



INTERNATIONAL
SERICULTURAL
COMMISSION

UNITED NATIONS REG. NO. 10418

ISSN 0250-3980

Volume 61 | Number 1&2 | 2021

SERICOLOGIA

Journal of Silkworms
A Quarterly Publication of
International Sericultural Commission





INTERNATIONAL
SERICULTURAL
COMMISSION

UNITED NATIONS REG. NO. 10418

SERICOLOGIA

Journal of Silkworms

MANAGING DIRECTOR

Mr. Rajit Ranjan Okhandiar

CHIEF EDITOR

Dr. Julia S. Nair

CHAIR, SCIENTIFIC COMMITTEE

Dr. R. K. Mishra

ADMINISTRATIVE COUNCIL

Mr. Dileep Kumar R.
Mr. Padmanav Nayak

PUBLISHED BY

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
www.inserco.org

PRINTED AT

Ramya Reprographic Pvt. Ltd.
No. 16/2B, Singasandra Village
Behind Dakshin Honda Showroom
Hosur Road, Bengaluru 560068
INDIA. Tel: +91 98440 36357
Email: ramyareprographic@gmail.com

EDITORIAL BOARD

Dr. Basavaraja H. K., India
Dr. Cappellozza S., Italy
Dr. Chen Y., China
Dr. Couble P., France
Dr. Dandin S. B., India
Dr. Daniel Dezmirean, Romania
Dr. Das B. C., India
Dr. Fonseca T. C., Brazil
Dr. Freddi G., Italy
Dr. Gapuz C. F., Philippines
Dr. Goldsmith M. R., USA
Dr. He K., China
Dr. Homidy H., Uzbekistan
Dr. Iatrou K., Greece
Dr. Jolly M. S., India
Dr. Kobayashi M., Japan
Dr. Kusakabe T., Japan
Dr. Lea H. Z., Korea
Dr. Machii H., Japan
Dr. Madyarov S., Uzbekistan
Dr. Mase K., Japan
Dr. Mauchamp B., France
Dr. Miranda J. E., Brazil
Dr. Rajkhowa R., Australia
Dr. Shimada T., Japan
Dr. Sivaprasad V., India
Dr. Somashekhar T. H., India
Dr. Sonwalkar T. N., India
Dr. Tenczek T., Germany
Dr. Tzenov P., Bulgaria
Dr. Xia Q., China
Dr. Yamashita O., Japan
Dr. Yungen M., China



Content

Volume 61 | Number 1 & 2 | 2021

Research Papers

Improved crossbreed of silkworm, *Bombyx mori* suitable for eastern India, developed through congenic breeding

N. Chandrakanth, T. R. Devi, A. K. Verma, V. Lakshmanan, A. R. Pradeep and V. Sivaprasad 1

Detection of microsporidia (*Nosema* spp. and *Vairimorpha* spp.) from excreta of frogs and birds, collected from mulberry field

Ritsuko Murakami, Kazuhisa Miyamoto and Kenji Watanabe 14

Silkworm (*Bombyx mori*) pupae proteins: The source of high value amino acids

Y. Thirupathaiah, R. Ananthan, S. Manthira Moorthy, K. B. Chandrashekar, M. Chandrasekharaiah, V. Sivaprasad and Pankaj Tewary 19

Haemocyte dynamics in the silkworm, *Bombyx mori* L. during the progressive infection of BmIFV

M. Mamatha and M. Balavenkatasubbaiah 23

Employability of Sericulture PG Diploma holders in East and North-East India

G. R. Manjunatha, Lalrinnungi, Kiran Kumar R. Patil, J. Parameshwarnaik and V. Sivaprasad 34

Reports

Forest insect industry for livelihoods support to the forest dependent people and its simultaneous impact on collaborative conservation of tropical forests in India: An analysis

Narendra Kumar Bhatia 45

The socioeconomic worth of silk farming

K. Sashindran Nair 69



Tasar seed cocoons hung for moth emergence



IMPROVED CROSSBREED OF SILKWORM, *BOMBYX MORI* SUITABLE FOR EASTERN INDIA, DEVELOPED THROUGH CONGENIC BREEDING

N. Chandrakanth, T. R. Devi, A. K. Verma, V. Lakshmanan, A. R. Pradeep and V. Sivaprasad*

Silkworm Breeding & Genetics Division, Central Sericultural Research and Training Institute,
Berhampore, West Bengal 742101, India.

