Average denier (d)	21.9		20.9		21.7	
Size deviation	1.1	4A	0.9	4A	0.99	4A
Evenness variation I (Count)	15	4A	7	4A	4	4A
Evenness variation II (Count)	0	4A	0	4A	0	4A
Cleanness (%)	93	2A	99	4A	99	4A
Average neatness (%)	92	3A	96	4A	98	4A
Low neatness (%)	88	3A	90	4A	90	4A
	Value	Class	Value	Class	Value	Class
Maximum deviation (Denier)	2.9	1	1.9	1	2.1	1
Evenness variation III (count)	0	1	0	1	0	1
Winding (breaks)	3	1	1	1	1	1
Tenacity (g / denier)	3.7	1	3.7	1	3.9	1
Elongation (%)	19	1	20	1	21	1
Cohesion (strokes)	148	1	169	1	172	1
Overall Grade		2A		4A		4A

The test results reveal that cleanness of both Multi-bivoltine and Bivoltine silk are better in the case of both CSTRI ceramic and slit buttons as compared to conventional porcelain buttons. But, it is to be noted that slit buttons have facilitated enhanced productivity by 10.7 % as compared to that of existing CSTRI ceramic buttons and conventional porcelain buttons. This is due to easy threading in the case of slit buttons. A reduction in threading time by 53 % along with reduced stress was encountered in the case of slit buttons as

against the conventional buttons. The results (Table 4) indicated that, the average observed time or selected time are 20.55 and 9.58 seconds in the case of porcelain / ceramic and slit button, respectively. Similarly, the average standards time was 10.43 seconds in the case of slit button and 21.88 seconds in the case of conventional buttons. The descriptive statistics (Table 4) registered higher standard deviation in the case of conventional button for observed time (2.53), normal time (0.21), standard time (0.22), rating factor (11.05) and allowance

period (0.011) whereas, lower standard deviation was recorded in the case of CSTRI-slit button for observed time (0.71), normal time (0.13), standard time (0.14), rating factor (7.08) and allowance period (0.007). The data on time consumption were subjected to student 't' test (Table 5) and from the results, it was found that, the timings of observed, normal, standard and allowance period were significant at 1 % level, whereas, the rating factor (%) is found non-significant as rating factor was given based on the type of reeling button, independently.

Overall, the reelers' threading time on reeling machine reduced by about 53 percentage. This helps reelers to pay more attention towards other important activities viz., maintenance of required number of cocoons at each end, joining of yarn by knotting, putting croissure and rectifying thread troubles as reported by Subhas and Somashekar (2008), which are essential works to be attended while reeling. In raw silk grading, the quality parameters, such as size deviation, cleanness percentage and neatness percentage are considered as major tests.

Table 4: Descriptive statistics of time study data on reeling threading

Parameter	Group	No. of samples	Mean	Standard deviation (S.D.)
Observed/ Selected time (in seconds)	Conventional button	33	20.55	2.53
	Slit button	33	9.58	0.71
Normal time (in seconds)	Conventional button	33	20.84	0.21
	Slit button	33	9.93	0.13
Standard time (in seconds)	Conventional button	33	21.88	0.22
	Slit button	33	10.43	0.14
Rating factor (%)	Conventional button	33	102.73	11.05
	Slit button	33	104.24	7.08
Allowances (5 %)	Conventional button	33	1.04	0.011
	Slit button	33	0.50	0.007
Threading time reduction (%) in the case of CSTRI slit button				53

Table 5: Student't' test of time study data of reeling threading

Factor	t-value	df	Sig (2-tailed)	Mean differences
Observed/ Selected time (in seconds)	24.020	64	0.000**	10.970
Normal time (in seconds)	252.367	64	0.000**	10.906
Standard time (in Seconds)	252.367	64	0.000**	11.451
Rating factor (%)	-.663	64	0.510NS	-1.515
Allowances (5 %)	252.367	64	0.000**	.5453

** - Significant at 1 % level,

NS - Not significant at 5 % & 1 % level.

Table 6: Comparative economics of slit versus conventional buttons on Multiend silk reeling machine

#	Particulars	Conventional button	CSTRI-Slit button
1	Multiend reeling machine 10 basin (ends)	100	100
2	Cost of each button (₹)	13.00	250.00
3	Cost of the buttons (₹)/10 basin Multiend reeling machine	1300.00	25000.00
4	Raw silk production / day (kg)	13.00	14.56
5	Enhancement in productivity / day (kg)		1.56 (10.7 %)
6	Raw silk production / Year (kg)	3900.00	4368.00
7	Labour required to run 10 basin ME reeling unit	20.00	20.00
8	Labour cost /day (for 20 labourers) (₹)	6000.00	6000.00
9	Labour cost per kg of raw silk (Productivity cost) (₹)	461.54	412.09
10	Labour cost saving /kg (Enhanced productivity) (₹)		49.45
11	Labour cost saving /day (₹)		720.00
12	Working days / year	300	300
13	Labour cost saving / year (₹)		216000.00
14	Life period of button (in no. of days)	30.00	300.00
15	Total no. of buttons used / year	1000	100
16	Total Expenditure incurred towards buttons/year (₹)	13000.00	25000.00
17	Additional expenses incurred by using the slit button/year (₹)		12000.00
Profit / year by using slit button (₹) [Labour Cost saving/year (13)] – [Additional expenses incurred by using slit buttons/year (17)]			2,04,000.00

While working out the economic feasibility of the newly developed gadget, it is understood that even though the initial cost of the slit button is at higher side, generation of a reasonable yearly profit of ₹ 2,04,000 (Rupees Two lakh and four thousand) (Table 6) is highly promising.

Conclusion

In the silk reeling operation, buttons are essential gadgets which play a vital role in removing the slugs/defects and

hence, improving cleanness and neatness (to some extent) property of raw silk yarn. The slit buttons developed by CSTRI are techno economically advantageous and highly viable as compared to the existing buttons and will certainly contribute to the silk reeling industry in enhancing the productivity and quality of raw silk by supporting the aged and new reelers to have easy threading who otherwise consume more time and undergo higher stress while threading through conventional buttons.

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GENOTYPIC AND PHENOTYPIC VARIABILITY IN A CLONE OF MULBERRY CULTIVAR, VISHALA

R. Ravi Kumara*, H. Thimma Reddy, M. R. Swamy Gowda, M. Devamani and
P. G. Radhakrishna

Division of Moriculture, Karnataka State Sericulture Research and Development Institute,
Thalaghattapura, Bengaluru 560109, India.

*Email: chandraravi.seri4@gmail.com

ABSTRACT

A Clonal-variant was identified from saplings raised from the cuttings of the mulberry cultivar, Vishala, at the seed multiplication plot of the Karnataka State Sericulture Research and Development Institute (KSSRDI), Bengaluru. The qualitative and quantitative traits of the Clonal variant were recorded and compared with those of their mother plant, Vishala. The phenotypic characteristics of the Clonal variant exhibited a few variations from those of their mother plant. Besides, the traits *viz.*, the average number of branches per plant (32.27 %), leaf length (2.65 %), leaf cuticular thickness (27.82 %), leaf moisture content (3.19 %), as well as leaf moisture retention capacity (11.24 %) have shown an increment in the Clonal variant over the cultivar, Vishala. The cytological evidence shows that Clonal variant and Vishala possess $2n = 3x = 42$ (triploid) chromosomes in somatic cells, while $n = 21$ chromosomes in the gametic cells. There was no gain or loss in the chromosomal complement and there was no significant variation in the 2C DNA content. Furthermore, inter-simple sequence repeat (ISSR) analysis clearly revealed the presence of genetic variation between the mother plant and their Clonal variant. Therefore, the basis for discrete variation in genetic and morpho-metric traits in the Clonal variant might be due to the natural bud mutation that occurred in the mulberry cultivar, Vishala.

Key words: Bud mutation, Clonal variant, mulberry, triploid, Vishala,

INTRODUCTION

Mulberry (*Morus* spp.) is a bio-energy food plant for the silkworm, *Bombyx mori* L., and forms the prime host plant of the sericulture industry with a wide array of varieties with ploidy patterns ranging from haploid ($2n=14$) to docosaploid ($2n=22x=308$). However, the cultivated varieties are diploid ($2n=2x=28$) and triploid ($2n=3x=42$) in nature. High-yielding mulberry varieties with desirable characteristics play an important role

in the vertical growth of sericulture and in making it a more remunerative and lucrative occupation. Thus, to boost the sericultural economy, one of the major long-standing approaches is both the qualitative, quantitative, and genetic improvement of mulberry, which primarily determines the healthy and economical cocoon production (Shabnam *et al.*, 2018). Breeding targets should be set with a long-term view. So far, breeding targets have included high yield, high nutritional value, and resistance against diseases and pests. But nowadays, new targets

have been added to cope with changes in the sericultural system, such as large numbers of silkworms being reared and the adaptability of densely planted fields for mechanical harvesting (Machii *et al.*, 2002). However, the genetic improvement in woody perennial plants like mulberry by hybridization has been inefficient and time-consuming due to their heterozygosity and long juvenility.

Clonally propagated domesticated plants are cited as examples of the power of somatic mutations to provide genetic variation that contributes to adaptive evolution (Whitham and Slobodchikoff, 1981). The clonal variation is often seen in mulberry plants due to “natural bud mutation”, which is caused by various factors, such as age of the mulberry plant (Basavaiah *et al.*, 1994), repeated pruning (Dandin, 1999), activity of transposable elements (Vijayan *et al.*, 2009), variation in the nuclear DNA content (Kumara *et al.*, 2021), distant hybridization, and certain external factors (Abdullaev, 1962). Many mulberry races in Japan were obtained from bud mutants, and those races mostly originated from the trees belonging to *M. alba* (Dzafarov, 1966). A spontaneous mutant with yellow leaves was observed by Isao (1979) among the cutting saplings of a mulberry variety, Ichinose. This mutant had exactly the same morphology, sprouting behavior, sex, and other characteristics as the original variety, except for the leaf color. The variety Ryomenguwa is a product of a bud variant that appeared on the old trees of Ichihei in Japan (Minamizawa, 1970). The mulberry mutant, Garyu, is a natural bud mutant with a bending stem of an unknown original type (Sopian *et al.*, 2009). Basavaiah *et al.* (1994) reported the incidence of spontaneous chimaeras in old mulberry gardens of M-5 and Mysore Local cultivars in Karnataka, India. Many varieties or genotypes of mulberry were clonally selected from different geographical regions of India; these varieties are Chinese white, Mandalaya, Viswa (DD), Vishala, TG-1 (Thalagattapura-1) and Anantha (Tikader and Kamble, 2007) and also a spontaneous chimera, the “Kadaganchi” genotype,

which was selected from the M-5 cultivar by the Karnataka State Sericulture Research and Development Institute (KSSRDI); which shows some adaptive characteristics for drought-tolerance.

The cultivar, Vishala (*Morus indica* L.) is a triploid ($2n=3x=42$), selected clonally from saplings raised from the cuttings obtained from the mulberry gardens of Shidlaghatta taluk, Kolar district of Karnataka State by the KSSRDI, Thalaghattapura, Bengaluru. Vishala is a fast-growing variety with an early maturity of leaves. It is recognized as a national check variety under the AICEM programme of the Central Silk Board. Under irrigated conditions, the average leaf yield in the southern test centers varied from 26,000 kg/ha/yr in Krishnagiri to 80,960 kg/ha/yr in Thalaghattapura, and under rain-fed conditions in Chamrajanagar, it yielded 11,240 kg/ha/yr. In northern India, the leaf yield ranged from 5,000 kg/ha/yr in Mirgund (Jammu & Kashmir) to 18,700 kg/ha/yr in Pampore (Jammu & Kashmir) under two crop schedules in a rain-fed system, and in eastern India, it ranged from 8,901 kg/ha/yr in Ranchi (Jharkhand) to 28,700 kg/ha/yr in Berhampore, West Bengal (Saratchandra *et al.*, 2011). Thus, exploring clonal variants is one of the most important breeding methods to obtain new cultivars with superior mulberry traits in India. However, as a source of plant variation, bud mutation not only selects new varieties directly, but also provides new germplasm for hybrid breeding, thereby making it a simple and effective method for breeding new varieties (Wang *et al.*, 2017; Du *et al.*, 2020). In addition, the special traits generated due to bud mutation can be stably maintained by asexual reproduction methods, such as grafting and cutting and can be inherited by the offspring (Chen *et al.*, 2019).

In this context, we have undertaken the present investigation on a Clonal variant and its mother plant, Vishala, for the comparative characterization of genetic and phenotypic traits to understand the causes of natural clonal variation and its importance in mulberry improvement.

MATERIALS AND METHODS

The Clonal variant was identified from saplings raised from the cuttings of the mulberry cultivar, Vishala, at the seed multiplication plot of the KSSRDI, Bengaluru, and then, the well-grown Clonal variant was pruned for further multiplication. The cuttings were planted in plastic bags and allowed to grow for up to six months. The six-month-old, well-grown fifteen saplings were planted in a field experimental plot with three replications along with their mother plant, Vishala. The Clonal variant and Vishala were grown as tree plants for characterization and comparative studies.

The observations on morphological, growth, and yield parameters were recorded as per set descriptors (Thangavelu *et al.*, 2000). Leaf anatomy and stomatal studies were carried out following the method described by Mallikarjunappa *et al.* (2007). Trichomes were observed by staining the decolorized leaf segments with 1 % Methylene blue for one minute. The leaf moisture content and retention capacity were estimated using tender, medium, and coarse leaves separately, following respective standard protocols (Thangavelu *et al.*, 2000). The chromosome numbers were confirmed from root tip squash by the aceto-orcin method. Meiotic studies were made from anther smears in 1 % aceto-carmin and pollen fertility was estimated by staining in 1 % glycerol-aceto-carmin (Sharma and Sharma, 1980). The chromosomes were screened under a microscope and photomicrographed. The nuclear DNA (2C) amount was estimated by flow cytometry from the relative fluorescence strengths of sample peaks and internal standards as previously described by Yamanouchi *et al.* (2008). Genetic variations between the mother plant and their derived Clone variant were detected using the molecular markers (ISSR) by adopting standard methods (Murray and Thompson, 1980; Williams *et al.*, 1990). The standard deviation ($\pm$) method was used to analyze the data, and mean values are presented.

RESULTS AND DISCUSSION

Clonally propagated crop species are less adaptable to environmental changes than those propagated sexually. As a consequence, clonal variation is the most important source of adaptive potential for vegetatively propagated plants (Lebot *et al.*, 2018). The plants with bud mutation show corresponding changes in external morphology, internal structure, physiology, and biochemistry and show different characteristics from the original plant, such as shoot, inflorescence, and fruit (Liu *et al.*, 2009; Foster and Aranzana, 2018).

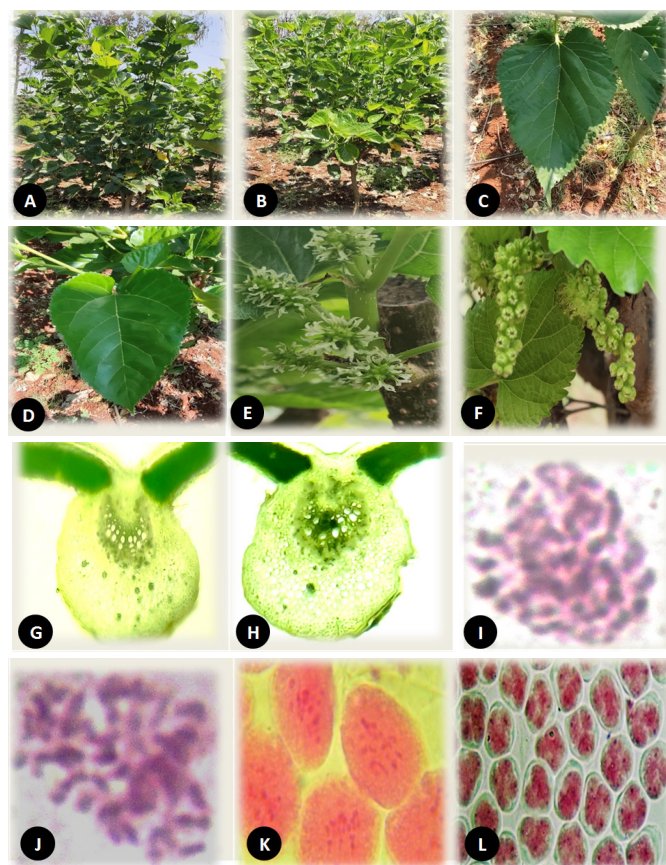


Figure 1: Phenotypic and genotypic characteristics of Vishala variety and its Clonal variant A) Vishala variety; B) Clonal variant; C) Leaf morphology of Vishala; D) Leaf morphology of Clonal variant; E) Female flowers of Vishala; F) Male flowers of Clonal variant; G) T. S. of Vishala leaf blade; H) T. S. of Clonal variant leaf blade; I) Somatic chromosomes of Vishala; J) Somatic chromosomes of Clonal variant; K) Meiotic metaphase – I of Clonal variant; L) Formation of triads, tetrads, and pentads in Clonal variant spore cells.

Table 1: Comparative account of characterization of the mulberry cultivar, Vishala and its Clonal variant

Characteristic	Vishala	Clonal variant	Variation (0/1)*
Morphological traits			
Plant vigor	High	Medium	1
Growth nature	Spreading	Erect	1
Branch nature	Slightly curved	Straight	1
Color of young shoot	Dark green	Green	1
Color of mature shoot	Greyish brown	Greyish brown	0
Stipule nature	Foliateous	Bud scale	1
Stipule duration	Caducous	Caducous	0
Bud attachment	Adhering to branch	Slanting outward	1
Accessory bud	Absent	Present	1
Mature bud size	Medium	Medium	0
Mature bud shape	Acute triangle	Acute triangle	0
Leaf nature	Homophyllous	Homophyllous	0
Lobation type	Unlobed	Unlobed	0
Leaf color	Dark green	Light green	1
Leaf surface	Non -glossy	Strongly- glossy	1
Leaf texture	Coriaceous	Coriaceous	0
Leaf hairiness	Hairy	Glabrous	1
Leaf shape	Broadly ovate	Narrow ovate	1
Leaf base	Cordate	Truncate	1
Leaf margin	Crenate	Crenate	0
Leaf apex	Acuminate	Acuminate	0
Shoot thickness	Thick	Thick	0
Lenticel shape	Elliptical	Elliptical	0
Sex	Gynoeceous	Androeceous	1
Growth and yield traits			Variation (%)
Number of branches/plant	26.71±3.02	35.33±4.02	32.27
Average shoot length (cm)	169.18±5.01	150.62±3.09	-11.15
Inter nodal length (cm)	6.33±1.11	6.34±2.33	0.15
Petiole length (cm)	5.46±2.16	4.32±1.14	-20.87
Leaf length (cm)	17.69±6.14	18.16±5.64	2.65
Leaf width (cm)	16.08±4.24	14.88±6.33	-7.46
Weight of 100 leaves (g)	608.34±3.00	586.71±1.61	-3.55
Leaf yield/plant (g)	811.14±5.12	674.32±4.19	-16.86
Leaf quality traits			
Leaf moisture content (%)	78.63	81.14	3.19
Leaf moisture retention capacity for 6 h (%)	69.46	77.27	11.24
Leaf anatomical traits			
Leaf thickness (µm)	181.36±2.41	153.13±1.37	-15.56
Upper cuticular thickness (µm)	6.54±3.02	8.36±2.07	27.82
Stomatal size (µm)	382.16±2.14	311.81±1.91	-18.40
Stomatal frequency(per mm ² area)	684.27±1.11	413.33±2.05	-39.59
Number of trichomes (per mm ² area)	147.24±3.10	23.27±2.16	-84.74
Nuclear DNA content			
Mean amount of nuclear DNA (pg/C)	0.692 pg (3Cx)	0.686 pg (3Cx)	-0.86
Chromosome number			
Somatic chromosome number	2n = 3x = 42	2n = 3x = 42	NA

*0 = Morphological variation is absent; 1 = Morphological variation is present

Plant growth vigor of medium degree, erect growth habit and straight branching nature with green color on the young shoot and greenish-brown on the mature shoot were observed in the Clonal variant (Figure 1 B), whereas its mother plant, Vishala, exhibited a high degree of vigor, spreading growth habit and slightly curved branching nature with green color on the young shoot and greyish-brown on the mature shoot (Figure 1 A). Mulberry varieties with an erect growth habit and straight branching nature are more suitable for cultivation as trees (Jalaja *et al.*, 2002). Moreover, the stipule nature is foliaceous in Vishala, whereas it is of bud scale in the Clonal variant. Both the genotypes possessed medium-sized buds with an acute triangle shape and caducous stipule duration. But, the bud attachment in the Clonal variant is slanting outward, while in Vishala, it is adhering to the branch (Table 1). It is critical for variety cultivation, selection, and breeding to establish the types, characteristics, and morphological structure of the buds (Petkov, 2007).