*Email: siva.nsso@gmail.com

ABSTRACT

Mulberry silk production in Eastern India is dominated by crossbreeds utilizing tropical Indian multivoltine races of *Bombyx mori*, particularly Nistari race due to prevailing adverse climatic conditions. This study aimed to develop multivoltine breeds with improved productivity following congenic breeding approach and identify improved crossbreed. MH1 was selected as donor and MCon1, MCon4 and M6DPC as receptor breeds based on multiple trait evaluation index (MTEI) ranking and the grading of silk content. Three congenic multivoltine silkworm breeds viz., 12Y, 21Y and 8W were developed by direct crossing (F1 hybrid), backcrossing (BC1F1-BC5F1) with receptor followed by sib-mating up to BC5F8 by applying directional selection targeting higher silk content and neatness. Six improved crossbreeds were evaluated for rearing performance utilizing BC5F8 females. 12Y × BCon1.BCon4, 21Y × BCon1.BCon4 and 8W × SK6.SK7 were further evaluated in Assam, Jharkhand, Odisha and West Bengal against Nistari × SK6.SK7 under multi-location trials. 12Y × BCon1.BCon4 performed better than the popular hybrid for yield consistency and economic traits. The low shell content (15-17 %) in 12Y x BCon1 × BCon4 prompted for further evaluation with new bivoltine breeds. 12Y × BFC1 exhibited 18-20 % of shell and higher cocoon yield (56-62 kg/100 DFLs) and hence, serve as an effective alternative for Nistari based crossbreeds.

Key words: *Bombyx mori*, congenic breeding, crossbreed, directional selection, shell content.

INTRODUCTION

The mulberry silkworm, *Bombyx mori* L. is an intensively domesticated insect for its economic importance in view of silk production. Bivoltine silkworms (two generations/year) originally from temperate regions do not withstand harsh climatic conditions, while multivoltine races from tropical regions (>2 generations/year) can adapt to variations in climatic conditions. Conversely, bivoltines produce cocoons with superior quality silk, while the multivoltines produce inferior quality silk (Datta, 1984). India being a tropical country, 90 % of the silk produced

is from multivoltine x bivoltine hybrids (Crossbreeds), which are of inferior quality (CSB, 2020). Therefore, it is highly pertinent to develop and identify more productive multivoltine silkworm hybrids capable of producing superior quality silk to meet the domestic demand.

Multivoltine silkworms are well adapted to the tropical climatic conditions of India and play a major role in the production of silk in India (Datta, 1984). Multivoltine breeds like Leimarin of Manipur, Sarupat, Chotapolu and Borapolu of Assam, Nistari of West Bengal and Pure Mysore of Karnataka are the indigenous races

that dominate Indian sericulture. Among them, Nistari and Pure Mysore are the major races that are well adapted to the fluctuating climatic conditions of India. Nistari is exploited largely for commercial raw silk production in Eastern India by rearing crossbreeds. Nistari race is the backbone of mulberry sericulture in West Bengal and the traditional rearing practiced for hundreds of generations has made it well adapted to the local environmental conditions (Nirmal Kumar, 2015). Nistari is bestowed with tolerance to abiotic and biotic stresses despite lower productive traits and inferior silk quality (Li *et al.*, 2012). It is of concern that the concerted efforts of silkworm breeders for more than 50 years to replace the indigenous Nistari race with better breeds could not get established in the field (Mukhopadhyay *et al.*, 2013; Chandrakanth *et al.*, 2021).

Previously, attempts to develop new multivoltine silkworm breeds by crossing multivoltines with exotic bivoltine breeds did not yield satisfactory results due to poor survivability, occasional egg hibernation and gradual deterioration of heterosis under fluctuating climatic conditions. Hence, new breeding approaches were explored. Congenic breeding approach involves introgression of genes/traits from the donor to the receptor in homozygous condition by backcrossing followed by sib-mating. The main consideration for congenic breeding is to minimize the heterogeneity and to develop syngenic lines for developing improved hybrids with higher heterosis (Verma *et al.*, 2016). According to Mukherjee (1994), heterosis has two general modes of expression *viz.*, increase in size, probably due to faster rate of cell activity and cell division, and increase in 'biological efficiency' such as reproductive rate and survivability. Congenic approach was utilized to demonstrate allozymic variations in silkworm by electrophoresis for esterase isozyme pattern (Chattopadhyay *et al.*, 2001 a, b, c). A few silkworm breeds were developed through congenic approach, but could not increase the productivity significantly. Congenic lines developed have to be employed to develop viable hybrids to suit agro-climatic conditions prevailing in Eastern India for commercial exploitation.

MATERIALS AND METHODS

Silkworm breeds and parent selection

Thirty one promising multivoltine silkworm breeds with high shell content were collected from different sericultural research institutes across India. These multivoltine breeds were reared and evaluated based on shell content at Central Sericultural Research and Training Institute (CSRTI), Berhampore. Silkworm rearing was conducted following the standard methods under recommended temperature and humidity conditions (Krishnaswami *et al.*, 1973). Data on rearing traits, such as fecundity, cocoon weight, shell weight, cocoon yield/10000 larvae by no. and weight and shell percentage were recorded. The rearings were conducted in triplicates of 300 larvae/replication. Rearing traits were subjected to multiple trait evaluation index (Mano *et al.*, 1993). Based on the evaluation index on rearing traits, the donor and receptor multivoltine breeds were selected to accomplish parental stock selection. Donor selection was based on higher shell weight and shell percentage.

Breeding method

Congenic breeding method was employed to evolve new multivoltine breeds with high shell content. To start with, female receptor parent was crossed with the male donor parent. The resultant hybrid (F1) was backcrossed with the receptor parent successively for five generations to attain BC5F1 generation. Backcrossing was aimed to bring the receptor genome in homozygous condition in the successive generations. In the BC5F1 generation (Filial generation), sib-mating was done to attain BC5F2 generation; the breeding process was continued till BC5F8 generation, wherein uniformity in morphological traits *viz.*, egg colour, larval mark, cocoon colour and cocoon shape was achieved and the desired traits were fixed. Directional selection was applied in each generation by selecting the cocoons with high shell content through single cocoon assessment. The rearing traits *viz.*, fecundity, cocoon yield/10000 larvae by no. and weight, cocoon weight, shell weight,

shell percentage and neatness were documented in each generation. The schematic representation of the congenic breeding method is presented in Figure 1. The congenic multivoltine breeds thus developed were evaluated under laboratory conditions.

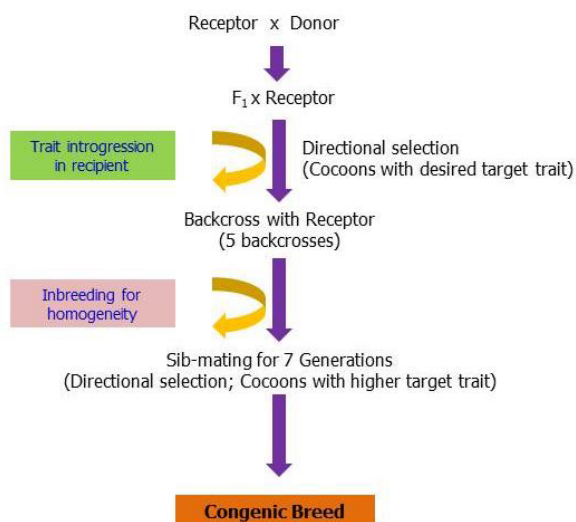


Figure 1: Schematic representation of breeding plan for development of multivoltine congenic breeds