The quantity and quality of mulberry leaf yield directly affects cocoon production. Therefore, acquaintance with the nature and characteristics of the mulberry leaf is of importance to the selection and cultivation of varieties (Dandin and Jolly, 1986). The leaves of the Clonal variant (Figure 1 D) are homophyllous, unlobed, of smooth surface, light green and strongly-glossy, whereas the Vishala leaves (Figure 1 C) are unlobed with a slightly rough surface, dark-green and non-glossy. The leaf apex, margin, and surface could be utilized for differentiation among the mulberry varieties (Peris *et al.*, 2014). The leaf hairiness is glabrous in Clonal variant and hairy in Vishala. Contrastingly, the sex expression has completely changed from Vishala to Clonal variant. Vishala is characterized by predominantly female flowers (Figure 1 E), whereas the Clonal variant possesses completely male flowers (Figure 1 F) during all seasons of the year, as in the Jumoinji variety, which was selected and raised from

the shootlets of mulberry, which bears plenty of flowers (Minamizawa, 1997). The Clonal variant was superior in terms of average number of branches/plant and leaf length (32.27 % and 2.65 % more, respectively) to its mother plant. These traits remain positively correlated with leaf yield contributing traits in the mulberry plants (Bindroo *et al.*, 1990).

Leaf anatomical modifications are common in clonally evolved mulberry genotypes to facilitate their growth in different agro-climatic conditions (Kumara *et al.*, 2021). As a consequence, the leaf thickness (-15.56 %), stomatal size (-18.40 %), stomatal frequency (-39.29 %), and number of trichomes (-84.74 %) per unit area are decreased, but the leaf cuticular thickness (27.82 %) is increased in the Clonal variant compared to that of the mother plant (Figure 1 G&H). The lower number of trichomes makes the leaf more acceptable to silkworms (Kesavacharyulu *et al.*, 2004). In mulberry (Jalaja *et al.*, 2003), the adaptive traits of leaves under moisture stress are decreased leaf thickness and stomatal density.

Leaf moisture content and its retention capacity are genetic characteristics and are influenced by available soil moisture and the root proliferation nature of the mulberry variety (Sahu *et al.*, 1997). Concomitantly, leaf moisture content (3.19 %) and its retention capacity (11.24 %) were also recorded higher in the Clonal variant over the cultivar, Vishala (Figure 2). These play a vital role in improving the quality and palatability of mulberry leaves for silkworms by favoring the ingestion and digestion processes and assimilation of nutrients. Both the cuticular wax and stomatal parameters might be involved in regulating water loss in mulberry leaves under field conditions. The variability in moisture retention capacity and cuticular wax characteristics might be important in evaluating and screening mulberry cultivars for increasing silkworm productivity and silk quality (Yu *et al.*, 2015).

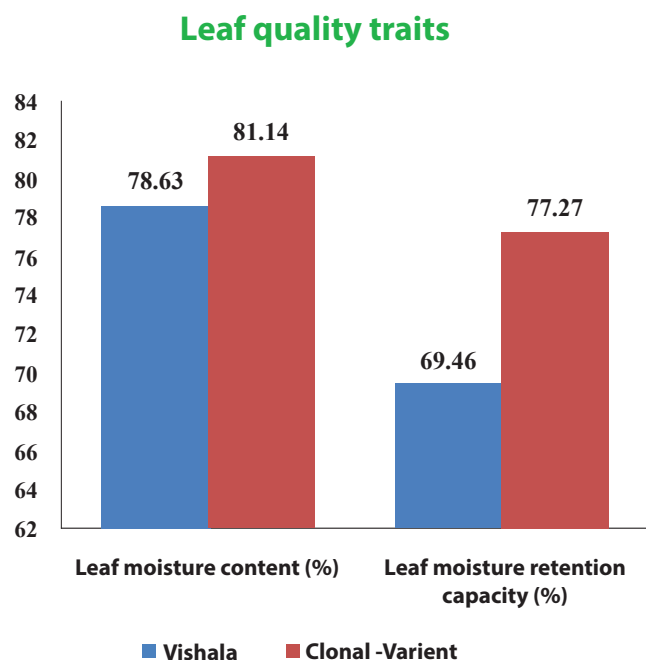


Figure 2: Leaf moisture content and moisture retention capacity in Vishala and Clonal variant

Chromosomal counts, as well as the detection of variation in DNA content, using flow cytometry, can provide complementary information about clonal variation. Many researchers have used information on chromosome and other nuclear component variations to determine clonal variations in the plants (Bairu *et al.*, 2011). During mitotic studies, Clonal variant (Figure 1 J) and cultivar Vishala (Figure 1 I) consistently showed the somatic chromosome number of $2n=3x=42$ in root tip cells and also in shoot tip cells, thus confirming their ploidy level as triploid. In the somatic complement of triploid, three mega chromosomes indicate the presence of three complements (Gill and Gupta, 1979). At prophase, chromosomes showed a varied degree of condensation in the Clonal variant than in its mother plant, Vishala. Chromosome segregation at anaphase and daughter nuclei formations was found to be normal in both the genotypes. There is no cell that shows an increase or decrease in chromosomal complement in the Clonal variant, as reported by Kumara *et al.* (2021) in the clonally selected mulberry cultivars. The regular mitosis found in both shoot and root meristematic tissues clearly indicated the stable nature of this Clonal variant.

According to meiotic investigations performed during microsporogenesis, Clonal variant has $n=21$ gametic chromosomes. The majority of the chromosomes bind themselves into trivalents (14.5) in the triploid, as one would expect. Other forms of relationships have a very low frequency, such as tetravalents (0.5), bivalents (3.6), and univalents (2.4) (Figure 1K). These are the average frequencies of various chromosome connections observed in 20 PMCs. A significant frequency of trivalent occurrence in metaphase I suggests that the elements of triploids are fairly homologous, as is the autotriploid nature of this mother plant, Vishala. This is consistent with the observations made by Basavaiah *et al.* (1990) in induced triploid mulberry varieties.

At anaphase-I, chromosomal separation was extremely uneven, with an unequal number of chromosomes at both poles. As a result of the unequal number of chromosomes in daughter nuclei during meiosis I, subsequent stages of meiosis II were also disrupted. During anaphase-II, separations in different PMCs, two to four laggards are seen. Furthermore, non-synchronous divisions were seen in the meiocytes of a microsporangium. Only a few tetrads had four spores of the same size, but the rest had spores of different sizes (Figure 1 L). The pollen grains were of a wide range of sizes, from 11.15 to 32.64 μm . The resulting tetrads are aberrant and imbalanced because of anomalies in the first and second meiotic divisions, and pollen fertility suffers as a result of chromatin materials being lost (Shafiei and Basavaiah, 2018).

When compared to their mother plant, the Clonal variant showed diversity in phenotypic features but had no significant difference in their nuclear DNA content (Vishala; 0.692 pg and Clonal variant; 0.686 pg). This shows that mutations may cause changes at the allele level rather than changes in nuclear DNA content (Kahrizi *et al.*, 2012). Furthermore, inter-simple sequence repeat (ISSR) analysis clearly revealed the presence of genetic variation between the mother plant and Clonal variant by showing differential DNA polymorphism. The number of amplified fragments of the total 10 primers varied from two to six, with fragment sizes ranging from 200 to 800 kb,

respectively. Out of ten ISSR primers, UBC-812 (V-1&C-1), UBC-815 (V-3&C-3), UBC-834 (V-5&C-5), UBC-844 (V-8&C-8), and UBC-845 (V-9&C-9) having strong resolving power, two genotypes were distinguished (Figure 2). It was found that the banding pattern is not conserved between the mother plant and their Clonal variant, indicating the introduction of genetic variability through asexual reproduction.

The molecular basis of clonal variation has been hypothesized in many clonally propagated plants, such as transposon activity, gene mutation, somatic recombination, and DNA methylation (Breto *et al.*, 2001). In mulberry, significant clonal variability was observed in sex expression and sprouting behavior in the cultivar S-36 due to the activity of a transposable element (Vijayan *et al.*, 2009). However, the Clonal variant showed changes in the majority of the corresponding characteristics of their mother plant, Vishala. Therefore, these discrete variations in genetic as well as morphological traits in Clonal variant might be natural bud mutations (Dzafarov, 1966; Isao, 1979; Minamizawa, 1997; Sopian *et al.*, 2009) that occurred in the mulberry cultivar Vishala. Since mulberry shoots are pruned quite frequently, the chances of the occurrence of mutants are higher (Dandin, 1999).

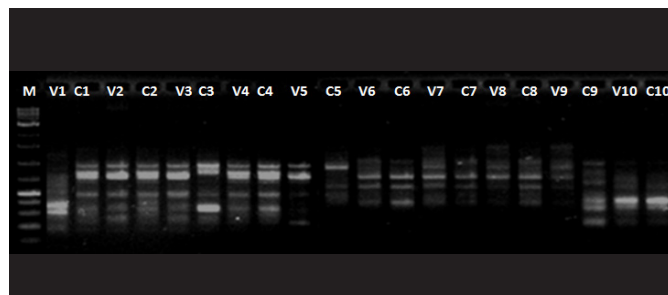


Figure 3: ISSR banding patterns of Vishala (V) and Clonal variant (C)

Conclusion

Clonal selection in mulberry offers an ample scope, as the clonal variety is stable and retains its original traits as in pure line variety. In the present investigation, we have detected improved economic characters in Clonal variant over its mother plant, Vishala with respect to branching nature, leaf length, leaf cuticular thickness, density of stomata and trichomes, leaf moisture retention capacity, and number of branches per plant. Therefore, identification, collection, characterization, and conservation of such natural clonal variants are of paramount importance to enrich the mulberry genetic resources in the germplasm.

Table 2: List of ISSR primers and their sequences

Sl.No.	Sample code	Primer	Nucleotide Sequence (5'- 3')	Size (bp)
1	V-1 & C-1	UBC-812	GAGAGAGAGAGAGAGAA	300–1500
2	V-2 & C-2	UBC-813	CTCTCTCTCTCTCTT	300–1500
3	V-3 & C-3	UBC-815	CTCTCTCTCTCTCTG	300–1500
4	V-4 & C-4	UBC-824	TCTCTCTCTCTCTCG	300–2000
5	V-5 & C-5	UBC-834	AGAGAGAGAGAGAGYT	200–1500
6	V-6 & C-6	UBC-840	GAGAGAGAGAGAGAYT	300–1000
7	V-7 & C-7	UBC-843	CTCTCTCTCTCTCTRA	300–1500
8	V-8 & C-8	UBC-844	CTCTCTCTCTCTCTRC	300–2000
9	V-9 & C-9	UBC-845	CTCTCTCTCTCTCTRG	100–2000
10	V-10 & C-10	UBC-853	TCTCTCTCTCTCTCRT	300–1500

V - Vishala; C - Clonal variant; Y = C and T & R = A/G.

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BIOCHEMICAL ALTERATIONS IN THE ENERGY METABOLISM OF SPINNING AND UNSPUN LARVAE OF SILKWORM, *BOMBYX MORI*

E. Bhuvaneswari*, Shaeza Anjum, Y. Thirupathaiah, G. Mallikarjuna and Babulal

Central Sericultural Research and Training Institute, Mysuru 570008, Karnataka, India.

*Email: bhuvi.ekambaram@gmail.com

ABSTRACT

In silkworm, *Bombyx mori*, cocoon formation is an energy intensive process, involving physiological and biochemical changes. In the present investigation, a comparative study on the energy metabolism in silk gland and haemolymph of spinning and unspun larvae was performed. The energy reserves in the silk gland of unspun larvae have shown a decline in the total carbohydrate levels by 18.79 %, glycogen by 1.94 % and pyruvate by 83.60 % as compared to healthy spinning larvae. However, unspun larvae reserved 60.85 % more of trehalose than spinning larvae. Similarly in the haemolymph too, unspun larvae reserved higher levels of trehalose by 60 % and total carbohydrate by 6.30 %, whereas, pyruvate and glycogen were seen as declined by 3.24 % and 5.88 %, respectively as compared to that of spinning larvae. The other biochemical constituents viz., aspartate (AAT) and alanine (AlAT) aminotransferases, glutamate (GDH) and succinate (SDH) dehydrogenases were found higher in both silk gland and haemolymph of unspun larvae. But, free amino acids were found 94.63 % higher in silk gland of spinning larvae and 13.34 % higher in haemolymph of unspun larvae. The overall trends indicated that both in silk gland and haemolymph, the active participation of AAT and AlAT was associated with the energy demands of the unspun silkworms. This study further confirms the pervasive shuttling mechanism between the biochemical components, viz., carbohydrates and amino acids, which in turn are required for silkworm under adverse conditions, such as non-spinning.

Key words: Aminotransferase, *B. mori*, energy metabolism, haemolymph, spinning, unspun.

INTRODUCTION

The genetic traits of breed, nutrition, environmental factors and disease incidence during silkworm rearing contribute in determining the cocooning ability and its quality. The natural cocoon spinning process in silkworms involves the conformation transition of the liquid silk protein in the silk gland to a fiber. Silk quality not only depends on the breed but also on the physio-biochemical status of

the silkworm during the spinning stage and care taken by the farmers. The factors, such as nutrition, temperature, light and hygienic conditions maintained in the silkworm rearing house play a crucial role in the cocoon spinning process (Rahmathula, 2012). The seasonal differences in the environmental components considerably affect the genotypic expression in the form of phenotypic output of silkworm crop, such as cocoon and shell weight and cocoon shell percentage. The quality of the cocoon determines

the quality of the fiber and fabric. Greater the quality of silk produced, higher the grade. In insects, the inbuilt physio-biochemical mechanisms cope with the outer environmental factors and thus enable them to withstand the adverse conditions while completing its life cycle (Sinclair *et al.*, 2003). Insects need an incessant flow of biochemical molecules as well as energy for their survival during larval stage, cocoon spinning, development of pupa and moth, copulation and finally egg production.

In sericulture, cocoon spinning is an important stage requiring optimum temperature and humidity conditions to build superior quality cocoon; the undesired conditions, such as disease prevalence in the crop impact the quality of cocoon production (Rahmathulla, 2012). Under adverse conditions *viz.*, heavy rain and cold weather, the cocoon spinning process will be extended for three to six days. Non-spinning is a serious threat to the industry (Sahan *et al.*, 2020). Sometimes, the inability of spinning leads to incomplete cocoon shell formation resulting in flimsy, thin shelled cocoon. The prevalence of flimsy cocoon production and non-spinning behaviour in the field have been noticed, as a consequence of environmental changes, such as extreme cold or high temperature and exposure to pesticide residues (Jyothi *et al.*, 2019). Since the silkworm is undergoing metamorphosis during the cocoon spinning process, it is necessary to examine the biochemical aspects in the healthy spinning and unspun conditions to differentiate the alterations in energy metabolism.

Silkworms depend on the biomolecules *viz.*, protein, carbohydrate, lipid *etc.* for the growth and development. During the larval feeding stages, energy reserves are accumulated in the fat body, later to be utilized for their growth and sequence of metamorphic events as well as to provide energy for the developing adult moth to drive copulation and egg laying (Sivaprasad and Bhuvaneswari, 2018). In the life cycle of silkworm, the fifth larval instar is considered as the silk synthesizing phase, where the silk gland grows tremendously and the insects prepare its body with the reserved metabolic compounds for its future metamorphic events. The amount of nutrients stored in

the form of biochemical reserve during the larval stages accommodates stage specific morphogenetic changes as well as pupal and adult metamorphic events due to its non-feeding nature. The health status of the larva determines the spinning behaviour, size of the cocoon, survivability of pupa and moth. If the larvae are exposed to unfavourable condition, it results in non-spinning or partial spinning and even if spun, the cocoon size will be smaller. In such conditions, silkworms adopt for survival rather spinning cocoon by depending on accumulated reserves, such as carbohydrates and amino acids. Hence, the present study enlightens the comparative analysis of the alteration of a few biochemical events associated with the energy metabolism of healthy spinning and unspun larvae.

MATERIALS AND METHODS

Rearing of silkworms and collection of tissues

The present experiment was carried out at Central Sericultural Research and Training Institute, Central Silk Board, Mysuru, India during January to March 2021. The silkworm breed selected for the investigation is a popular bivoltine hybrid (FC1x FC2). Disease free layings (DFLs) were obtained from Silkworm Seed Production Centre, Mysuru, India. The hatched larvae were raised on fresh V1 variety mulberry leaves as per the standard rearing package (Rajan *et al.*, 2001). During the fifth instar, the silkworms have eaten the mulberry voraciously and got ready for spinning by the 7th day. The mature larvae were mounted on plastic collapsible mountages. A few of the healthy spinning larvae (which have initiated cocooning) and unspun larvae (the larvae which could not spin the cocoon even after five days of initiation of spinning) were selected. The spinning-initiated silkworms were distinguished and collected from the rearing bed by the behavioural features expressed *viz.*, non-feeding, active and wandering nature, emitting silk fluid from the spinneret and initiation of cocooning process, and the morphological traits (Figure 1 a, b) *i.e.*, slightly shrunken, transparent and flexible body with pale-yellow colouration compared to the feeding larvae. Haemolymph

appeared clear and yellow in colour. Whereas, the unspun larvae were identified based on the features, such as (Figure 1 c, d) non-feeding, sluggishness, soft and shrunken body, reduced inter segmental length with saggy skin and lack of rigidity. The haemolymph seemed thick, unclear and pale yellow in colour. Both the types of larvae were dissected out in silkworm ringer solution and the tissues, such as haemolymph and silk gland were collected and preserved at - 4°C for biochemical analysis.

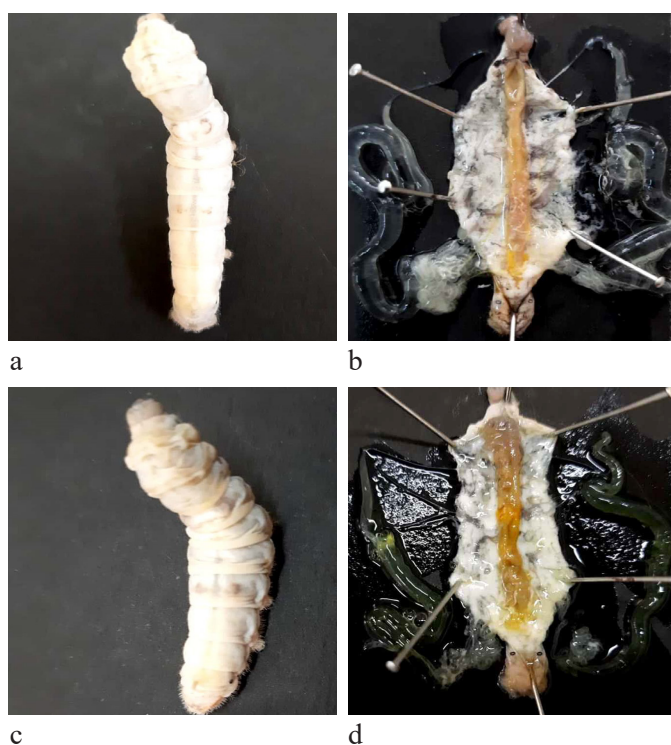


Figure 1: Morphological and anatomical features of healthy spinning (a, b) and unspun (c, d) larvae

Biochemical studies

Biochemical studies were carried out for the tissues of silk gland and haemolymph of healthy spinning initiated larvae and un-spun larvae by following spectrophotometric methods. The levels of total carbohydrates and glycogen were estimated by following the method of Carroll *et al.* (1956) and the values are expressed as mg/g wet weight of tissue. Similarly, estimations of trehalose (Roe, 1955); pyruvate (Friedmann and Hausen, 1943) and free amino acids

(Moore and Stain, 1954) were made and the values are expressed as mg/g wet weight of tissue. The activities of Aspartate aminotransferase (AAT) and Alanine amino transferase (AlAT) were estimated by the method of Reitman and Frankel (1957) and the enzyme activity was expressed as μ moles of pyruvate formed/ mg protein/ hour. The Succinate dehydrogenase (SDH) and the Glutamate dehydrogenase (GDH) activities were estimated by the methods of Nachalas *et al.* (1960) and Lee and Lardy (1965), respectively and expressed as μ moles of formazan formed /mg protein/hour.

Statistical analysis

The experimental data of three replications were statistically analyzed by working out mean, standard deviation (SD), per cent change (PC) and test of significance (t-test) using M.S. Excel platform and online software packages, <https://w.graphpad.com/quickcalcs/ttes> and www.percent-change.com.

RESULTS AND DISCUSSION

Anatomical features of spinning and unspun silkworms

The anatomy of spinning larvae has shown (Figure 1), a pair of silk glands attached to the spinnert, having viscous fluid in the anterior silk gland. The digestive system displayed three different regions; fore gut, mid gut and hind gut filled with rich digestive fluid, which is slightly turbid but no traces of mulberry leaves were observed up to the post mid gut region, but in the hind gut, some excrement particles were observed. The malphigian tubules were found freely floating in the haemolymph. The digestive cells appeared delicate and the gut peritrophic membrane exhibited signs of initiation of histolysis. Internally, rich fat bodies were seen attached to the body wall, showing slight initiation of dissociation into the coelomic region. In the unspun larvae, some of the distinctive anatomical changes were observed in the silk gland, gut, and coelomic organs and in the fat body (Figure 1). A pair of silk glands attached

to the spinneret appeared fragile with degrading cells present in all the three regions (anterior, middle and posterior). The gut also exhibited a fragile appearance with little fluid, showing high rate of histolysis and no traces of food were observed. The malpighian tubules and fat bodies were moderately disintegrated and the cells released into the haemolymph were observed.

Biochemical alterations in the carbohydrate energy reserves

Carbohydrates are the major sources of metabolic energy for plant feeding insects like *Bombyx mori*, which plays a pivotal role in the biochemical process underlying growth and development. The nutritive effects of carbohydrates and selected nutrients are studied either by determining their effects on weight gain and survival or by assaying the rate of conversion to blood trehalose or fat body glycogen which is converted in a rhythmic manner in respect of photoperiod (Bhuvaneswari and Sivaprasad, 2013 a). In addition, the impact of nutrients on *B. mori* is assessed with reference to economic traits of sericulture. A few reports have stated the presence of sugars in the silk cocoons, which may be due to biotransformation of molecules from leaf to larvae and to silk (Mondal *et al.*, 2007; Bhuvaneswari and Sivaprasad 2013 b). It acts as a co-factor of many enzymes including alkaline phosphatase, carbonic anhydrase, glutamate dehydrogenase and alcohol dehydrogenase. In the present investigation, the variation in a few carbohydrate reserves was assessed in the silk gland and haemolymph of healthy spinning as well as unspun larvae of *B. mori*.

The carbohydrate reserves of silk gland of spinning and unspun silkworms were quantified and presented in Table 1 and Figure 2 wherein it reveals significant alterations in a few cases. The four metabolites *viz.*, total carbohydrates, glycogen, trehalose and pyruvate measured 11.120, 4.635, 1.40 and 0.0305 mg/g, respectively in healthy spinning silkworms. Whereas, the corresponding values were 9.030, 4.545, 2.252 and 0.005 mg/g, in unspun silkworms. A reduction in the total carbohydrates to the extent of 18.79 % was detected

in the silk gland of unspun larvae. Such a drop in the total carbohydrate contents of silk gland reveals breakdown of carbohydrates and a corresponding enhancement in the metabolic efficiency of the silk gland and other tissues of the larvae to meet the energy demand under stress conditions as well as to extend its survival (Manohar Reddy, 2004). Glycogen serves as the major food reserve in insects which undergoes significant changes during the larval instar and metamorphosis in silkworms (Simex and Kodrik, 1986). The amount of glycogen in an organ indicates the end result of the processes of glycogenesis and glycogenolysis. The utilization of glycogen mainly depends upon the nutritional demand of the insect body (Lakshmikantham and Bharathi, 2014). In the silk gland, during spinning time, the increased level of glycogen *i.e.*, 4.635 mg/g, might be due to an active movement of haemolymph glucose to silk gland via glycogenesis (Thompson, 2003). But in unspun larvae, a declined level to the tune of 1.941 % has been observed due to reversal of glycogenesis *i.e.* glycogenolysis initiation in respect of energy demand in the silk gland. Trehalose is an important metabolite in insects; a major carbohydrate compound synthesized principally by the fat body and its quantity varies among the tissues during the growth, metamorphosis, diseased and stress conditions (Saito, 1963).

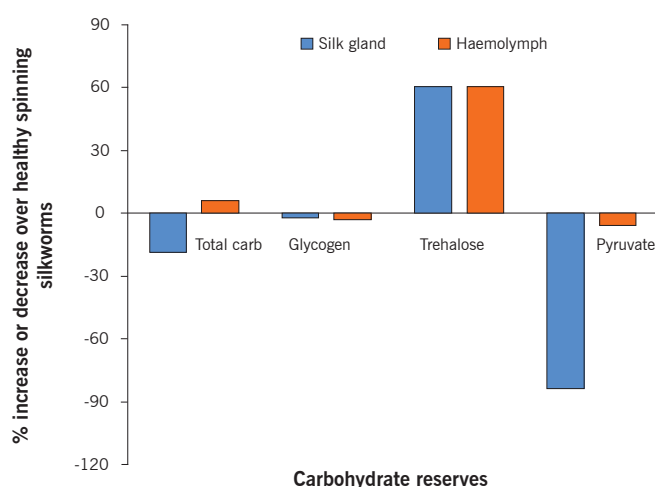


Figure 2: Per cent changes in the carbohydrate energy reserves in the silk gland and haemolymph tissues of unspun silkworm larva over the spinning larva

In the silk gland, the increased level of 60.85 % of trehalose observed in the unspun larvae (Figure 2) might be due to degradation of reserved carbohydrates in the coelomic organs and its mobilization towards the silk gland to meet the energy demands. An unspun larva thrives to survive and hence, modulate the biochemical constituents levels in different organs based on the demand and protect the structural integrity of the cells. Trehalose enhances stress resistance as a stabilizer and protectant of proteins and membranes due to its physical, colligative and chemical properties. Decrease in pyruvate and increase in the carbohydrate metabolism may also be attributed for elevation in the glycolytic pathway (Bricteux *et al.*, 1959; Mahaswaramma, 1994).

silkworms (Table 1 and Figure 2). Whereas, the respective values were 86.00, 82.00, 17.6 and 0.0032 mg/ ml in unspun conditions. Silkworms have an open circulatory system consisting of circulatory fluid; haemolymph with depository of nutrients, energy reserves and metabolic intermediates for all organs and cells (Banno *et al.*, 2010). The alterations are largely caused by the ongoing metamorphic activity as well as the synthetic activity coupled with the operation of an exchange shuttle between the haemolymph and other tissues. In healthy spinning larvae, the decline in the level of carbohydrates of the haemolymph may be due to excess utilization of carbohydrate molecules to meet the high energy demand

Table 1: Carbohydrate energy reserves in the silk gland (mg/g) and haemolymph (mg/ml) of spinning and unspun larvae of *B. mori*

Silkworm tissue	Silkworm larva	Total carbohydrates	Glycogen	Trehalose	Pyruvate
Silk gland	Spinning	11.120 ± 0.351	4.635 ± 0.330	1.400 ± 0.336	0.0305 ± 0.003
	Unspun	9.030 ± 0.367 NS (-18.795)	4.545 ± 0.754 NS (-1.941)	2.252 ± 0.330 * (60.857)	0.005 ± 0.005 * (-83.606)
Haemolymph	Spinning	80.900 ± 0.886	84.750 ± 0.718	11.000 ± 0.267	0.0034 ± 0.036
	Unspun	86.000 ± 1.574 * (6.304)	82.000 ± 0.619 * (-3.24)	17.6 ± 0.134 * (60.00)	0.0032 ± 0.0289 NS (-5.882)

*Statistically significant (P<0.005), NS- Statistically not significant.

Values represent the mean ± standard deviation of three separate observations. For each observation, tissue samples from 10 to 15 larvae were pooled. The values in brackets are per cent change for unspun larvae, calculated considering healthy spinning larvae as control.

Significantly, the decline in the level of pyruvate in the unspun larvae by 83.60 % indicates up-regulation of glycolysis and TCA cycle to stock energy and amino acids for biosynthesis of body proteins (Asakura *et al.*, 1988).

In the case of haemolymph, the total carbohydrates, glycogen, trehalose and pyruvate recorded 80.90, 84.75, 11.00 and 0.0034 mg/ ml, respectively in healthy spinning

from the silkworm to initiate cocoon spinning (Snehal *et al.*, 2021). Reversely, slight increase in the concentration of total carbohydrate levels in the haemolymph of unspun silkworm larvae by 6.304 % clearly denotes its physio-biochemical changes in the system. On the other hand, the depletion in carbohydrate reserves in the silk gland, digestive system and fat bodies may also cope with

its elevated concentration in haemolymph. In the healthy spinning larvae, the glycogen and the pyruvate content is a little high but in unspun larvae, its concentration slightly decreased by 3.24 % and 5.88 %, respectively, may be due to up-regulation of glycolysis and TCA cycle to reserve energy and amino acids for biosynthesis to withstand the stress condition (Zhou *et al.*, 2015). But the trehalose level getting increased by 60 % with the declining of glycogen content in the unspun larvae of silkworm is indicative of stockpiling of trehalose (at the expenses of nutrients) to manage the undesired condition (Figure 2). Trehalose is the principal insect sugar that accounts for 23 % of the total carbohydrate content of the body and the concentration is regulated in a tissue specific manner (Bhuvaneswari and Sivaprasad, 2012). In healthy spinning larvae, trehalose depletion together with the significant elevation of glycogen indicated conversion of trehalose into glycogen and glucose, subsequently consumed via glycolysis to generate energy to be utilized for silk-spinning and metamorphosis since larvae stop taking in nutrients during this period.

Biochemical alterations in the amino acids; AAT, AIAT, GDH and SDH activity levels

The silkworm, *B. mori*, derives almost all the nutrients required for its growth and development from the mulberry leaves. In this regard, amino acids play an important role in the insect's physiology (House, 1974). The concentration of free amino acid is known to be influenced by various factors, such as the changing dietary condition, proteolytic action of the molting fluid, age and climatic factors (Rahmathulla, 2012). Amino acids not only act as precursors for proteins required for silk synthesis but also participate in a variety of functions. More importantly, they get converted as carbohydrates and serve as glycogenic amino acids. One such mechanism is transdeamination in which three enzymes, viz., AAT, AIAT and GDH play a vital role and metabolize freely available, but selective amino acids towards providing the carbon skeleton for the generation of glucose that drives the metabolic machinery during silkworm metamorphosis (Li and Xu, 1982). In the present investigation, alterations of amino acids and its associated enzymes during spinning as well as unspun conditions were studied (Table 2 and Figure 3).

Table 2: Free amino acids (mg/g in silk gland and mg/ml in haemolymph); AAT, AIAT, SDH and GDH activity levels (μ moles) in spinning and unspun larvae of *B. mori*

Silkworm tissue	Silkworm larva	Free amino acids	AAT	AIAT	SDH	GDH
Silk gland	Spinning	11.941 $\pm$ 0.919	0.0185 $\pm$ 0.004	0.0180 $\pm$ 0.011	0.0095 $\pm$ 0.001	0.0222 $\pm$ 0.0025
	Unspun	0.641 $\pm$ 0.946* (-94.63)	0.0315 $\pm$ 0.0015* (70.27)	0.036 $\pm$ 0.004* (100)	0.01725 $\pm$ 0.002* (78.94)	0.0267 $\pm$ 0.0005* (20.27)
Haemolymph	Spinning	16.318 $\pm$ 0.227	0.206 $\pm$ 0.016	0.265 $\pm$ 0.010	0.18575 $\pm$ 0.024	0.408 $\pm$ 0.019
	Unspun	18.496 $\pm$ 0.555* (13.34)	0.278 $\pm$ 0.024* (6.92)	0.423 $\pm$ 0.022* (59.62)	0.31025 $\pm$ 0.019* (40.32)	0.6477 $\pm$ 0.013* (58.57)

*Statistically significant (P<0.005)

Values represent the mean $\pm$ standard deviation of three separate observations. For each observation, tissue samples from 10 to 15 larvae were pooled. The values in brackets are per cent change for unspun larvae, calculated considering healthy spinning larvae as control.

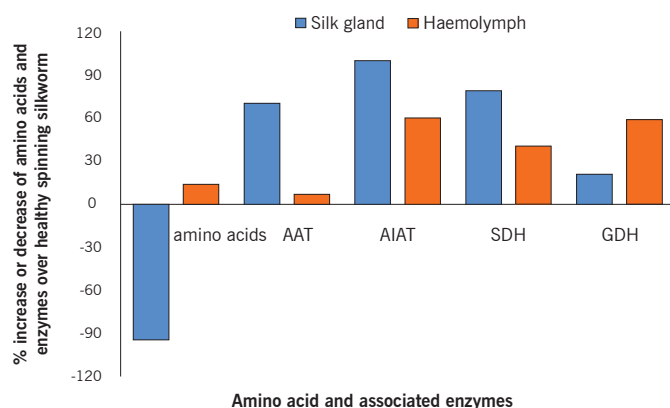


Figure 3: Per cent changes in the free amino acids; AAT, AIAT, SDH and GDH activities in the silk gland and haemolymph tissues of unspun silkworm larva over the spinning larva

In silkworm, the requirement of amino acids varies with the physiological aspects. The larvae during the fifth instar, requires the proteinogenic amino acids for the silk gland, but during the unfavourable conditions, to lift the survivability, it depends on the reallocation of amino acids in the energy metabolism rather than silk protein synthesis through transdeamination process. In the present investigation, the metabolites *viz.*, amino acids, and its associated enzymes were estimated in the silk gland in respect of spinning and unspun larval tissues. The amino acid concentration was 11.941 mg/g in spinning larvae and 0.641 mg/g in unspun larvae. The enzymes *viz.*, AAT, AIAT, SDH and GDH measured 0.0185, 0.0180, 0.0095 and 0.0222 μ moles, respectively in healthy spinning silkworms. Whereas, in unspun silkworms, the corresponding values were 0.0315, 0.0365, 0.0172 and 0.0267 μ moles, respectively (Table 2). In the silk gland tissue, during cocoon spinning condition, the free amino acid content was detected as 11.941 mg/g and in the unspun larvae, it declined to 0.641 mg/g *i.e.*, to the tune of 94.63 %, the quantitative variation in this biochemical constituent clearly indicates that the larvae were preparing amino acids for biosynthesis of silk protein in later period of fifth instar (Kaplan, 1994). In unspun larvae, the shuttles of free amino acids to the energy cycle have been initiated. Asparagine is one of the main amino acids in sericin and can readily be fed into

TCA cycle via oxaloacetate. Similarly, in insect, proline can be utilized more than a dietary stuff and is being considered an energy source in readily available form. It does not require carrier proteins and serves as carbon shuttling molecule between the muscle, fat body and haemolymph. Proline is an effective metabolic fuel that acts as a sparker of the TCA cycle through oxidation. It can create an energy of 0.52 mol of ATP/ g, which makes so similar to lipids (0.65 mol/ g) than the carbohydrates (0.18 mol/ g). Changes in asparagine and proline ought to be considered with a view of biochemical alterations in the complex metabolic network of the silkworm (Bursell and Downer, 1981).

The aminotransferases (AAT and AIAT) mediate the transfer of amino groups of the amino acids to oxoglutarate, oxaloacetate and pyruvate to form glutamate, aspartate and alanine, respectively (Lehninger, 1978). Degradation of proteins in stressed condition increases amino acid pool and also suppresses protein synthetic capabilities of silkworm. The free amino acids may have been fed into the TCA cycle as ketoacids by transdeamination hence, the activities of transaminases (AAT and AIAT) are also on the increased side (Nath, 2000), which is clearly exhibited in the unspun silkworm larvae through an elevation of AAT by 70.27 % and AIAT by 100 %. The SDH (78.94 %) and GDH (20.27 %) activities also showed similar trends as transaminases in this investigation. GDH is an enzyme of great importance in the intermediary metabolism of amino acids and acts as a general marker of amino acid oxidations in the tissues (Rodwell, 1988). The GDH is also known to catalyze the inter conversion of glutamate and α -ketoglutarate and acts as a link between amino acid and carbohydrate metabolism. In other words, glutamate and GDH have a unique role in amino group transfer (Sailaja, 1999), this enzyme ensures availability of the α -ketoglutarate for the citric acid cycle. Noteworthy, the enhanced activity of GDH by 20.27 % in silk gland indicates increased oxidation of glutamate in the unspun larvae. The increase in SDH activity (78.94 %) in silk gland is in synchrony with glycolytic pathway; which indicates that TCA cycle

is also elevated in tune with pyruvate production under the unfavorable conditions and this might be due to high energy demand of the silkworm (Rajasekhar, 1993).

Haemolymph, functions as a reservoir tissue in the supply of pooled amino acids derived from different organs. Physiological significance of amino acids in haemolymph seems to have varied roles as potent buffers, contributor for protein synthesis and as energy source. The variation in the qualitative and quantitative status exhibits the correlation between the new structure formation in the adult or the reserved material kept for the survival during unfavourable condition or disease incidence. In haemolymph, the free amino acid concentration was 16.318 mg/ml in spinning larvae and 18.496 mg/ml in unspun larvae. The enzymes *viz.*, AAT, AIAT, SDH and GDH measured 0.206, 0.265, 0.185 and 0.408 μ moles, respectively in healthy spinning silkworms. Whereas, they measured 0.278, 0.423, 0.310 and 0.647 μ moles, respectively in unspun silkworms (Table 2 and Figure 3). In holometabolous insects, like silkworm, withstanding larval stage being an energy intensive process, necessitates the alteration of biochemical constituents. In healthy spinning larvae, the sequence of processes of histolysis, histogenesis, differentiation and morphogenesis are driven through endocrine system and ultimately re-architecture of insect structures from larva to pupa and finally to moth but, abnormal variations are noted in the unspun larvae (Hemalatha *et al.*, 2014). The free amino acids level is increased in unspun larvae by 13.34 % compared to healthy spinning larvae due to existence of dynamic exchange mechanism of biochemical constituents among various tissues of silkworm (Nagata and Kobayashi, 1990). Similarly, elevation in the AAT (6.92 %) and AIAT (59.62 %) levels (Figure 3) indicated an active transportation of amino acids which provide keto acid to serve as precursors in the synthesis of essential constituents under stressed conditions (non-spinning). Noteworthy, the elevated SDH (40.322 %) and GDH (58.57 %) activity in the unspun larval haemolymph, could be due to the

disruption of mitochondrial organization or increment in the production of glutamate as a result of increased AIAT and AAT activities demand (Rajasekhar 1993; Hemavathi *et al.*, 2004). It is clearly understood that, the physio-biochemical processes are directed towards the single objective of generating energy resources like amino acids during stressed condition via AAT, AIAT, SDH and GDH activity.

Conclusion

Our findings confirm the pervasive shuttling mechanism between the biochemical components, such as carbohydrates and amino acids, which in turn are required under adverse conditions of the silkworm life cycle. Due to the energy requirements, the reserved carbohydrate glycogen is converted to trehalose, a major insect blood sugar that accompanies the survival. Notably, the significantly increased trehalose levels in the haemolymph of unspun larvae clearly revealed the importance of carbohydrates and the reciprocating mechanism that they endure under the available resources. Correspondingly, the excess availability of free amino acids and its transportation from the silk gland and other tissues; besides its physiological functions mainly related to the energy cycles, the increased activity levels of AAT, AIAT, SDH and GDH in unspun larvae have evidently shown the shift gear in the transdeamination mechanism, an alternative energy generation approach in unspun silkworms.