Hybridization (Three-way cross)

To produce multivoltine $\times$ bivoltine F₁s, the two well-known popular dumbbell silkworm foundation crosses in Eastern India *viz.*, SK6 $\times$ SK7 and BCon1 $\times$ BCon4 were identified as male components. New congenic multivoltine breeds with high shell content were crossed with the males of SK6 $\times$ SK7 and BCon1 $\times$ BCon4. The rearing and reeling performances of F₁s was recorded in different seasons (3 replications with 300 larvae each/hybrid). Most popular multi $\times$ bivoltine hybrid, Nistari $\times$ SK6.SK7 was maintained as control hybrid. The data collected were subjected to multiple trait evaluation index (Mano *et al.*, 1993) for ranking of improved crossbreeds based on overall performance.

Evaluation of crossbreeds

Based on ranking and shell content, three crossbreeds were selected for further evaluation in the laboratory

in all the seasons during 2016-17. The data on rearing traits *viz.*, fecundity, cocoon weight, shell weight, shell percentage, cocoon yield/ 10000 larvae by no. and weight, pupation rate, cocoon yield/100 DFLs along with reeling parameters and neatness were documented. The improved crossbreeds were subsequently tested with the selected farmers for two years (2017-2019) covering all the commercial crops in Assam (Jorhat), Jharkhand (Bhandra), Odisha (Koraput) and West Bengal. The data on rearing traits, such as cocoon yield/100 DFLs, cocoon weight, shell weight and shell percentage along with reeling parameters (filament length, reelability, renditta, silk recovery and neatness) were recorded for assessing the field performance. Improvement over the control hybrid (Nistari $\times$ SK6.SK7) and the economic significance under field conditions *i.e.*, yield realization potential (%) over the laboratory performance was also documented and analyzed. Significant differences in the rearing traits were detected at a critical difference of 5 %.

Identification of bivoltine male component

In order to improve the shell content, four bivoltine breeds (4S, BMFD1, CSR16 and CSR51) with high shell content were collected from CSRTI-Mysuru. These breeds were hybridized with females of popular bivoltine silkworms (SK6, SK7, BCon1 and BCon4). Following an elaborate and systematic inbreeding programme involving line isolation, outcrossing and stabilization, a bivoltine foundation cross *i.e.*, BFC1 (BCon1 $\times$ 4S) was evolved. BFC1 was crossed with 12Y to develop improved crossbreed and the overall rearing and reeling performance was evaluated under laboratory conditions in five seasons (3 replications with 300 larvae each). The 12Y crossbreed, 12Y $\times$ BCon1.BCon4 developed by crossing with popular bivoltine foundation cross, BCon1. BCon4 was maintained as control.

RESULTS

Morphological variations

Thirty one multivoltine silkworm breeds from different

sericultural research organizations of India were considered for this study. Among them, 15 silkworm breeds *viz.*, A25, G, Leimarel, M2, M15, MU1, MH1, MCon1, MCon4, M6M81, M6DPE, M6DPC, O, PM and P2D1 have recorded high survival (>85 %). These silkworm breeds were further evaluated for rearing performance and variations in morphological characteristics, such as larval marking patterns, cocoon shape and cocoon colour were documented (Table 1). All the silkworm larvae were plain in appearance, except for MH1, MCon4, O and G. Four types of cocoon shapes *viz.*, spindle, spatulate, oval and elongated oval were recorded. The colour of the cocoons spun by M6DPE, MCon4, M6M81, M6DPC, O, Leimarel, A25, M2 and G was yellow; greenish yellow by PM, MU1 and P2D1, white by MCon1 and M15; and off-white by MH1.