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TRENDS AND DRIVERS OF IMPORT DEMAND FOR RAW SILK IN INDIA

P. Kumaresan

Central Silk Board, BTM layout, Madiwala, Bengaluru 560068, India.

Email: kumaresanp.csb@nic.in

ABSTRACT

India has been importing raw silk for many years and has become the largest importer as the domestic production of raw silk could not meet the industry requirements. The quantum of raw silk imports increased drastically after the free imports of raw silk were allowed during 2001, but with the increase in raw silk production, it has reduced in recent years. China is the primary source of imports of raw silk. However, the imports of raw silk from Vietnam have also been on the rise. The regression analysis of data on different variables indicated that domestic silk production and customs duty negatively influenced the growth in raw silk imports.

Key words: Imports, raw silk.

INTRODUCTION

Sericulture is one of the oldest industries in India that dates back several centuries. The ancient Indians were fully aware of silk and the techniques for reeling silk from wild silkworms (Ray, 1995). India also participated substantially in the global silk trade, which has gone for a record period of about 3,000 years (Liu, 1988; Debin, 1998).

India dominated in the trade of raw silk from the first half of the 17th century to the 19th century (Guha and Choudhury, 2001). The share of Indian raw silk in the world markets during 1825/30 was 18.1 % against the 11.7 % share of Chinese raw silk (Kaneko, 2006). But as a result of a decline in the Indian silk industry especially in Bengal, India's raw silk imports began to exceed the exports from the 1870s losing both the export and domestic markets (Kaneko, 2006). The decline in raw silk production could be attributed to a combination of

reasons, such as a reduction in demand for silk goods due to large scale imports of fancy cotton goods from England, cessation of silk trade by the East India Company in 1835, loss of support for the industry from the colonial government and unfavorable industrial and trade policies (Bag, 1989; Kaneko, 2006; Roy, 2015; Hoque, 2020). Eventually, the share of Indian raw silk in the global trade declined to 0.2 % in 1926 (Federico, 1997).

Various measures taken during the post-independence era by both central and state governments for promoting sericulture resulted in an increase in raw silk production in the country from 1,211 MT in 1950 to 35,820 MT in 2019-20 at a compound annual growth rate of 4.96 %. As the demand for silk increased concomitantly, the import of raw silk also grew at 3.38 % during the same period to reach 3,315 MT in 2019-20 from 320 MT in 1950, making the Indian silk industry rely on imported silk unfailingly.

Protectionist measures against imports of silk

The Indian sericulture industry has been enjoying various protectionist measures and government concessions for many years. The government constituted tariff boards/commissions during 1933, 1938, 1943, 1951, and 1954 to conduct inquiries on the protections required for safeguarding the Indian sericulture industry from the imports of silk. The boards/commissions recommended for imposing tariffs on imported raw silk and value-added products and other protection and concession measures to safeguard the interest of the domestic sericulture industry.

Silk imports in the earlier years were allowed through certain specified agencies and distributed to actual users. Later on, imports were linked with exports, and replenishment (REP) licenses were issued to exporters for the imports of silk for the value-added exports of silk products. Subsequently, in the mid-1980s, exporters were allowed to import raw silk and other silk yarns, such as dupion, spun silk yarn, noil silk yarn, and tasar yarn without paying customs duty against certain export obligations and value addition norms specified under the Duty Exemption Scheme (DES). The free imports of raw silk without any restriction have been allowed under Open General License (OGL) since 2001.

Higher tariffs of 35 % and above were levied on the imported raw silk before 2001 due to the political and economic factors and the perspective of looking at high employment generating potential of the industry (Joseph and Kamath, 2017). The basic customs duty on raw silk was reduced drastically from 35 % to 5 % in 2011-12 (Table 1). In the subsequent period, the tariffs were pegged in a range between 5 % and 15 %. The customs duty reductions in 2011 and 2015 were not perceived positively by the Indian sericulture industry resulting a kneejerk reaction of crash in mulberry cocoon and raw silk prices (fibre2fashion.com, 2011; Khan, 2015).

Table 1: Customs duty on raw silk from 2001-02 to 2021-22

Year	Basic customs duty (%)
2001-02	35
2002-03 to 2010-11	30
2011-12 to 2012-13	5
2013-14 to 2014-15	15
2015-16 to 2019-20	10
2020-21 to 2021-22	15

Upward and downward revisions of tariff were due to the pressure of the weavers on one side and the farmers and reelers on the other side, on the government to adjust the duty structure in favour of them. The weavers demand for customs duty reduction, which facilitates cheaper availability of good quality imported raw silk. On the other hand, the sericulture farmers and reelers oppose the cheap silk imports in protest of its adverse effect on domestic silk prices.

When the restrictions on the import of raw silk were removed during 2001, imports of raw silk and silk fabrics at cheaper rates from China increased drastically. Umesh *et al.* (2009) reported that the rate of growth in silk imports increased during the post-trade liberalization period and the competitiveness in the production of raw silk reduced. In view of this, the Indian government imposed anti-dumping duties on imported Chinese raw silk and silk fabrics to protect the domestic silk industry from the cheaper imports. The details of anti-dumping measures taken by the Indian government on Chinese raw silk and silk fabrics are shown in Table 2. The anti-dumping duty imposed on raw silk during 2003 continued in different forms up to 2020, whereas the anti-dumping duty on silk fabrics was released during December 2015. Mouzam *et al.* (2016) reported that implementation of anti-dumping measures had put an end to the unfair advantages gained by Chinese raw silk and in turn helped to prevent the decline of the domestic industry.

Table 2: Details of anti-dumping duty imposed on Chinese raw silk and silk fabrics

Product	Anti-dumping duty	Period
Mulberry raw silk of 2A grade and below	Reference price of US\$ 27.97/kg of raw silk	January 2003 to January 2008
	Reference price of US\$ 37.32/kg of raw silk*	January 2008 to January 2014
Mulberry raw silk of 3A grade and below	US\$ 1.85/kg	December 2015 to December 2020
Silk fabrics of weight ranging from 20 to 100 g/m	Reference price ranging between US\$ 1.66 & 4.55/m according to fabric weight	November, 2006 to May 2011
	Reference price ranging between US\$ 2.08 & 7.59/m according to fabric weight*	December, 2011 to December, 2015

** - levied based on sunset review

Statement of the problem

Though India is the second-largest producer of raw silk in the world, it is in a precarious position as the largest consumer and importer of raw silk. The raw silk is imported not only to suffice the supply-demand gap but also for its quality. The power loom weavers prefer the imported silk over domestic silk considering more uniformity, few winding breaks, and low degumming losses (Naik and Babu, 1992). But the prices of imported raw silk influence the domestic raw silk prices, which in turn affect the domestic cocoon prices (Tikku, 1999; Rajesh, 2011; Halagundegowda *et al.*, 2021). The growth in the volume of imported silk affects the domestic silk production in general and in reaching the goal to become self-sufficient in silk production by promoting the import substitute bivoltine silk production in the country in specific.

Though many studies have touched upon different aspects of imported silk, there is hardly any comprehensive study that specifically analysed the impact of raw silk imports on the Indian sericulture industry during the post-liberalization period. In this context, it is imperative to analyse the growth and pattern of imported silk and its consequences on the domestic sericulture industry,

for formulating strategies and development plans for the country.

METHODOLOGY

The present study is purely based on year-wise time series data collected for a period from 1990-91 to 2019-20. The year 2019-20 was considered as a reference year for the study because 2020-21 presented an abnormal scenario due to the COVID-19 pandemic. The statistics on global silk production, world and India's trade on raw silk, and other required information used in the study were collected from the COMTRADE database of the United Nations and publications of the International Sericultural Commission (ISC) and Central Silk Board, Government of India, Bengaluru.

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

$$Y = ab^t e, \quad \dots(1)$$

Where,

Y = Dependent variable for which growth rate is estimated,

a, b = Regression coefficients,

t = Time variable, and

e = Error term.

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

$$\ln Y = \ln a + t \ln b + \ln e_t \quad \dots(2)$$

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

$$g = (\text{Anti log of } \ln b - 1) \times 100 \quad \dots(3)$$

The factors influencing the imports of raw silk were identified using a regression model, which can be algebraically stated as:

$$Y = a + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5 + \mu \quad \dots(4)$$

Where,

- Y = Raw silk imports (MT)
- X₁ = Raw silk production in India (MT)
- X₂ = Average price of imported raw silk (₹/kg)
- X₃ = Average price of domestic raw silk (₹/kg)
- X₄ = Customs duty on imported raw silk (%)
- X = Dummy variable for anti-dumping duty imposed on imported Chinese raw silk (1 for the tariff period and 0 for the non-tariff period)
- a = Intercept

b_i = Regression coefficient of the ith variable
(i = 1 to 5)

μ = Random term

The regression analysis was carried out for a time span of 30 years (1991-92 to 2020-21), using the ordinary least squares (OLS) method.

RESULTS

Global supply of raw silk

The global raw silk production declined from 1.30 lakh MT in 2011 to 1.09 lakh MT during 2019 at a compound growth rate of -3.32 % (Table 3). China and India are the major silk-producing countries, when put together accounting for about 95 % of the global raw silk production. But the global silk market is dominated unambiguously by China as the largest producer and supplier of raw materials (raw silk) and finished goods (Roy, 2016). The silk production grew at a compound annual growth rate of 10.00 % and 6.73 %, respectively, in Uzbekistan and Vietnam during the last decade. However, they have not yet emerged as sizable silk producers.

Table 3: Global raw silk production from 2011 to 2019

Country	Raw silk production (MT)					CAGR (%)
	2011	2016	2017	2018	2019	
China	104000	158400	142000	120000	68600	-6.35
India	23060	30348	31906	35468	35820	5.07***
Uzbekistan	940	1256	1200	1800	2037	10.00***
Vietnam	500	523	520	680	795	6.73***
Thailand	655	712	680	680	700	0.62**
Brazil	558	650	600	650	469	-2.57
Others	573	623	601	577	690	2.29***
World	130286	192512	177507	159855	109111	-3.32

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

Global trade in raw silk

Among the major silk producers, China, India, and Thailand have a strong production base of raw silk and facilities for converting the raw silk into fabrics and other finished products for domestic as well as export markets. On the other hand, countries, such as Brazil, Uzbekistan and Vietnam, produce raw silk mainly for export purpose. With a broad production base, China accounted for about 64 % of the global trade in raw silk during 2019 (Table 4). But the exports of raw silk reduced gradually at a rate of -6.00 % per annum from 7,122 MT in 2011 to 4,305 MT in 2019, as China has been shifting focus over the years on exports of finished products rather than raw materials. Kui (2010) reported a changing structure of the silk trade from raw silk to value-added products over a period of

time. Vietnam and Uzbekistan have been emerging as reliable raw silk suppliers in recent years but in small quantities. Though Italy does not produce raw silk, it re-exports around 350 MT of raw silk every year, which is imported from other countries.

India is the largest importer of raw silk and imported around 48 % of the global raw silk traded during 2019 (Table 5). Many European countries *viz.*, France, Italy, Romania, Germany, the United Kingdom (UK), Switzerland, *etc.*, do not produce raw silk but import raw silk and convert it into finished products for their domestic and export requirements. It can be inferred from Table 5 that the major raw silk importing countries reduced their raw silk imports during the last decade.

Table 4: Major raw silk exporting countries during the period of 2011 to 2019

Country	Raw silk exports (MT)					CAGR (%)
	2011	2016	2017	2018	2019	
China	7122	6927	5936	4581	4305	-6.00***
Vietnam	32	334	507	496	859	66.85***
Uzbekistan	-	-	652	593	782	-
Italy	362	342	321	340	376	0.56
Others	1492	1571	1871	439	441	-13.12*
World	9008	9174	9287	6449	6763	-3.52**

*** Significant at 1 %; ** Significant at 5 %; * Significant at 10 %.

Table 5: Major raw silk importing countries during the period of 2011 to 2019

Country	Raw silk imports (MT)					CAGR (%)
	2011	2016	2017	2018	2019	
India	5597	3757	4003	2728	3264	-5.32**
Romania	1989	1610	1076	1542	1225	-3.46
Italy	711	710	607	660	640	-1.72
Vietnam	1156	902	725	620	566	-3.14
Iran	302	393	292	325	428	-1.11
Japan	563	395	456	303	292	-8.24***
France	113	159	185	236	131	0.91
Germany	114	104	162	89	80	-3.40
North Korea	533	310	271	184	138	-14.32***

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

India's import of raw silk

The details of raw silk imports of India during 2000-01 to 2019-20 are shown in Table 6. The raw silk imports increased drastically from 4,713 MT in 2000-01 to 9,054 MT in 2002-03 and remained above 7,000 MT during 2002-03 to 2009-10 except in 2006-07. In this period, the raw silk imports grew at a compound rate

of 2.02 % and the value of raw silk imports increased by 6.09 % per annum. However, the raw silk imports registered a negative growth of -6.47 % in volume but a modest positive growth of 1.22 % in value during the period between 2010-11 and 2019-20. The unit price of imported silk grew at 8.23 % in the second period, which could mainly be attributed to the increase in the prices of imported silk.

Table 6: India's domestic silk production and raw silk imports during 2000-01 to 2019-20

Year	Domestic production of raw silk (MT)		Raw silk imports		
	Bivoltine silk	Total silk	Quantity (MT)	Value (₹ crores)	Unit price (₹/kg)
2000-01	573	15857	4713	475	1008
2001-02	840	17351	6808	625	918
2002-03	685	16319	9054	647	715
2003-04	609	15742	9258	628	679
2004-05	893	16500	7948	607	764
2005-06	971	17305	8383	780	930
2006-07	1100	18475	5565	673	1210
2007-08	1175	18320	7922	734	927
2008-09	1250	18370	8392	903	1076
2009-10	1200	19690	7338	934	1272
2010-11	1400	20410	5820	928	1594
2011-12	1685	23060	5683	1112	1956
2012-13	1984	23679	4959	1239	2498
2013-14	2559	26480	3260	896	2750
2014-15	3870	28708	3489	971	2783
2015-16	4613	28523	3529	1006	2851
2016-17	5266	30348	3795	1092	2878
2017-18	5874	31906	3712	1218	3282
2018-19	6987	35468	2785	1041	3739
2019-20	7009	35820	3315	1149	3467
CAGR (%)					
Period I (2000-01 to 2009-10)	8.85***	2.11***	2.02	6.09***	3.98*
Period II (2010-11 to 2019-20)	21.57***	6.23***	-6.47***	1.22	8.23***
Entire period (2000-01 to 2019-20)	14.83***	4.72***	-5.25***	4.22***	9.94***

*** Significant at 1 %; * Significant at 10 %.

Since the imported mulberry silk is bivoltine in nature, boosting up the quality as well as quantity of domestic bivoltine silk production could be the best means to substitute it. The production of bivoltine silk grew at a rate of 8.85 % in India and the total silk production at 2.11 % during 2000-01 to 2009-10, when the imports of raw silk were very high. In the subsequent period, while the bivoltine silk production increased substantially along with the total silk production, the raw silk imports moved to a negative growth trajectory. Table 5 also indicates that the raw silk imports increased when there was a decrease in the unit prices of imported silk.

Commodity structure in raw silk imports

India's raw silk imports comprise mulberry, dupion, and non-mulberry silks (Table 7). Mulberry silk constituted the largest segment (82.65 %) in total raw silk imports, followed by non-mulberry silks (15.78 %) and dupion silk (1.57 %) during 2019-20. The mulberry raw silk imports decreased from 3,448 MT in 2000-01 to 2,740 MT in 2019-20 at a rate of -5.27 % per annum. The dupion and non-mulberry silk imports also witnessed negative growth of -9.61 % and -4.52 %, respectively.

Table 7: Types of raw silk imported by India from 2000-01 to 2019-20

Year	Raw silk imports (MT)				% share		
	Mulberry	Dupion	Non-mulberry	Total	Mulberry	Dupion	Non-mulberry
2000-01	3448	575	690	4713	73.16	12.20	14.64
2006-07	3517	1440	608	5565	63.21	25.87	10.92
2011-12	4374	728	581	5683	76.97	12.82	10.22
2016-17	3111	233	451	3795	82.00	6.13	11.87
2017-18	1635	1616	462	3712	44.03	43.53	12.44
2018-19	1751	559	475	2785	62.88	20.08	17.05
2019-20	2740	52	523	3315	82.65	1.57	15.78
CAGR (%)	-5.27***	-9.61***	-4.52***	-5.25***			

*** Significant at 1 %

Sources of imported silk

China has been the primary source of raw silk for many years (Table 8). Chinese raw silk accounted for more than 90 % of total raw silk imports till 2014-15. But China's share in total imports has reduced in recent years, as the raw silk imports from Vietnam have increased drastically after 2015-16. While the raw silk imports from Vietnam recorded a high positive growth rate of 39.15 % during the period between 2000-01 and 2019-20, the imports from China registered a negative growth of -6.24 %, which is less than the overall growth in silk imports (-5.25 %).

As Vietnam enjoys the Most Favoured Nation (MFN) status with India to promote free trade between two countries, raw silk and other silk items imported from Vietnam attract no customs duty. Therefore, the silk imports from Vietnam increased steeply after 2016-17. Vietnam's raw silk exports to India were more than its domestic production for the last three years, which indicates that the Chinese silk was re-exported by Vietnam to India taking advantage of duty-free exports of silk goods to India. The Times of India (2019) has reported that increased imports of silk fabrics from Vietnam due to duty-free imports affect the domestic weavers.

Table 8: Quantum of raw silk imported from China and Vietnam during 2000-01 to 2019-20

Year	Raw silk imports (MT)				% share		
	China	Vietnam	Others	Total	China	Vietnam	Others
2000-01	4333	2	378	4713	91.93	0.04	8.03
2006-07	5381	10	174	5565	96.70	0.18	3.12
2011-12	5166	16	501	5683	90.90	0.28	8.82
2016-17	3008	482	305	3795	79.26	12.70	8.04
2017-18	2928	624	160	3712	78.88	16.81	4.31
2018-19	1971	763	52	2785	70.77	27.38	1.86
2019-20	1951	1271	93	3315	58.85	38.34	2.81
CAGR (%)	-6.24***	39.15***	-10.34***	-5.25***			

*** Significant at 1 %

Determinants of the import of raw silk

A multiple regression model was fitted using year-wise time series data for the period between 1990-91 and 2020-21 to identify the factors influencing India's raw silk imports. After considering several variables in the regression model, the variables such as domestic silk production, price of imported silk, price of domestic silk, customs duty and anti-dumping duty were identified to capture the variations in raw silk imports. The results of the regression analysis are presented in Table 9. The coefficient of multiple determination (R^2) of the regression function was 0.74, implying that 74 % of variations in raw silk imports could be explained by the variables included in the function.

The regression coefficient of domestic raw silk production (-0.72) was highly significant ($p > 1\%$) and negative, implying that for every unit increase in domestic raw silk production, there would be 0.72

unit decrease in the raw silk imports keeping all other variables constant. The findings are in confirmation with the results of the study conducted by Roy (2016).

A negative association between prices of imported raw silk and the quantum of raw silk imports is expected according to the law of demand. A negative and highly significant regression coefficient of -8.63 for the prices of imported silk implies that if there is a unit decrease in imported raw silk prices, it would lead to 8.63 units increase in raw silk imports. Domestic silk is a substitute for imported silk. As the cross elasticity of demand for substitute goods is always positive, the demand for imported raw silk is expected to increase when the prices for the domestic raw silk increase. The regression coefficient of prices of domestic raw silk was positive but not significant. Therefore, it could be concluded that the prices of domestic raw silk did not play any significant role on the import of raw silk to India.