Rearing performance

Six important rearing traits *viz.*, fecundity (no.), cocoon weight (g), shell weight (g), cocoon yield/ 10000 larvae by no. and weight (kg) and shell percentage were analyzed in fifteen multivoltine silkworm breeds. The

highest and lowest fecundity were recorded in MCon4 (529) and Leimarel (274), respectively. The highest cocoon yield per 10,000 larvae by number was recorded in MU1 (9411) and the lowest in G (7300). Maximum cocoon yield per 10,000 larvae by weight (14.38 kg) and cocoon weight (1.596 g) was recorded in M6DPE; while the minimum cocoon yield (8.37 kg) and cocoon weight (1.026 g) was observed in G and P2D1, respectively. MH1 performed the best in terms of shell weight and shell percentage (0.253 g and 16.14 %, respectively) and MU1, the least (0.106 g and 9.63 %, respectively).

Multiple trait evaluation index performed on the rearing parameters of multivoltine silkworm breeds clearly showed that M6DPE topped the rank list with 62.73 followed by MH1 (62.20), MCon4 (61.38) and MCon1 (54.90) with evaluation indices of >50 (Table 1). MH1 with the highest shell weight and shell percentage was selected as donor parent, whereas the other high performers *viz.*, MCon1, MCon4 and M6DPE were selected as receptor parents for initiating the breeding program to develop productive congenic breeds.

Table 1: Evaluation of multivoltine silkworm breeds

Breed	Larval marking	Cocoon shape	Cocoon colour	Fecundity (No.)	Cocoon yield/ 10,000 larvae by no.	Cocoon yield /10,000 larvae by wt. (kg)	Cocoon weight (g)	Shell weight (g)	Shell %	Cumulative multiple trait evaluation Index	Rank
M6DPE	Plain	Spatulate	Yellow	461	8789	14.38	1.596	0.233	14.62	62.73	1
MH1	Marked	Spindle	Off-white	496	8111	12.82	1.566	0.253	16.14	62.20	2
MCon4	Marked	Spindle	Yellow	529	8700	10.60	1.489	0.239	16.07	61.38	3
MCon1	Plain	Spindle	White	517	8678	10.71	1.245	0.185	14.83	54.90	4
M6M81	Plain	Oval	Yellow	420	8817	10.68	1.271	0.154	12.10	49.19	5
M15	Plain	Spatulate	White	419	8963	9.71	1.158	0.145	12.50	48.52	6
M6DPC	Plain	Spatulate	Yellow	411	8989	9.93	1.152	0.146	12.71	48.44	7
O	Marked	Oval	Yellow	468	9056	9.81	1.164	0.133	11.44	48.13	8
Leimarel	Plain	Spindle	Yellow	274	7865	12.44	1.572	0.176	11.19	47.52	9
A25	Plain	Elongated oval	Yellow	477	7989	9.20	1.170	0.142	12.10	46.07	10
PM	Plain	Spindle	Greenish yellow	400	8517	9.78	1.041	0.133	12.78	45.13	11
M2	Plain	Oval	Yellow	336	8221	9.55	1.240	0.154	12.45	45.04	12
MU1	Plain	Elongated oval	Greenish yellow	404	9411	9.82	1.103	0.106	9.63	44.83	13
P2D1	Plain	Elongated oval	Greenish yellow	404	9108	9.07	1.026	0.111	10.78	43.19	14
G	Marked	Oval	Yellow	451	7300	8.37	1.186	0.147	12.39	42.72	15
Mean				431	8568	10.46	1.265	0.164	12.78		
Minimum				274	7300	8.37	1.026	0.106	9.63		
Maximum				529	9411	14.38	1.596	0.253	16.14		
Standard deviation				64.69	546.70	1.55	0.19	0.04	1.81		

Breeding of congenic breed

The breeding program was initiated by crossing female receptor parents (MCon1, MCon4 and M6DPE) with the male donor parent (MH1). The resulting hybrids, MCon1 × MH1, MCon4 × MH1 and M6DPE × MH1 were backcrossed with their respective receptor parents for five generations to attain BC5. The breeding program was continued till the breeding lines attained desired targeted traits *i.e.*, shell content (>16 %). The evolved breeding lines recorded better shell percentage in all the generations over the donor parent. The breeding programme was continued till BC5F8 (Congenic breed) which exhibited >17 % cocoon shell. MCon1 × MH1 achieved the highest shell percentage in all the generations followed by MCon4 × MH1 and M6DPE × MH1 (Tables 2-5). For convenience, easy handling and

to avoid ambiguity, the breeding lines MCon1 × MH1, MCon4 × MH1 and M6DPE × MH1 were denoted as 8W, 12Y and 21Y, respectively.