Table 9: Regression coefficients of variables influencing India's raw silk imports

Variable	Coefficient	Standard error	t statistics	P value
Constant	4507.65	2604.14	1.73	0.10
Domestic raw silk production	-0.72	0.19	-3.70	0.00
Price of imported raw silk	-8.63	2.08	-4.15	0.00
Price of domestic raw silk	1.14	1.27	0.90	0.38
Customs duty	-150.40	59.37	-2.53	0.02
Anti-dumping duty	1800.79	667.78	2.70	0.01
$R^2 = 0.74$		N = 30		

Tariffs are important barriers to trade, which are used as a policy tool to protect domestic industries by reducing the competitiveness of the imported goods in the domestic market. India used customs and anti-dumping duties as safeguard measures against the imported silk.

The regression coefficient of the customs duty was highly significant and negative, which implies that the imports for Indian silk would decrease with an increase in customs duty on imported raw silk; with one per cent increase in customs duty on imported raw silk, the raw silk imports would decrease by about 150.40 MT. Nevertheless, the regression coefficient of anti-dumping duty was positive and highly significant, which is against as expected *a priori*. Mouzam *et al.* (2016) also reported a growth in imports of raw silk after imposition of anti-dumping duty. However, the growth rate of imports decreased during the anti-dumping tariff period.

Summary and conclusions

India is a net importer of raw silk. The raw silk imports increased drastically after the free imports of raw silk were allowed during 2001. However, the growth in raw silk imports reduced in recent years with the increase in domestic raw silk production. Though China is the largest exporter of raw silk to India, the imports of raw silk from Vietnam have been increasing drastically. Strict measures are required to be taken up by the government to restrict the duty free imports of raw silk from Vietnam, as Vietnam is not producing the adequate quantity of silk to export to India.

The regression analysis indicated that an increase in domestic silk production and prices of imported silk and customs duty led to reduced raw silk imports. The imports of raw silk could be reduced by increasing the raw silk production, especially bivoltine silk production in the country. Customs duty, which is an important trade barrier, might be continued on raw silk till India achieves self-sufficiency in silk production.

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Brief Note

PRODUCTION OF UNION FABRICS USING INDIAN TASAR SILK YARN AS WEFT AND MULBERRY BIVOLTINE SILK YARN DYED IN TASAR SHADE AS WARP

S. N. Mishra*, H. H. Sambhulingappa and Subhas V. Naik

Central Silk Technological Research Institute, Central Silk Board, Govt. of India,
Bengaluru 560068, Karnataka, India.

*Email: snmishra.csb@gmail.com

ABSTRACT

Indian Tasar silk fabrics are conventionally woven by using imported Chinese/Korean Tasar silk yarn as warp and Indian Tasar silk yarn as weft. This is because the indigenous Tasar silk yarn doesn't offer enough weaving comfort when used as warp. Hence, the weavers are bound to depend on imported Chinese/Korean Tasar silk yarn for the purpose. Presently in India, adequate quantity of superior quality mulberry bivoltine raw silk is produced with the support of advanced technology packages involving Automatic Silk Reeling Machines. Under this backdrop, an exploratory study was conducted to substitute the imported Tasar warp yarn with Indian bivoltine mulberry silk yarn after dyeing it with Tasar shade. The results are also expected to be an add-on to product diversification in Tasar fabrics.

Key words: Bivoltine, fabric, mulberry, saree, Tasar, union, warp, weft.

India holds second position in Tasar silk production in the world with more than 3000 metric tonnes of Tasar raw silk produced annually (Okhandiar, 2019). In India, most of the Tasar fabrics are woven by using Imported Chinese/Korean Tasar silk yarn as warp and Indian Tasar silk yarn as weft, as it is not strong enough to be used as warp yarn. Thus, there is a great dependency on imported Chinese/Korean Tasar silk yarn to be used as warp (Mori, 2019). Under the present scenario of India with introduction of mulberry bivoltine silk and use of Automatic Silk Reeling Machine, sufficient amount of higher grade of bivoltine raw silk is being produced. Hence, an exploratory study was conducted to substitute the imported Tasar warp yarn with Indian bivoltine mulberry silk yarn after

dyeing it in Tasar shade. This would definitely provide Indian mulberry bivoltine silk, another marketing / consumption channel. Further, this attempt could reduce dependence on import of Tasar silk and in turn, enhance product diversification in Indian Tasar silk sector.

Silk yarns: Raw silk yarns viz., dry reeled Indian Tasar, wet reeled Indian Tasar, imported reeled Chinese Tasar & mulberry bivoltine reeled on Automatic Reeling Machine and dyed in Tasar colour were used as basic materials. Each silk yarn lot was of 2 kg weight. Tasar and mulberry silk yarns were sourced from Vanya Silk and Mulberry Silk Reeling sections of CSTRI, respectively. The basic qualities of these yarns are listed in Table 1.

Table 1: Basic qualities of experimental silk yarns

Silk yarn	Yarn composite (Denier)	Yarn tenacity (g/denier)	Yarn elongation (%)
Dry reeled Indian Tasar	86.81	1.56	30.20
Wet reeled Indian Tasar	70.09	2.72	31.70
Imported reeled Chinese Tasar	34.57	3.32	26.38
Mulberry silk dyed in Tasar colour 2 ply	35.52	3.74	15.00

Twist optimization: Twist optimization was conducted for the raw sik yarns and the wet reeled Indian Tasar yarn responded very well to twisting on up-twisting machine. It was twisted very well with ease in primary Z –Twist up to 722 TPM (twist per metre). Twisting appeared very difficult with dry reeled Indian Tasar silk yarn due to more wastage and high number of breaks. However, a low twist level of primary Z-twist with 448 TPM could be achieved. Mulberry silk yarn was given primary twists of 814 TPM (Z – twist) in 1- ply component and the 2 –ply composite yarn was subjected to 722 TPM (S –twist) secondary composite twists.

Optimizing mulberry silk yarn dyeing in Tasar shade: Twisted Mulberry silk yarn was subjected to standard degumming process followed by optimization of dyeing in Tasar colour with 3 % shade. With the object of achieving Tasar colour for bivoltine silk, some basic sample dyeing tests were conducted and then the standard recipe was arrived at. The degummed yarns were subjected to dyeing in liquor ratio of 1:40 and the dye used as standard recipe was mixture of Vat Yellow 2GCN (30 g), Disperse Yellow Brown 2RC (7.50 g), Dark Brown 5R Atul (7.50 g) , Pigment Dyes like Red 2BC CON (7.50 g) and Grey BM (7.50 g). These yarns were later converted to warp sheet on a sectional warping machine and transferred to warping beam.

Weaving and finishing: Weaving was conducted on two fly shuttle pit looms at two locations. The loom was fitted with 120 hook jacquard and 48 lattice dobby. The loom that used imported Tasar warp was fitted with reed of count 80 and the other loom using mulberry yarn dyed

in Tasar colour was fitted with reed of count 120 (Kulloli and Naik, 2014). Sarees were woven with plain body and dobby design on pallu-border (Figure 1). Two pieces of plain sarees woven were subjected to screen printing for consumer response. All saree thus woven were given felt calendaring for fabric appearance improvement (Figure 2).



Figure 1: Tasar x Mulberry silk union fabric saree with Dobby design



Figure 2: Screen printed Tasar x Mulberry silk union fabric saree

Product details

Under this study, a total of 12 pieces of sarees were produced in 3 combinations. These combinations with each of 4 sarees are: (i) Chinese Tasar x Indian Tasar (dry reeled), (ii) Mulberry bivoltine x Indian Tasar (dry reeled)

and (iii) Mulberry bivoltine x Indian Tasar (wet reeled). The grams per square metre weight (GSM) was the highest of 64 g in the case of Mulberry bivoltine x Indian Tasar (dry reeled) due to high weft denier and high warp ends per inch (EPI) of 2 ply mulberry bivoltine warp. The product details of sarees produced are presented in Table 2.

Table 2: Tasar and Tasar-Mulberry silk union fabric product details

#	Product	Warp	Weft	Weight (g)	Length (m)	width (m)	Area (m²)	GSM	EPI	PPI
1	Tasar design saree	Chinese Tasar	Indian Tasar (Dry)	340	5.35	1.17	6.26	54.32	80	80
2				355	6.00	1.18	7.08	50.14	80	78
3				390	5.40	1.18	6.37	61.21	80	82
4				390	5.75	1.18	6.79	57.48	80	78
Average				369	5.63	1.18	6.63	55.66	80	80
5	Tasar design saree	Mulberry (BV)	Indian Tasar (Dry)	370	5.50	1.16	6.38	57.99	120	70
6				398	5.70	1.13	6.44	61.79	120	68
7				410	5.50	1.13	6.22	65.97	120	64
8				420	5.20	1.14	5.93	70.85	120	70
Average				400	5.48	1.14	6.25	64.03	120	68
9	Tasar plain saree	Mulberry (BV)	Indian Tasar (Wet)	278	5.40	1.14	6.16	45.16	120	64
10				266	5.50	1.16	6.38	41.69	120	64
11				265	5.45	1.15	6.27	42.28	120	68
12				296	5.45	1.18	6.43	46.03	120	70
Average				276	5.45	1.16	6.31	43.75	120	67

Fabric Testing: The Tasar fabrics *viz.*, Chinese Tasar x Indian Tasar (dry reeled) and Mulberry bivoltine x Indian Tasar (dry reeled) were subjected to testing for fabric properties, such as fabric geometry, tearing strength, drape coefficient *etc.* The comparative, fabric testing results are presented in Table 3. The properties of Mulberry bivoltine x Indian Tasar (dry reeled) silk union fabric were observed at par with Chinese Tasar x Indian Tasar (dry reeled).

Colour compatibility test: Colour compatibility test was conducted for the Tasar union fabrics by using Colour spectrometer and following standards of Commission International for Illumination (CII) and Colour Measurement Committee (CMC). The Tasar union fabric woven with bivoltine mulberry warp yarn dyed in Tasar colour were computable to the prevailing product and the colour compatibility test results are indicated in Table 4.

Table 3: Properties of Tasar and Tasar-Mulberry silk union fabrics

#	Fabric test	Instrument	Unit	Chinese Tasar x Indian Tasar (Dry)	Mulberry Bivoltine x Indian Tasar (Dry)	Standard of test
A	Fabric geometry					
1	Warp ends	Counting Glass	EPI	80	120	IS1963:1981
2	Weft picks	Counting Glass	PPI	80	68	IS1963:1981
3	GSM	Electronic Balance	g	56	64	IS1964:2001(a)
4	Thickness	Thickness Tester	mm	0.20	0.18	IS7702:1975
B	Tearing strength					
1	Warp	Tearing tester	Newton	12.55	17.57	IS6489:1993
2	Weft	Tearing tester	Newton	16.94	19.45	IS6489:1993
C	Drape coefficient	Drape Tester	%	61.84	61.00	IS8357:1977

Table 4: Colour spectrometric test of Tasar and Tasar-Mulberry silk union fabrics

Fabric		Colour value as per CII				Colour change		
		Colour coordinates			Used in pigments, paints & textiles		CII-DE*	CMC DE
							Lab reading	Lab reading
		L-Light	(A) -green, +red	(B) -blue, +yellow	C-Chrome	H-Hue	DE	DE
1	Chinese Tasar x Indian Tasar (Dry reeled)	67.38	5.01	19.92	20.54	75.87	0.00	0.00
2	Mulberry Bivoltine x Indian Tasar (Dry reeled)	67.28	4.78	17.76	18.39	74.96	0.23	0.39
3	Mulberry Bivoltine x Indian Tasar (Wet reeled)	71.50	5.12	18.45	19.15	74.51	0.49	0.28

*DE Value less than 0.50 indicates colour uniformity and purity; CII: Commission International for Illumination; CMC: Colour Measurement Committee.

Product costing: The production costing was worked out and compared. The production cost of silk sarees woven with Chinese Tasar x Indian Tasar (dry reeled) was ₹9128.00 per saree, while it was reported considerably low for silk saree woven with mulberry bivoltine x Indian Tasar (dry reeled) to the level of ₹6484.00 per saree. Thus the union silk fabric has registered considerably lower production cost as reported also by Desai *et al.* (2013).

The products developed were impressed by the consumers, stake holders and policy makers. It's interesting to state that three industrial units have already taken up production of Tasar x Mulberry silk union sarees of geometrical specification as achieved in this study. As the union fabrics produced from mulberry silk yarn dyed in Tasar colour as warp and Indian Tasar silk yarn as weft are at par with the fabric woven with Chinese Tasar silk yarn as warp, Indian bivoltine mulberry silk could be a substitute for imported Tasar silk, for this purpose.

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Report

TOWARDS IMPROVING THE LIVELIHOOD DELIVERY OF MULBERRY SERICULTURE IN THE JAMMU DIVISION OF NORTHWEST INDIA

Narendra Kumar Bhatia

Silkworm Seed Production Centre, National Silkworm Seed Organization,
Central Silk Board, Ministry of Textiles, Govt. of India, Mithiberi, Premnagar,
Dehradun, Uttarakhand 248007, India.
Email: nkb11238594@gmail.com

ABSTRACT

The state of Jammu and Kashmir (J&K), now a Union Territory (UT), is the only state among all five traditional sericultural states of India that produce only Bivoltine silk since its inception. Records indicate that the silk production efficiency of the J&K (UT) has now witnessed a sharp decline of 45.53 % in raw silk productivity despite a 104.6 % increase in its mulberry acreage from 2007-08 to 2020-21. During the corresponding period, Andhra Pradesh improved raw silk production by 77.4 % and raw silk productivity by 39.91 %, by adding just 26.8 % to their existing mulberry acreage. Similarly, West Bengal has improved the raw silk production by 36.24 % and raw silk productivity by 31.17 % by adding just 3.87 % of its mulberry acreage in the same period. In the pressing scenario of climate change, upsetting monsoon, turned down agricultural growth, increasing rural unemployment, and many more, this article summarizes and evaluates the present state and scale of mulberry sericulture in the Jammu Division of J&K (UT) and also discuss the ways and means to improve the cocoon productivity. The findings of this study may be used by Sericulture Development Department (SDD), Jammu in the policy formulation and implementation of the area-specific sericultural projects to improve the livelihood delivery potential of mulberry sericulture to its dependents in the Jammu Division.

Key words: Bivoltine sericulture, livelihood improvement, sericulture extension mechanism, silkworm breeds, silkworm seed.

INTRODUCTION

In the crucial scenario of environmental degradation, climate change, upsetting monsoon, turned down agricultural growth, migration of rural populace, the persisting impact of Covid-19 pandemic and many

more; Sericulture, a land-based natural resource-driven, women-oriented and eco-friendly occupation of 91.78 lakh persons (Roy and Roy, 2020) with export earnings of INR 2031.89 crore (PIB, 2019), still signifies its potential for Indian Rural Sector with an overall mulberry wealth of 2.4 lakh ha and 35819.6 MT of annual raw silk production (CSB, 2021).

In India, 68.84 % of the total population lives in rural areas, and in J&K, this figure stands at 72.79 % (Census, 2011). Agriculture in India, which has provided 60.25 % employment (% of total employment) in 2000, has now shrunk to 41.5 % in 2020 (Trading Economics, 2021); but in J&K (UT), agriculture with its allied sectors, still provides livelihood support to 71 % of its rural households (FAO, 2021), besides contributing 36 % to the GDP by engaging about 80 % of the total population (Jagvir Dixit *et al.*, 2014). Out of the total area of 42.24 lakh ha in J&K, only 14.17 % of the total area in Jammu Division that is 3.7 lakh ha and only 21.88 % of the total area in Kashmir Division that counts to 3.49 lakh ha, is available for crops, which is dominated by paddy, wheat, maize, pulses, oilseed and bajra (J&K Govt., 2021).

Literature survey indicates that many people in rural India want to leave agriculture if they get a better livelihood option (Gautam and Bhardwaj, 2013). Agriculture in

J&K has certain constraints, such as limited cash returns, low per capita availability of cultivable land, monsoon dependency, acute seasonality effect, *etc.* that has adversely affected the livelihood potential of the agriculture sector in J&K. However, given both the on-farm and off-farm employment potential, the sericulture industry can reduce the seasonality effect in the agriculture sector of J&K (UT).

Sericulture in India is an indispensable part of the tradition and as an exclusive craft; it holds a unique distinction in traditional knowledge and societal evolution of all the communities in rural areas of J&K. Sericulture industry in J&K dates back to Zain-ul-Abidin (1420-1470) that later got British patronage during Dogra Dynasty (1846-1947). The Department of Sericulture in J&K was created in 1889 to promote the silk industry in the state that is now known as Sericulture Development Department (SDD). Presently, over 29,000 families in J&K are associated with Sericulture and the number of mulberry trees has now increased to 6500,000

Table 1: Progress of mulberry sericulture in the traditional states of India during last four plan period

Traditional Sericultural States of India	By the end of the 10 th Plan period [2002-07] by March 2007			By the end of the 11 th Plan period [2007-12] by March 2012			By the end of the 12 th Plan period [2012-17] by March 2017			By the end of the 13 th Plan period [2017-22] by March 2021		
	Mulberry Plantation (ha)	Raw Silk Production (MT)	Silk Yield (kg/ha)	Mulberry Plantation (ha)	Raw Silk Production (MT)	Silk Yield (kg/ha)	Mulberry Plantation (ha)	Raw Silk Production (MT)	Silk Yield (kg/ha)	Mulberry Plantation (ha)	Raw Silk Production (MT)	Silk Yield (kg/ha)
Karnataka	91434	8240.00	90.12	70958	7796.00	109.90	91492	9571.00	104.61	106384.300	11142.600	104.74
Andhra Pradesh	35180	4485.32	127.50	40314	6446.64	159.90	33156	5970.00	180.06	44607.20	7957.00	178.38
Tamil Nadu	14047	1368.00	97.39	14593	1417.59	97.140	17574	1914.00	108.91	23268.00	2154.40	92.59
West Bengal	15148	1660.36	109.61	13557	1923.78	141.90	15990	2524.00	157.85	15733.90	2262.10	143.77
J&K (UT)	4000	105.00	26.25	7082	133.00	18.780	8444	145.00	17.17	8183.00	117.00	14.30
Sub-total	159809	15858.68	99.24	146504	17717.01	120.90	166656	20124.0	120.75	198176.40	23633.10	119.25

Source: Annual Reports of the Central Silk Board <http://csb.gov.in/publications/annual-report/>

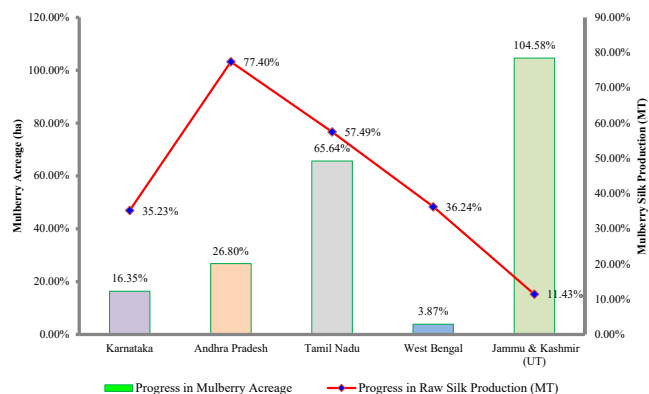


Figure 1: Absolute progress in Mulberry Acreage (ha) vis-à-vis Raw Silk Production (MT) from April 2007 to March 2021 in Traditional Sericultural States of India

Innovations in sericulture technology have improved silk productivity at the National level, but their impact in Northwest India has been quite uneven. The J&K (UT) is one of the five traditional sericultural states of India enjoying cent-per cent bivoltine silk production for many decades, but records indicate that the sericulture

potential of J&K (UT) has witnessed a sharp reduction of 45.53 % (from 26.25 kg/ha in 2007-08 to 14.30 kg/ha in 2020 - 2021) in terms of raw silk productivity despite an increase of 104.58 % in its effective mulberry acreage since 2007 till 2020 (Figure 2); however, the average per hectare raw silk productivity in traditional states of India has increased from 99.24 kg/ha in 2007 to 119.25 kg/ha in 2020 (Table 01 and 02).

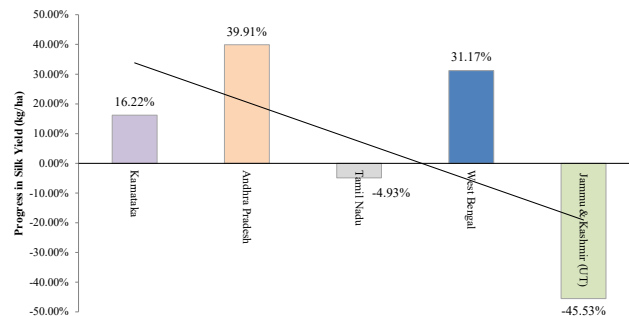


Figure 2: Absolute progress in Raw Silk Productivity in Traditional States of India over the last 14 years from 2007 to 2021

Table 2: Cumulative growth rate (annual) of mulberry sericulture in the traditional states of India from April 2007 to March 2020

Traditional Sericultural States of India	Progress & Cumulative growth rate during 11 th Plan period [April 2007 to March 2012]						Progress & Cumulative growth rate during 12 th Plan period [April 2012 to March 2017]					
	Mulberry Acreage (ha)		Raw Silk Production (MT)		Silk Yield (kg/ha)		Mulberry Acreage (ha)		Raw Silk Production (MT)		Silk Yield (kg/ha)	
	ha	%	MT	%	kg	%	ha	%	MT	%	kg	%
Karnataka	-20476	-4.94%	-444.0	-1.10%	19.75	4.04%	20534	5.21	1775.00	4.19%	-5.26	-0.98%
Andhra Pradesh	5134	2.76%	1961.3	7.52%	32.41	4.63%	-7158	-3.8%	-476.64	-1.5%	20.15	2.40%
Tamil Nadu	546	0.77%	49.6	0.71%	-0.25	-0.05%	2981	3.79%	496.41	6.18%	11.77	2.31%
West Bengal	-1591	-2.19%	263.4	2.99%	32.29	5.30%	2433	3.36%	600.22	5.58%	15.95	2.15%
J&K (UT)	3082	12.10%	28.0	4.84%	-7.47	-6.48%	1362	3.58%	12.00	1.74%	-1.61	-1.78%
Sub-total	-13305	-1.72%	1858.3	2.24%	21.70	4.03%	20152	2.61%	2406.99	2.58%	-0.18	-0.03%

Table 3 : Absolute progress of mulberry sericulture in the traditional states of India from April 2007 to March 2021

Traditional Sericultural States of India	Progress & Cumulative growth rate during 13 th Plan period [April 2017 to March 2020]						Absolute Progress from April 2007 to March 2021 [14 years period]					
	Mulberry Acreage (ha)		Raw Silk Production (MT)		Silk Yield (kg/ha)		Mulberry Acreage (ha)		Raw Silk Production (MT)		Silk Yield (kg/ha)	
	ha	%	MT	%	kg	%	ha	%	MT	%	kg	%
Karnataka	14892	3.06%	1571.6	3.09%	0.13	0.02%	14950.30	16.35%	2902.60	35.23%	14.62	16.22%
Andhra Pradesh	11451	6.11%	1987	5.91%	-1.68	-0.19%	9427.20	26.80%	3471.68	77.40%	50.88	39.91%
Tamil Nadu	5694	5.77%	240.4	2.39%	-16.32	-3.19%	9221.00	65.64%	786.40	57.49%	-4.80	-4.93%
West Bengal	-256.1	-0.32%	-261.9	-2.17%	-14.08	-1.85%	585.90	3.87%	601.74	36.24%	34.16	31.17%
J&K (UT)	-261	-0.63%	-28	-4.20%	-2.87	-3.59%	4183.00	104.58%	12.00	11.43%	-11.95	-45.53%
Sub-total	31520	3.53%	3509.1	3.27%	-1.50	-0.25%	38367.40	24.01%	7774.42	49.02%	20.01	20.17%

Among all five traditional sericultural states of India, Andhra Pradesh (AP), topped the list by improving raw silk production by 77.4 % and raw silk productivity by 39.91 %, which they achieved by improving mulberry acreage by just 26.8 % (Figure 1 & 2). It indicates that AP has improvised the sericulture potential of the state through improved sericultural practices. Similarly, West Bengal has improved raw silk production and productivity by 36.24 % and 31.17 %, respectively by adding just 3.87 % in its effective mulberry acreage (Figure 1 & 2). Data of Tables 1, 2 & 3 and Figures 1, 2 & 3 indicates that in the last two decades, there has been an unusual deterioration in J&K compared to other traditional sericultural states of India. And thereof, the farmer's income has been reduced due to the existing cocoon yield gap that has affected the mulberry sericulture business in the J&K (UT).

Conceptually, there are two types of cocoon yield gaps in sericulture. Yield gap 1 indicates the gap between the potential cocoon yield of a sericulture research station and a demonstration plot. Yield gap 1 is mainly attributed to differences in the locality factors, such as soil, slope, aspect, moisture regime, climatic deviations, *etc.*, and non-transferable parts of technology. However, Yield gap 2 deals with the difference between the potential cocoon yield of a demonstration plot and the cocoon yield at the farmer's level.

Therefore, Yield gap-2 is very common and mostly arises when sericulture farmers use inappropriate technology, apply low inputs, and face managerial constraints. In traditional silk producing states of India, several studies have been undertaken on trends, profitability, and cocoon yield gap analysis in one form or the other (Sinha *et al.*, 1985; Ravindran *et al.*, 1993; Lakshmanan *et al.*, 1996; Raveendra *et al.*, 1997; Kumaresan *et al.*, 2005; Prakash and Dandin, 2005; Lakshmanan, 2007; Raveendra *et al.*, 2009;), but no such study has been undertaken in the mulberry sector of Jammu Division in Northwest India.

In the present study, Yield gap-2 is analyzed concerning the mulberry sericulture of the Jammu Division, where productivity enhancement is the last option for the

sustainability of sericulture practices. This study gives insights about underlying reasons for the low cocoon productivity and the corresponding reduction in the livelihood delivery potential of mulberry sericulture in the Jammu Division and discusses the ways and means to improve it. Findings of this study may be used in policy formulation and implementation of specific sericulture projects in the Jammu Division by SDD, Jammu and Central Silk Board, Ministry of Textiles-Government of India to improve the livelihood delivery potential of mulberry sericulture in the state.

METHODOLOGY

1. Door-to-door field visits

This study is an outcome of an extensive door-to-door joint field survey of different sericulture villages of the Jammu Division in three districts *viz.*, Jammu (Gordah, Nalliah and Bishan), Samba (Purmandal, Gawal, Chahra and Nadh) and Kathua (Khanpur, Badoli, Bakrak, Labdichak and Barnoti). Three Scientists from Central Silk Board and the concerned officers of SDD, Jammu including Additional Director, SDD, Jammu, Deputy Directors of the respective districts, and their field staff participated in the joint survey that was conducted on 10th and 11th April 2021, when worms were in the final to the spinning stage during spring 2021 rearing.

At the start of the field visit, the baseline information regarding F-1 seed source, hybrid combination, date of brushing, *etc.* related to the ensuing spring 2021 crop was collected from all the circle officers of the Jammu Division. Committee interacted with all the farmers in one-on-one discussion mode and was acquainted with the ground sericultural realities on different aspects of silkworm rearing and cocoon generation. Many of the farmers asked a common question that why their worms are not entering into spinning even after 10-12 days of feeding after the 4th moult. The farmers' rearing condition was not alike and so were their points of discussion. Farmers' interactions were aimed at knowing the level of sericulture technology adoption; deviations, if any;

knowing the previous history of their sericultural activities and how they did that; level of extension support extended by the sericultural personnel of SDD, Jammu; how they do cocoon marketing and its constraints if any; what are the aspiration and expectation of the rearers from SDD, Jammu towards efficiency orientation, ease of *seri-business*, capacity building *etc.*

2. Collection of sericultural data and its interpretation

Data on mulberry plantation area and raw silk production for all the five traditional sericultural states of India from 2002 to 2020 was collected from various Annual Reports of the Central Silk Board, Ministry of Textiles - GOI. Microsoft Office Excel 2007 and Online compound growth rate calculator was used to calculate the annual Linear Growth Rate (LGR) on three variables *viz.*, mulberry area, total raw silk production and per hectare raw silk productivity.

RESULTS AND DISCUSSION

If someone wants to feel the pulse and passion of the cluster mode of sericulture, the Gordah cluster of SDD Jammu, situated 40 km away from the Jammu district headquarters may be one of the best examples. The population of Gordah village is 1371 (Indian Village Directory, 2021), and 80 families are associated with mulberry silkworm rearing and cocoon generation, of which 32 families have got Government subsidies for the construction of rearing houses.

1. Mulberry plantation in Jammu division exists only on boundaries of the agriculture field

In the Jammu Division, fast urbanization and industrialization coupled with demographic expansion have reduced agricultural acreage and have forced “mulberry” to exist only on the boundaries of the agriculture field (Figure 3). The average landholding of J&K (UT) is just 0.66 ha, which is very low compared to the National average of 1.68 ha. Agricultural landholdings in J&K are used to grow cereals and

vegetables for domestic consumption and marketing. The Jammu Division has more cropping intensity (176.8 %) than that of the Kashmir Division (123 %) and the Ladakh Division (106 %). On the front of the irrigation facility, only 41.7 % of the net sown area is irrigated and the major source of irrigation is the canal that shares 93 % of the total irrigated area of J&K (Jagvir Dixit *et al.*, 2014).

In the Jammu Division, there is no concept of mulberry block plantation or paired row plantation in the agricultural land. Only border mulberry plantation consisting of 328 plants planted at a distance of 4 feet on the circumferential periphery of 1312 feet of one ha of agriculture land is considered as one ha mulberry plantation. As per the recent estimates, the reported mulberry area of J&K is 4,183 ha. Mulberry trees on the boundaries of the agricultural field are seldom governed by any nutrient supplementation regime or pruning schedule that reduces optimum leaf production efficiency, both in terms of quality and quantity that affects cocoon productivity, adversely (Bhatia *et al.*, 2013).

2. Farmers don't follow any pruning schedule in the Jammu division

Unlike other traditional states of India, the farmers of the Jammu Division don't prune their mulberry trees. Here, farmers lop the whole branch of mulberry and follow branch feeding to silkworms twice or thrice in 24 h. Branch lopping during the rearing period acts like pruning for the bordered mulberry trees. As per the defined pruning schedule of Central Sericultural Research and Training Institute, Pampore (J&K), the first pruning is to be done in the second fortnight of June to have a good mulberry flush for autumn rearing in September-October, and second pruning is to be executed in December last week to take the major crop of spring in March-April. However, in Jammu Division, there exists a complete mismatch between forced lopping of mulberry trees and the suggested pruning schedule of CSRTI, Pampore (J&K). Mulberry trees, lopped in April during spring crop

are further utilized in September-October for autumn rearing; and by the time, the grown-up mulberry leaves become over-mature that invites leaf diseases creating multiple rearing problems like the sluggish growth of silkworm larvae, increased susceptibility to silkworm disease, especially Nuclear Polyhedrosis Virus (NPV) and if rearing completes anyhow, the productivity remains very poor. Further, being a unique feature of J&K, the mulberry trees looped in September-October during autumn rearing is left unattended till the spring crop of March-April in the next year. In between autumn and spring, there exists an acute low-temperature regime of 60 days during winter in December-January obligating mulberry plants to become leafless due to reduced plant physiological activities.



Figure 3: Mulberry wealth of the Jammu Division along the boundaries of the agricultural field

Mulberry sprouting in the Jammu Division starts in early February, and by the second fortnight of March, silkworm larvae, brushed in the March first week, come out from the second moult and enter into late-age rearing. But many a time, it is found that farmers face scarcity of mulberry leaves due to the available less gestation period for proper growth of mulberry leaves. The problem of less leaf productivity becomes more intense when the low-temperature regime lasts for an extended period. And, this is a known climatic restriction for sericulture activities in the Jammu Division of Northwest India, that affects cocoon production adversely.

3. Spring is the main rearing season that contributes to 90 % of the annual cocoon generation of the Jammu Division

Due to climatic restrictions, there exist only two cropping patterns in the Jammu Division. The spring crop of March-April is the main crop that contributes to 90 % of the total annual cocoon generation; however, the autumn crop is not very popular among the farmers of the Jammu Division because of its lower success rate. The silkworm seed demand for spring 2021 was 14.23 lakh DFLs against 1.07 lakh DFLs for autumn 2021. The stabilized spring crop serves as the main crop of the Jammu division, and the autumn crop serves as a subsidiary one. The average cocoon productivity of spring stands at 30-45 kg; whereas, in autumn, it is hardly 10-25 kg. The main reasons for the lower rearing performance during autumn are - suboptimal climatic conditions, over mature mulberry leaves, interruptive rains during late age rearing, and crop losses due to silkworm diseases.

4. There is no concept of complete Chawki rearing in many areas of the Jammu division

Our extensive door-to-door survey in three districts of the Jammu division indicates that only 10 % of the total silkworm seed are subjected to complete Chawki rearing. In the rest of 90 % of cases, just hatched-out larvae after having one or two feeds are wrapped in a newspaper and distributed to the farmers. The silkworm seed incubation facility available at SDD Jammu is good, but there is no

uniform adoption of black boxing procedures; however, black-boxing is a significant component for having synchronized brushing. SDD Jammu may take needful initiatives to improve the efficiency of brushing operation to have maximum hatching of silkworm larvae.

Presently, farmers of the Jammu division rear the newly hatched silkworm larvae in their dwelling houses under sub-optimal conditions during the first week of March, when the outdoor temperature remains in the range of 10 to 20 °C. It is true that to have cent per cent CRC facilities for all the supplied silkworm seed of 14.21 lakh DFLs, it would take a lot of sincere efforts by SDD Jammu to create a vast infrastructural facility along with men and materials. In this direction, SDD Jammu may list out all the well-established sericulture farms of the Division to take all the initiatives to improve the production of quality mulberry leaf. The most awaited beginning of departmental Chawki rearing would benefit the overall sericulture industry of the Jammu Division. The distribution of just-hatched larvae is not justified because the Chawki rearing concept cannot be substituted by adopting a shortcut method, by supplying just hatched silkworm larvae to the poor farmers of the Jammu Division. Introduction of complete Chawki Rearing Concept in the Jammu Division is the most sought-after area to improve cocoon productivity and livelihood delivery of mulberry sericulture to their dependents.

5. Floor rearing, the oldest rearing method of the Jammu Division is still in vogue

Floor rearing or veranda rearing with shoot feeding is the oldest rearing method of the Jammu Division and remained the first choice. In the floor rearing method, a clean cemented or mud floored room or veranda is used, and only branch feeding is done instead of traditional tray rearing using harvested mulberry leaves. It is found that the floor rearing is less expensive, women-friendly, easier to operate and manage, and optimizes cocoon yield and quality because of the existing space for bed expansion that provides improved aeration to decrease

pathogen load. But while visiting the spring 2021 rearing in different areas of the Jammu Division, we noticed many unusual things and some of them are as under;

a. The inordinate high thickness of the silkworm rearing beds:

It was found that many silkworm rearers of the Jammu Division, especially at the Gordah cluster, hardly practice any bed cleaning during the entire period of late age rearing that raises the height of rearing beds, sometimes up to 2 to 4 feet (Figure 4). Visibly, the lower two-third portion of the rearing bed looks like a systematic piling of the dried mulberry twigs arranged in a zigzag fashion with a top layer of green mulberry twigs to feed the growing/spinning silkworms. The height of the dried mulberry twigs is not a big problem; but, the rotted and dried silkworm larvae hanging in between the dried twigs with heavy pathogen load becomes a growing problem for the success of the cocoon crop due to the higher possibilities of disease outbreak.

b. Rearing houses without ventilation facilities:

Farmers of the Jammu division are less aware of the significance of cross-ventilation during silkworm rearing, especially during the last two stages. During the door-to-door visit of the Gordah cluster, about 30 % of the houses were detected without any ventilation facilities. Even though some of the rearing houses (40 %) were provided with one or two windows, they were found closed. In some cases, where the windows were found open, they were covered with a thick plastic sheet or double-layered curtain making it impossible for the fresh air to pass through the rearing room. It is a prevailing disbelief there that the worms may be affected by hot and cold weather conditions. This self-made adverse situation by the farmers was responsible for the heavy pathogen load of Nuclear Polyhedrosis Viruses, causing different problems, such as worm loss, non-spinning of the silkworm batches, eventually creating distress among farmers.



Figure 4: Inordinate thickness of the silkworm rearing bed

6. Improper moult settling and early resumption

It was observed that some of the farmers never stop feeding or don't understand when to stop feeding to settle the worms for a moult. Sometimes, there exists three types of worms simultaneously; worms preparing for the moult, already under the moult process, and another category of out of moult worms. In silkworm rearing, uniform larval growth is the precursor of a good cocoon crop. Improper moult settling, early resuming, crowded worm population and insufficient feeding are the major causes for unequal larval growth. Farmers may be demonstrated about proper moult settling and resuming to have uniform larval growth and improved cocoon productivity.

7. Occurrence of extended larval period

At many places, farmers complained about the extended last-age larval period and blamed this abnormality on the seed quality. Farmers informed that silkworm larvae are not feeding the mulberry leaves; even when they are provided with fresh ones. We tried to convince them that an extended larval period is not associated with seed quality.

8. Delayed spinning or non-spinning in a few silkworm batches

Lower temperature regime during the night, unequal larval growth, poor ventilation, high moisture buildup, non-cleaning of rearing beds, improper feeding and

occurrence of Grasserie could be ascribed as factors responsible for delayed or no spinning during spring 2021 crop. In many villages of Samba district, we found some cases of forced mounting because worms were scattered everywhere, even on the roof of the rearing houses. Enriching the rearing knowledge through systematic extension education may help the farmers to adopt improved silkworm rearing practices.

9. Successful cocoon crop in spring 2021

It was not like that during spring 2021, all the farmers of the Jammu Division were having one problem or the other in cocoon crop generation. Because of the adoption of scientific rearing practices (Figure 5), the majority of the farmers harvested good cocoon crops. The successful crop with many farmers of the Gordah cluster suggests that adoption of improved rearing technology is sure to narrow down the existing cocoon yield gap in the Jammu division.

10. Misconception about Seed quality among a few staff and farmers of the Jammu Division

In Jammu Division, there is an inculcated misconception among a few field staff of SDD, Jammu, and with some of the farmers that if anything goes wrong during late-age rearing, especially before spinning, it is because of the low quality of silkworm seed supplied by the SSPCs of NSSO, Central Silk Board. But interestingly, the field staff of SDD Jammu has never raised any questions on the quality of seed produced by them. The present tendency of SDD, Jammu in blaming the seed quality even at the fag-end of rearing needs self-realization. It is well known that if there is any problem with the seed, it will not hatch, or if hatched anyway, there would be irregular pattern of hatching leading to the unequal size of worms, but none of the rearers was noticed as having any issue of unequal worms.



Figure 5: Good cocoon crop harvested by farmers of the Jammu Division during spring 2021

Factors, such as the occurrence of grasserie either due to infection of the previous crop being carried forward due to erratic disinfection practices, poor health of worms due to improper feeding, prevalence of unhygienic condition, building up of heavy pathogen load inside the rearing house due to non-ventilation condition, wide temperature fluctuations in the tin shaded rearing houses and wide temperature fluctuations between night (15-17 °C) and day (32-36 °C) are certain to impact the status of late age rearing of the Jammu Division. If there is any question on the seed quality, it should be raised at the right time for seed replacement but, not at the fag-end of rearing. Some people opined that it is easier to put all the managerial and climatic constraints of the rearing failures on the seed quality.

11. Discarding final stage worms due to misconception on the quality of silkworm seed

During the door-to-door farmer's visit in the Kathua district of Jammu Division, it was found that one of the

farmers had thrown away all her about-to-spin worms in her backyard due to a misconception that lot number 5 of silkworm seed supplied by SSPC, Hindupur is quite problematic (Figure 6). Since three farmers had already thrown away their mature worms due to the bad quality of seed, she just followed their wild decision. We observed this attitude in the Samba district also, where starved and healthy larvae were discarded which later formed cocoons at the thrown away places. This false inculcated belief of the farmer on the quality of seed even at the time of worm's spinning needs to be averted, through sincere counselling by the staff of SDD, Jammu.



Figure 6: Fifth stage silkworm larvae discarded by rearers due to misconception on seed quality

12. Rearing in Tin-shaded closed rearing houses

It was found that due to heavy variation between the maximum (32-36 °C) and minimum (15-17 °C) temperature regime in the Tin-shaded rearing houses, incidence of grasserie disease was on the higher side, and many silkworms displayed typical symptoms of grasserie. The farmers were suggested to spread over paddy straw or any similar crop residue on the top of the tin floor to have an insulation effect on raising and dropping the temperature inside the rearing room.

13. Improved rearing practices in the Kathua district

Adoption of 3-4 tiers of shelf rearing stands made by using low-cost local materials and maintenance of improved rearing conditions by many of the farmers of Kathua district of the Jammu Division was found praiseworthy (Figure 7). But, many of such farmers were doing their silkworm rearing under tin-shaded roofs, due to which the indoor temperature was found inordinately very high. Further, they have not adopted the shoot feeding even during the 5th stage of rearing. Under these circumstances, SDD, Jammu may plan for providing financial assistance for the construction of rearing houses to needy farmers. But in Uttarakhand, the overall experience of providing rearing houses has been quite discouraging; because, after getting rearing house subsidies, many farmers discontinued sericulture.

14. Non-practice of mountages of any type in the Jammu division

Sericulture farmers in the Jammu division don't use any mountages; instead, they use local materials for spinning purposes. In this local spinning method, silkworm feeding is stopped at larval maturity and the whole rearing bed is covered with semi-dried local materials like twigs of Kamble (localname), palm leaves, mustard shoot, paddy straw, leaves of mango, pines, *etc.* and allow the

silkworm to complete spinning. This spinning method has the following limitations:



Figure 7: Improved rearing condition noticed at many places in Kathua district of the Jammu Division

- There is no concept of picking the ripe silkworms, so many times, the left over eating silkworm larvae either form flimsy cocoons or die prematurely, creating problems in cocoon harvesting.
- Rotten silkworms smell very foul that sometimes invites complaint from neighbours or even family members.
- The probability of double and deformed cocoon formation increases due to the uneven distribution of the spinning silkworms under space constraints.
- Local spinning materials must be half-dried, but many times, fresh plant materials are used by the farmer, leading to high humidity buildup in the spinning room.
- Traditional spinning requires a large space area, and the process is not silkworm friendly. Farmers need to be convinced to adopt collapsible plastic montages to reduce worm loss during spinning and enhance the formation of quality cocoons.

15. Occurrence of heavy crop loss due to grasserie in autumn

The success and profitability of silkworm rearing primarily rely on the quality of seed, it being the basic input, quality of the mulberry leaves is also a primary component followed by rearing management and maintenance of cleanliness, and general hygiene. But in the Jammu Division, the silkworm disease incidence during the autumn is of the prime concern; because more than 35 % of crop losses are attributed to silkworm diseases. As a ground reality, silkworms are reared in dwelling cum rearing houses, and most of them are unhygienic and badly ventilated, helping in pathogen build up and multiplication. Besides this, many of the farmers do not disinfect their rearing places properly. During late age rearing, farmers seldom pick up diseased larvae regularly, or even if they pick them up, it is not disposed of properly, leading to further contamination. Sometimes, farmers dispose of diseased worms haphazardly near their dwelling places, which are easily picked up by the

birds, and pathogens get disseminated all around the area through their faeces. Sometimes, gunny bags used for throwing the bed refuse are used for transportation of mulberry branches without disinfection leading to further contamination. We can educate the farmers on these simple managerial aspects of silkworm rearing through systematic extension education, but the low staff strength of SDD Jammu is a principal constraint here.

16. Need for the re-introduction of traditional hybrid of Northwest India, especially in the autumn season

SH6 x NB4D2 and its reciprocal had been the ruling traditional silkworm hybrid in the Jammu Division for many decades and had dominated the then seed production channel. But with the introduction of the double hybrid, FC1 x FC2 combination and its reciprocal, the Jammu Division has completely stopped the rearing of traditional hybrids in both the rearing seasons of spring and autumn. However, other Northwest Indian states are still taking proportionate quantities of traditional silkworm hybrid seed in addition to the double hybrid.

Recent R&D intervention of the Regional Sericultural Research Station, Jammu indicates that farmers can get successful cocoon crops in the autumn season by rearing traditional silkworm hybrids. This is because traditional silkworm hybrids are region specific and possess inbuilt sturdiness and seasonal acclimatization capabilities to perform better than the double hybrid during any climatic crisis. Farmer's income can be improved by increasing the seed demand of traditional hybrids in the Jammu Division, especially during autumn rearing. Multi-locational trials of traditional silkworm hybrids may help in raising the confidence of the farmers to improve its adoption level that may add a shining chapter in the sericulture prosperity of the Jammu Division.

17. Prospect for an additional summer crop in June-July in the Jammu Division

Spring crop, the main rearing season of the Jammu division, is completed by the second week of April, and

lopped mulberry trees attain their full flush by the last week of June. But farmers neither take up any silkworm rearing nor do they prune their mulberry tree as per the pruning recommendations of CSRTI, Pampore. The grown-up mulberry leaves of May-June become very coarse and develop leaf spot disease by the beginning of autumn crop in September and hence, adversely affects the cocoon crop. Hence, there exists a fair and square chance to introduce an additional summer crop by having the brushing schedule during the third or last week of June every year. Recently, RSRS, Jammu has taken a welcome initiative in this direction with the seed support of Silkworm Seed Production Centre (SSPC), Dehradun for traditional silkworm hybrid of SH6 x NB4D2 and has successfully demonstrated the possibilities of an additional summer crop at farmer's level during June-July 2020 and has harvested excellent cocoon crop (Figure 8). In the same direction, SDD, Jammu may take a few experimental summer crops of traditional silkworm hybrid with the seed support of SSPC, Dehradun (UK) or SSPC, Udhampur (J&K) with selected farmers and based on the results, it can be adopted for all.



Figure 8: Encouraging results of experimental summer crop rearing conducted in the Jammu district during spring 2020

18. Need for implementation of Minimum Support Price (MSP) mechanism for F-1 cocoons in Jammu division in line of DoS, Uttarakhand

In Uttarakhand, the Directorate of Sericulture (DoS) functioning under the Department of Agriculture has formulated and implemented a policy to assess and fix the Minimum Support Price (MSP) for commercial cocoons, before the cocoon harvest in every spring and autumn. MSP for F1 mulberry cocoon is decided by a designated committee; comprising of the Director, DoS, Uttarakhand; 02 Deputy Directors of DoS; Scientist-D and In-charge officers (3 members in total) from the Central Silk Board, one member each from Regional Sericultural Research Station, Sahaspur, Dehradun; Silkworm Seed Production Centre, Premnagar, Dehradun and Sericulture Training Service Centre, Premnagar, Dehradun; and 2 Reelers' representatives from Uttarakhand being the members under the Chairmanship of the Additional Secretary of Agriculture Department, Govt. of Uttarakhand. A six-monthly meeting of this committee is conveyed by the President of Uttarakhand Co-operative Resham Federation (UCRF), Dehradun before completion of the crop.

In Uttarakhand, UCRF provides cushioning effect in the cocoon market on MSP to the sericulture farmers, especially in the wake of any opportunistic lobbying by the cocoon purchasing parties gathered from different states, basically from Bangalore and West Bengal. In the cocoon market, if the offered cocoon procurement rate by the qualified bidder happens to be lower than the MSP, then UCRF intervenes into the market operations and procures all the available cocoons in the market on that day at the decided MSP. Though, the MSP of the cocoon is not enforceable by law on the cocoon bidders; MSP safeguards the farmer's interest to a minimum profit level if the open market offers a lesser price than their cost of production.

There is no such system of MSP for cocoons in the Northwestern Indian States, except Uttarakhand. The SDD, Jammu may take the needful initiative to formulate

and implement the MSP mechanism during cocoon marketing in the Sericulture Sector to safeguard the farmer's interest. The Uttarakhand model of MSP and its regular revision for commercial cocoon may also be adopted by the SDD, Jammu with required modifications if any. Implementation of MSP on generated cocoons and providing competitive market facilities may be the priority of SDD, Jammu to improve the livelihood delivery of mulberry sericulture to its dependents.

19. Implementation of a workable mechanism for Annual revision of the stagnated rate for P1 seed cocoon in Jammu Division

Presently, based on the pupation percentage, the rate of P1 cocoon in south India ranges from INR 700.00 to 800.00/kg; whereas, in Uttarakhand, it is INR 550-600 per kg; but in Jammu Division it has been stagnating at INR 350.00 to 400.00 per kg since spring 2018. But, since 2012 to 2018, the P1 cocoon rate was stagnated at a still lower rate of INR 250.00/kg. The P1 seed cocoon farmers of south India are blessed with congenial weather conditions for silkworm rearing that provides multiple cropping opportunities besides having access to modern sericulture innovations and competitive market facilities. But, the farmers of Jammu Division don't have any systematic mulberry plantation, their Sericulture avocation being dependent on mulberry trees grown on the bunds of agricultural field, they are left with only one assured crop of spring, the success of which depends mainly on nature and have to wait for months together to sell their dried cocoons when the market is arranged by SDD, Jammu, and the cocoon rates are not subjected to any MSP support of the Govt. of J&K (UT). Furthermore, the farmers of the Jammu Division live at geographically disadvantaged locations of remote hilly areas and are socially more backward and poor than the sericulture farmers of the Jammu Division. Despite all these disparities, the P1 seed rearers of the Jammu division are the lowest paid Adopted Seed Rearers in India, which seems to be unjustified and the people governing sericulture in J&K must address this vital public issue.

If we take the example of Uttarakhand, there exists a committee at the DoS level that meets once in a year to revise the procurement rate of P1 seed cocoon; but, in Jammu Division, there is no such system or any workable mechanism for revision and regularization of P1 seed cocoon rate either annually or even biannually to safeguard the livelihood interest of the seed rearers. And this is the reason, why the rates of P1 seed cocoons in the Jammu region remain stagnated for many years and the P1 seed rearers are deprived of getting their genuine return for their hard work. The P-1 seed rearers of the Jammu Division are facing a marginalized situation due to policy paralysis on the part of SDD, Jammu, Government of J&K (UT) for not having any plan or intent to regularly revise P1 seed cocoon rates. Many of the sericulture farmers were optimistic that the abrogation of Articles 370 and 35(A) in the J&K may equalize their cocoon rate with south or at least with the farmers of Uttarakhand, that also belongs to Northwest India and moreover, all the operational modus operandi for sericulture is at par in J&K (UT) and Uttarakhand, besides existing similarities in all other governing variables of mulberry sericulture.

Therefore, the SDD, Jammu should take a workable initiative to remove disparities of P-1 cocoon rate in the Jammu Division; otherwise, the mind and spirit of the P1 seed rearers may be diminished and diverted from P1 silkworm seed rearing, which may incur an irreversible loss to the Seed Production Efficiency (Quality, Quantity, and Cost-effectiveness) of State and Central grainages.

20. Introduction of lead farmer concept at Gordah cluster

The cocoon crops of many farmers of the Gordah cluster were fantastic. Their rearing methodologies, acquired confidence, the adoption level of improved rearing technologies, and other managerial innovations should be communicated to other farmers of the cluster by some identified lead farmer(s). Lead farmer(s) may be provided with specific sericulture training by RSRS, Jammu based on the prevailing ground-level realities of silkworm rearing and its management aspect. Trained

lead farmer(s) may be provided with an admissible honorarium by SDD Jammu as a token of respect and recognition for their extension services.

21. Advancement of brushing schedule of Kathua district by ten days

Before 2016-17, farmers of the Kathua district were getting Chawki reared worms by the end of February every year, and the crop was completed by 20-25 March, averting the high-temperature regime of April. But now, farmers are getting Chawki reared worms a bit late by 15-20 March, due to which their late-age rearing suffers owing to a high-temperature regime in April every year. The present brushing schedule of March first week may be advanced for 10 days so that silkworms could complete spinning by March-end. This technical intervention may substantially improve the cocoon productivity of the Kathua district of the Jammu Division.

22. Sericulture staff strengthening in the Jammu Division

It was reported that only one watcher (local sericulture extension worker) looks after all the business of silkworm rearing from distribution of worms to completion of the crop. When 40-50 diseased worms are there in any rearing bed, farmers think that the whole rearing is infected and get depressed, so regular crop supervision may boost the confidence of the rearers to apply silkworm disease management protocol, but operational command area under individual watcher is inordinately huge. So a pragmatic and performance-oriented staff strengthening by the SDD Jammu seems quite essential.

23. Improvement in cocoon productivity of the Jammu Division at par with the Adopted Seed Rearers of SSPC, Udhampur (J&K)

Based on the twenty years data on the Adopted Seed Rearing performance of SSPC, Udhampur (J&K) presented in Table 4, it can be believed that achieving a higher cocoon productivity level of 50-70 kg/100 DFLs at farmer's level in Jammu Division is a quite possible proportion.



Figure 9: Introduction of shelves/floor rearing to improve the technical & managerial efficiency of P1 rearing at ASR level

The encouraging rearing performances of SSPC, Udhampur can be replicated in other areas of the Jammu Division. It is also befitting to mention that the average cocoon productivity of the ASRs of SSPC, Udhampur (J&K) is the highest among all the states of Northwest India that provides encouraging hopes to the people of

SDD, Jammu. All the ASRs of SSPC, Udhampur (J&K) are the farmers of the Jammu Division and doesn't have any special facility, which is not available with the rest of the farmers of the Jammu Division. The only difference between the farmers of Jammu Division and the ASRs of SSPC, Udhampur (J&K) is; Chawki support and day-to-day personnel involvement of all the team members of the SSPC, Udhampur in a team spirit, besides input and manpower support for twice disinfection of the rearing houses along with rearing appliances and free supply of newspapers and bed disinfectants. The introduction of a multitier shelf rearing system has improved the technical & managerial efficiency of the P1 seed rearing of the ASRs of SSPC, Udhampur (Figure 9). The self rearing system can be introduced in the whole of the Jammu Division.

Table 4: Rearing performance of ASRs, SSPC, Udhampur (J&K)

Year	DFLs reared (No.)	Cocoon production (kg)	Yield/100 DFLs (kg)
2001	8,702	4,968.50	57.10
2002	8,230	4,653.70	56.55
2003	8,400	3,523.75	41.95
2004	8,520	4,876.50	57.24
2005	9,050	4,802.00	53.06
2006	9,200	5,385.50	58.54
2007	9,590	5,080.20	52.97
2008	8,653	4,763.30	55.05
2009	9,760	5,803.60	59.46
2010	9,529	4,558.80	47.84
2011	9,000	5,216.20	57.96
2012	9,000	4,574.00	50.82
2013	10,250	6,682.00	65.19
2014	11,000	7,326.00	66.60
2015	11,300	5,405.00	47.83
2016	11,003	5,993.00	54.47
2017	9,100	5,998.00	65.91
2018	9,600	6,669.00	69.47
2019	8,800	5,588.40	63.50
2020	8,800	4,161.00	47.28
2021	9,000	4,432.50	49.25
Average	9,357	5,260.05	56.10
Maximum	11,300	7,326	69.47
Minimum	8,230	3,524	41.95

Conclusion

This paper examined the state, scale, and constraints of the mulberry sericulture in the Jammu Division of Northwest India. It also counted the areas of improvement at the field level and at the administrative and government level to increase the livelihood functions of the mulberry sericulture to its dependents. Case study on higher rearing performance of SSPC, Udhampur (J&K) demonstrated that cocoon productivity of 50-60 kg/100 DFLs is achievable by the farmers of the Jammu division. Arguments and constructive criticism of this communication may provide sericultural administrators and policy-makers with the necessary input and insights to take up needful action for strengthening the mulberry sericulture of the Jammu Division. Paper recommends a phased-out conversion of the underperforming sericulture areas of Jammu Division into a prosperous sericultural village having “Mulberry Sericulture” as a viable livelihood option for silkworm rearers.

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SILK AS SMART TEXTILES IN THE DEVELOPMENT OF HEALTHCARE E-TEXTILE SYSTEMS

Susmitha Mukund Kirsur*, R. Ashok Kumar, Y. C. Radhalakshmi¹ and M. K. Sindhu

BMS College of Engineering, Bengaluru 560019, India.

¹Central Silk Technological Research Institute, Central Silk Board, Bengaluru 560068, India.

*Email: sushmithamk06@gmail.com

ABSTRACT

Silk has been used as a textile material for thousands of years. In the recent past, since reported as an environmentally safe material with great bio-compatibility, it is being used for different purposes other than textiles, particularly in the medical field as smart textile. These wearable smart-textiles provide user-defined applications as well. Silk has a limited use in e-textile applications due to its poor conductive property which is a must for e-textiles. Scientists have developed different methods to introduce conductive materials (*e.g.*, metal particles, graphene, *etc.*) into silks. A successful method is to carbonise silk fabrics. Such e-textiles can be washed automatically or with high-intensity ultrasonics. These carbonised silk can be used as wearable sensing platforms to detect and monitor physical and chemical signals, such as force, temperature, and solvents indicating potential uses for wearable devices, healthcare monitoring, and human-machine interfaces. Silk exhibits reversible contraction, expansion, and rotation reactions following water absorption, suggesting that it could be a suitable material for moisture-responsive smart textiles also. Diagnostics, detection of pathogenic microbes, affinity purification systems, and even therapeutic techniques are all made possible by silk which has a single-chain fragment variable (scFv) of IgG protein linked to silk fibroin protein. The medical field is one of the major areas where these new smart products are being successfully implemented. These products are being developed for continuous patient monitoring in large-scale hospitals as well as for customized patient requirements. They are also used for complex medical treatments which replace conventional methods. In fact, for sure, progress in the smart textiles area has been revolutionizing the entire health care system. The paper discusses the latest developments in the area of smart textiles using silk especially in the medical field.

Key words: Carbonized silk, conventional methods, external stimuli, healthcare e-textile systems, smart textiles.

INTRODUCTION

The smart textiles applications are now found in the fields of healthcare, protective clothing, firefighting clothing, smart clothing, sports clothing, military uniforms,

electronic fabrics, bio-medical applications *etc.* This study aims to dovetail an overview of smart textiles in general and their application in the health care industry in particular.

The very name, smart fabrics are based on the term *intelligent* or *smart* materials. The history of smart textiles dates back to 1989 which takes its roots in Japan. The first smart material discovered was silk thread with induced shape memory. *The shape memory of silk thread* has been studied by Chan Vili in developing smart fabrics that work well by considering ways to enhance the beauty of woven inner fabrics. There has been an increasing demand in the existing market which in fact has encouraged entrepreneurs to explore the smart textile market further.

Smart textiles are increasingly replacing traditional textiles, such as heart-monitoring clothing, heat-sensitive jackets, discoloration fabrics, detoxification fabrics, dermatological fabrics, fabrics monitoring pulse and immune systems, gloves with microphones, sensors in mattresses, cooling clothing, and so on. The new sector has been fueled by the emergence of sophisticated materials, nanotechnology and clever materials, such as phase switches, shape-remembering materials, continuous fabric polymers, and other newly developed information technology chips.

Functions of smart textiles

Smart textiles detect and process the wearer's condition additionally to perceive and convey ambient factors. Despite the fact that some electronic elements are reduced to the minimal to be used in clothes, smart garments should be built entirely of textile materials.

Sensors play an important role in smart fabrics. A sensor's basic function is to convert one signal into another that may be read and comprehended by a predetermined reader, which would be a physical appliance or an individual. As a result, they make great measuring instruments. Temperature; bio - potentials: cardiogram, myography; acoustic: heart, lungs, digestive tract, joints; ultrasound: blood flow; movement:

breathing; moisture: sweat; pressure: blood *etc.* could be a number of bio - signals. There are a spread of materials and fabrications capable of converting signals:

- 1) Thermal sensors detect variations in temperature, like a thermistor that changes resistance as temperature varies.
- 2) Photo resistors for example, transform light energy into voltage output.
- 3) Sound sensors, like piezo-electric materials, take the surrounding noise and convert it into the electrical signal.
- 4) Moisture sensors determine whether the humidity is complete or relative. A capacitive device, which alters dielectric features when moisture is absorbed, is one example that might be helpful in textiles.
- 5) Sensors that convert pressure to an electrical signal are called pressure sensors. Simple procedures like opening or shutting a circuit will create a pressure sensor.
- 6) Chemical sensors detect the presence and/or concentration of a chemical or chemical mixture.
- 7) Bio - sensor: A bio-sensor may be a sensing device using biological elements.

Silk as a smart textile

For centuries, silk has been used as a textile material. However, it has recently been reported as a safe material with great bio-compatibility, being used for purposes other than textiles, particularly in the medical field. Transgenic silkworms were created in the year 2000, resulting in transgenic silk fibres with extra functions. Tensan silk, a natural fabric produced by the Japanese oak silk moth, *Antheraea yamamai*, is said to have outstanding properties, such as elasticity of pressure and chemical resistance.

Light weight, low cost, stability, durability, biocompatibility, and mass production are all advantages of silk. Scientists have developed a variety of ways to add driving elements (*e.g.*, metal particles, graphene, CNTs) into silk, which includes wet spinning, dry spinning, and feeding carbon nano-materials to silkworms and spiders.

The e-textiles can be washed automatically or with high-intensity ultrasonics. These CSF e-textile fabrics can be used as wearable sensors to detect and monitor physical and chemical signals, such as energy, temperature, and solvents, indicating potential uses for wearable devices, human enhancement, healthcare monitoring, and human-machine interfaces, water absorption and desorption, indicating that it could be a suitable material for moisture-responsive smart textiles.

Affinity Purification systems, diagnostics, detection of pathogenic microbes, and the creation of therapeutic techniques are all made possible by silk, which has a single-chain fragment variable (scFv) of IgG protein linked to silk fibroin protein. Silk, therefore is considered as a clever substance that is employed in medical and related fields.

Data processing

Textile sensors have the potential to offer a massive amount of data, but what do they really mean? Significant signal differences between patients, complex analysis of static and time-dependent symptoms, lack of standard vaccine values, and lack of knowledge of complex correlations between parameters are all problems. Besides, the material of the fabric itself possesses no computational capability. Although of course incorporated in water-resistant materials, their longevity is still limited. Furthermore, the processor's energy consumption is a current issue. Because the electronic components required for energy are not small enough or flexible enough, they differ from the textile structure. Another issue is the need for these energy units and other

electronic devices to be waterproof. This is not a problem in the case of automobiles because data processing devices can be installed inside the vehicle.

Actuators

Actuators are available devices programmed to take the appropriate action in response to sensors or processors. Actuators perform tasks, such as delivery of objects, releasing building materials, and creating noise by responding to a sensor effect and possibly transmitting this effect through the information processor. The best examples in this section are shape memory items.

Shape memory Alloys can be made into lattice structures. Shape memory objects can be utilized as actuators due to their re-acting in temperature changes, and they meet the requirements of intelligent fabrics. Secretory materials have a variety of commercial uses, as skin protectants, anti-bacterial products, and other such items.

Types of medical wearables

1) Clothing and vest for patients

Without the need for a variety of connected devices, electrodes integrated inside a patient's garment or vest to measure temperature, heart rate, and blood pressure are a few examples for medical wearables. The data from the gown can be transferred to a compatible computer accessible by the physician even before meeting the patient. The garment-based ECG monitoring system was developed by Nuubo, a wearable medical equipment company. These electrodes keep track of the patient's progress in cardiac resuscitation and provide relief.

Before the patient leaves, the internal system is installed on a doctor's computer in order to capture/record the patient's health readings. Later, The Micro SD is removed and downloaded onto a computer for inspection when it's time to produce a report.

2) Every day apparel

Outside the office, e-textile/smart textile technology can be utilized to monitor and treat health concerns. The best part about this software is that it eliminates the need for a patient to visit a doctor.

3) Caps and gloves

Sensors and antennas placed in a fitting cap can provide an insight into the brain function and help treat neurological disorders like epilepsy. It could potentially be utilized for those who have problems of insomnia. Therapeutic gloves are another application for e-textile technology. The pain management is one of the most interesting features of this technology of gloves. These gloves can be worn by arthritis patients to relieve pain by electrical stimulation and compression.

4) ECG

Scientists have created a gadget known as cardiac support device (CSD) designed to minimize the course of heart failure as shown in Figure 1. Fabrics, both knitted and woven, are employed here as a cardiac support device. They are used to create an innovative medical device that correct heart and circulatory system disorders. The new devices require fewer invasive surgical procedures and carry a lower risk than earlier devices, as well as fewer problems and hospital stays.

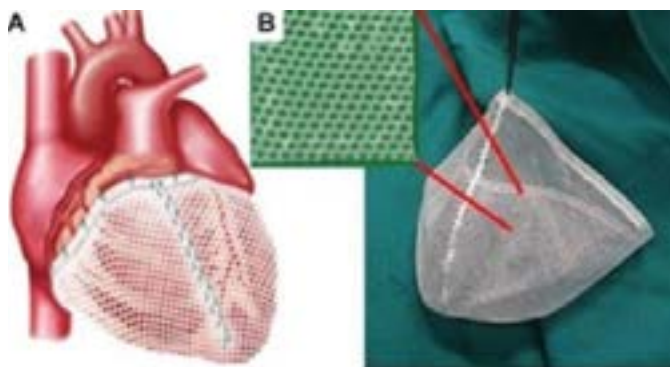


**Figure 1: A. Device for cardiac support-Cor Cap;
B. The *in situ* implementation**

(Source: <https://www.intechopen.com/chapters/73836>)



Figure 2: Healthcare e-textile devices

(Source: <https://www.mdpi.com/2079-9292/11/1/99/htm>)

The classification of healthcare devices formed out of e-textiles is as shown in Figure 2. Another example that is commonly used nowadays is the multiparameter tracker. The increase in investment in health care infrastructure is due to an increase in the elderly population as well as the incidence of chronic diseases. Due to the consumers' focus on self-monitoring, the current COVID-19 epidemic has increased oximeter tracking as displayed in Figure 3. In the next two years, the pulse oximeter market is expected to double in size.



Figure 3: Healthcare e-textile system prototype design ("Astroskin" shirt by Carre Technologies Inc. (Hexoskin))

(Source: <https://www.mdpi.com/2079-9292/11/1/99/htm>)



Figure 4: A few smart gadgets

(Source: <https://www.mdpi.com/2079-9292/11/1/99/htm>)

A first approach to integrate electronics into textile structures was certainly achieved by gloves wired to the computer that allows it to take input from user's hand gestures. Sensors in the glove (DataGlove™ VRLOGIC with flex sensors) detect the wearer's hand movements (Figure 4 a). Four wires were used for each finger or tube to build up a circuit. The voltages coming out are varying depending on the finger position. Figure 4 b depicts a flexible integrated sensing array (FISA) coupled to a smart wrist band that may be used to screen metabolites and electrolytes in human sweat in a selective and simultaneous manner. Skin temperature can be measured for both indoor and outdoor activities. The sensors were made from a flexible polyethylene terephthalate (FPET) substrate. The performance of each sensor was monitored using a variety of analyte solutions. In another case (Figure 4 c), children's underwear was specially developed to detect pee leakage while sleeping in order to help youngsters with enuresis. With the use of wires, these sensors were connected to an alarm enabling speedy conveyance of information to the parents. It is based on bio-impedance measurements taken in real time. Leakage sensors measure the conductivity of urine liquid in the bladder and electrical modules process the signals. After numerous washing cycles at 60 °C, however, electrical conductivity was degraded. With the use of Bluetooth

data, this early detection can be tied to a cell phone as shown in Figure 4 b.

Medicinal devices

Wearable e-textile systems could replace traditional therapy methods in therapy procedures. Neuromodulator Devices, used for transcutaneous electrical nerve stimulation (TENS) and spinal cord stimulation (SCS) therapies, are examples of pain management equipment. Radio-frequency ablation and cryoablation treatments are also performed with these pain management equipment. In the same way, wearable textiles are used to prepare intrathecal insertion pumps and external pumps. Another area where e-textile system preparations are being used is the treatment of neuropathic pain. Lung ventilation and related cardiac processes are also treated with wearable e-textile devices. Chemical sensors embedded in wearable textiles are also being utilized to investigate metabolic disorders. Phototherapy is another application for smart textiles. Figure 5 describes the photodynamic treatment with textile optical fibers. Here, flexible light-emitting woven structures were used for actinic keratoses treatments. The authors have experimented with different types of structures, including woven-based, embroidery-based, panel-based containing micro-perforations, *etc.* After various experiments, they claimed that woven-based structures gave the best results.



Figure 5: Photodynamic therapy for actinic keratoses with light-emitting fabrics

(Source: <https://www.mdpi.com/2079-9292/11/1/99/htm>)

E-textiles for healthcare development for commercial use

In recent years, the healthcare system has made significant progress, and various Lab scale samples are now available at research institutes. Some prototypes have it already gone to promote for customer scale, while others are within the works. Here are some samples in this series. *Kymira*, a wise textile startup, has created a prototype of a heart-monitoring T-shirt that will detect the risk of a player's attack. It sends heartbeat to smartphone via Bluetooth, with the detection of an abnormal rhythm that would result in abrupt cardiopulmonary arrest. These products, however, don't seem to be yet available within the marketplace for buyers, and their prices haven't yet been announced. ECG sensors are built into the *Xiaomi Mijia* cardiogram T-shirt to watch the patient's physical condition. Another smart T-shirt is with ECG attached to nerves to monitor heart rate coupled in a mobile app for recording data and transferring it to medical professionals. However, they're only available for pre-order at a value of \$249 USD. Sensoria fitness goods are another example (Figure 6). Outside, the sensory care micro - electronics is connected with a snap button. These socks have a cool Bluetooth device attached to it that counts steps, help to burn calories, measures height, and records distance. It can identify and avoid behaviors which often cause running injuries. In addition to the use of any additional belts, the smart Sensoria Fitness T-shirt (Figure 6) provides continuous reading of important signs. These fitness products are quite suitable for athletes who focus on their thirst for sports.



Figure 6: Sensoria fitness products

(Source: <https://www.mdpi.com/2079-9292/11/1/99/htm>)

Progress in the development of healthcare e-textile systems Diagnostic and monitoring device

Textile-based sensors are increasingly being used in everyday life for a variety of applications, including physical and biological sensing. Flexible/stretchable stress-strain sensors are a good example. These sensors can detect and record the impact of fabric stress on the fabric as well as the degree of recovery against it. Knitted fabrics with conductive coatings are widely available. Fabrics with graphene coatings and fabrics made of carbon nanotubes (CNTs) are also in the market. Another type of textile-based sensor is pressure sensors. They can be either capacitive or opposing pressure sensors (Figure 7). In the smart textile business, temperature sensors are also commonly used. These sensors can be used in conjunction with the system or alone for specific purposes. It's possible that these sensing mechanisms are piezo-electric, piezo-resistive, or capacitive.



Figure 7: Textile based ECG sensor

(Source: <https://www.mdpi.com/2079-9292/11/1/99/htm>)

Conclusion

Textile technologies, novel materials, nano-technology and micro-electronics and wearables make more efficient programs. For all these smart textiles, silk is the best fibre and, the critical characteristic for users to embrace the things you wear is comfort. This is regarded as a difficult nature of the human body and nature, as well as a mechanically resistant and durable environment. Furthermore, the circuit design of intelligent textile,

knowledge / wisdom, micro-electronics, and chemistry, all combined with a complete understanding of silk in smart textile production explores a new horizon of smart textiles.

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26th Congress of International Sericultural Commission

The 26th International Sericultural Commission Congress; “SERITECH- The New Concepts in Sericulture” was held at the University of Agricultural Science and Veterinary Medicine, Cluj Napoca, Romania during 7-11 September 2022. The Congress was jointly organized by the University and ISC. The highlights of the Congress are as following:

1	Total No. of delegates	155
2	No. of Countries represented	18
3	Research papers presented (No.)	109
	Oral- Physical	50
	Oral- Online	53
	Poster	6
7	Awards presented	7
8	Book released	1

The Congress was inaugurated by Prof. Cornel CATOI, Rector, University of Agricultural Science and Veterinary Medicine, Cluj Napoca.





The book developed by ISC; **“The Chronicles of Silk”** was released during the inaugural ceremony of the Congress by Mr. Antal Szabolcs Barabási, State Secretary in the Ministry of Agriculture and Rural Development, Romania. The book narrates the origin and history of mulberry and non-mulberry silk and its trail through various civilizations of the world. In the second part of the book, images and descriptions of silk products from different countries are depicted which displays the diverse craftsmanship and designs existed in the diverse geographical regions of the world. The book is expected to be a unique manuscript containing hitherto unknown facts about silk. For the first time in the history, the origin of Wild Silk Industry is revealed and its spread to various civilizations is mapped. The Book in 450 plus pages would be a unique experience to the silk enthusiasts, historians and the common people alike.

Mr. Dileep Kumar, Executive Director, ISC presented a video highlighting the main theme of the Book. The concept of the book was well received by the delegates.



International Awards on Silk Industry

The inaugural function also witnessed the presentation of ISC Awards by Mr. Rajit Ranjan Okhandiar, the Secretary General of International Sericultural Commission.



Louis Pasteur Awardees – 2022



Dr. Yasushi TAMADA, Japan

Dr. Tamada has undertaken research on chemical and genetical modifications of silk proteins, new fabrication methods using silk protein aqueous solution, analyses of cell behaviour on silk protein substrate, and evaluation of silk materials for cartilage regeneration scaffolds. These works are expected to accelerate the use of silk in pharmaceutical sector.

The sulfated silk proteins developed by Dr. Tamada has the potential to be commercialized as a preventive agent for HIV infection. Initial works for an industrial collaboration with a Japanese chemical company is currently underway. The silk protein resin developed have excellent dielectric properties and thermal conductivity which are being disseminated to field. The silk fibroin sponge materials developed by him is used in cosmetics, aesthetic, and medical fields through collaboration with a reputed chemical company. Dr. Tamada's research work on interactions between cells and silk materials provides crucial information for developing medically applied products, such as wound dressings and cell scaffolds for regenerative medicine.



Mrs. Somying Chuprayoon, Thailand

Mrs. Somying Chuprayoon has been involved in the development of quality standards for Thai silk, which culminated in successful industrial utilization of hand reeled Thai silk. She was also involved in developing testing and reeling equipment in collaboration with Kasetsart University and National Bureau of Agricultural Commodity and Food Standards. These equipment have been readily accepted and popularized in the field. In 2017, she developed a prototype of a silk producer according to TAS 8000-2012 standard to enable farmers to set up a silk production system to meet quality and certified according to standard, receiving "Q" mark. She was instrumental in introducing contract farming system which helped the farmers to increase their income for more than 30% consistently throughout the year.



Dr. Subhas V. Naik, India

Dr. Naik was involved in developing indigenous multi-end reeling machine and automatic reeling machine along with the package of practices suitable to the cocoons produced for the Indian

conditions. He has also been involved in popularizing 650 MRMs and 127 ARMs all across the country. These efforts have significantly enhanced the production, productivity and quality of Indian silk. India is now in a position to produce internationally graded silk for local consumption and resultantly the import of silk to the country has significantly reduced.

Awardees of Excellence in Sericulture Science (ESS) - 2022

Category	Name and Country		Contribution
Host Plant Development		Mr. Somchai Luemunkong, Thailand	Developed three high yielding varieties which are very popular in the field.
Silkworm Development		Dr. S. Manthira Moorthy, India	Dr. Moorthy has developed a promising bivoltine hybrid for the eastern and central regions of India. Historically, these regions were known to practice multivoltine races as the climatic conditions are not suitable for bivoltine rearing. However, the Hybrid developed by Dr. Moorthy has broken this myth and has become so popular in the region. Resultantly, the bivoltine production in the region has significantly increased from 38 MT in 2010 to 2386 MT in 2020.
Post Cocoon and Post Yarn Technology		Mr. Meechai Taesujariya, Thailand	Mr. Meechai Taesujariya has been involved in developing a new textile design called “Pa Kaab Bua” with the combination of techniques like Mudmee, Khit and Mubmai on stripped warp. This has become so popular in Thailand and other parts of the world. Mr. Meechai has got several awards for the “Pa Kaab Bua” design in the field.

Category	Name and Country	Contribution
Silkworm and Silk in Non-Textile Industry	 Dr. Somchai Jomduang, Thailand	He has been involved in developing many by-products from sericulture with the concept of “Zero Waste”. One of the major breakthrough research of Dr. Somchai was identification of pupae extract as a viable agent for vasodilation. This knowledge has the potential to develop medicines for sclerosis and high blood pressure.

ISC Executive Committee Meeting

The Executive Committee Meeting of ISC was held at 17:00 hrs on 7 September 2022 in the Chamber of Rector, University of Agricultural Science and Veterinary Medicine, Cluj Napoca, Romania. The meeting witnessed the participation of delegates from India, Japan, Romania, Thailand and Uganda. The major highlights of the EC Meeting are:

- a) To organize the 27th ISC Congress in 2025 in one of the ISC Member Countries.
- b) Commercial release of the Book “The Chronicles of Silk Industry” by 2022.
- c) Member Countries to nominate suitable candidates for the “Training on Sericulture and Silk Industry” and the “Training on Post Cocoon Technology”.
- d) ISC to organize the 10 days training for its National Delegates in China or Thailand.



Applications invited for ITEC Training:

The ISC invites online filing of applications for the two training programmes on silk industry sponsored by the Ministry of External Affairs under the ITEC programme. The details are given below:

#	Course	Institute	Period
1	Training on Sericulture and Silk Industry	Central Sericultural Research and Training Institute, Mysore, India	6 Nov to 3 Dec 2022
2	Training on Post Cocoon Technology	Central Silk Technological Research Institute, Bengaluru, India	8 Jan to 4 Feb 2023

The link for filing the applications:

1) Training on Sericulture and Silk Industry:

https://www.itecgoi.in/courses_list?salt3=NThiNWRhNmU0MTIwMjltMjAyMw==&salt4=NmM3NDM5ZTNjMzM1&salt=ODgzMjcxY2JmMzIwNQ==

2) Training on Post Cocoon Technology:

https://www.itecgoi.in/courses_list?salt3=ZDFmNTgwYThiZDIwMjltMjAyMw==&salt4=NmRhNzY0ZTZhNTQw&salt=YzMwN2ExNjgwZDIxNQ==



APPLICATION FOR ASSOCIATE MEMBERSHIP

Name *			
Person – In-charge **			
Institute			
Address			
Country			
Tel		Fax	
Email			
(*) Individual Associate Members : Individuals to subscribe journal ' <i>Sericologia</i> '			
(**) Collective Associate Members : Institutions, Libraries, etc.			

I wish to become an Individual Associate / Collective Associate Member of ISC

New Application ☐

Renewal ☐

Rates: Individual Associate Members : **US\$ 50 per year (equivalent to Rs. 3,750/-)**

Collective Associate Members : **US\$ 150 per year (equivalent to Rs. 11,250/-)**

Applicants signature: _____ Date: _____

Membership fees can be remitted either by cheque/DD or by Bank Transfer

ISC BANK REFERENCE	
Beneficiary	- International Sericultural Commission
Account Number	- 3188283389
Bank and Branch	- Central Bank of India, CSB Branch, Bangalore, India
Bank Code	- IFSC - CBIN0283975; SWIFT - CBININBBMRB
<u>For overseas transfer</u> (THROUGH SCBL US 33, STANDARD CHARTERED BANK, NEW YORK, USA TO A/C NO.3582-050570-001 OF CENTRAL BANK OF INDIA, OVERSEAS BRANCH, MUMBAI, SWIFT: CBININBBOSB)	

This form along with your cheque/DD or the references of your Bank Transfer must be mailed to the Office of the International Sericultural Commission.

INFORMATION TO CONTRIBUTORS

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Submission of a paper to SERICOLOGIA implies that it has not previously been published, that it is not under consideration for publication elsewhere and that, if accepted in SERICOLOGIA, it will not be published elsewhere in the same form without the written consent of the Chief Editor.

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Sericologia

International Sericultural Commission

CSB Complex

BTM Layout, Madiwala, Bengaluru - 560068

Karnataka, India

Phone: +91-80-26282191

+91-80-26680162

+91-80-26681663

Fax: +91-80-26681663

Email: sericologia@gmail.com

Website: www.inserco.org