The rearing and reeling performances of the congenic multivoltine silkworm breeds were evaluated under laboratory conditions. 12Y recorded the highest with regard to fecundity (533), cocoon yield/10000 larvae by no. (9300) and weight (14.43 kg), cocoon weight (1.538 g), shell weight (0.268 g), shell percentage (17.42), filament length (640 m), neatness (88 p) and better denier (2.41 d). Highest reelability (79.33 %) and raw silk (11.14 %) was observed in 8W as compared to the other congenic breeds. Data subjected to one sample ‘t’ test resulted in the significant differences among the rearing and reeling traits of congenic silkworm breeds ($P < 0.001$; Table 5).

Table 2: Rearing performance of F1 hybrids

F1 hybrid	Fecundity (No.)	Cocoon yield /10,000 larvae by no.	Cocoon yield/ 10,000 larvae by wt. (kg)	Cocoon weight (g)	Shell weight (g)	Shell %
MH1 (Donor)	496	8132	11.33	1.478	0.244	16.51
M.Con.1 x MH1	401	9667	15.67	1.651	0.282	17.05
M.Con.4 x MH1	563	8700	12.50	1.442	0.228	15.81
M6DPE x MH1	421	8746	12.52	1.502	0.225	14.98
Mean	470	8811	13.01	1.518	0.245	16.09
Minimum	401	8132	11.33	1.442	0.225	14.98
Maximum	563	9667	15.67	1.651	0.282	17.05
Standard deviation	64.20	550	1.61	0.08	0.02	0.78

Table 3: Performance of congenic batches *wrt* targeted traits in BC1F1 – BC5F1 generations

Breed / Line	BC1F1		BC2F1		BC3F1		BC4F1		BC5F1	
	Shell %	Neatness (p)	Shell %	Neatness (p)	Shell %	Neatness (p)	Shell %	Neatness (p)	Shell %	Neatness (p)
MH1 (Donor)	16.52	78	15.64	84	15.57	80	15.30	78	15.83	82
M.Con.1 x MH1	17.17	80	16.08	88	16.50	84	17.46	82	17.74	84
M.Con.4 x MH1	17.14	75	15.28	88	16.19	84	17.52	82	17.06	83
M6DPE x MH1	17.36	75	14.42	89	16.25	86	17.16	84	17.50	82
Mean	17.05	77	15.36	87	16.13	84	16.86	82	17.03	83
Minimum	16.52	75	14.42	84	15.57	80	15.30	78	15.83	82
Maximum	17.36	80	16.08	89	16.50	86	17.52	84	17.74	84
Standard deviation	0.32	2.12	0.61	1.92	0.34	2.18	0.91	2.18	0.74	0.83

Table 4: Performance of congenic batches *wrt* targeted traits in BC5F2 – BC5F7 generations

Breed / Line	BC5F2		BC5F3		BC5F4		BC5F5		BC5F6		BC5F7	
	Shell %	Neatness (p)	Shell %	Neatness (p)	Shell %	Neatness (p)	Shell %	Neatness (p)	Shell %	Neatness (p)	Shell %	Neatness (p)
MH1 (Donor)	15.47	85	15.00	83	14.98	80	15.78	84	14.20	88	15.60	85
M.Con.1 x MH1	17.32	89	17.34	83	17.33	81	17.27	84	17.67	88	17.31	88
M.Con.4 x MH1	17.30	88	17.78	83	16.81	82	16.73	83	17.65	88	17.31	88
M6DPE x MH1	15.69	86	16.83	84	16.01	80	15.79	83	15.64	90	16.07	90
Mean	16.45	87	16.74	83	16.28	81	16.39	84	16.29	89	16.57	88
Minimum	15.47	85	15.00	83	14.98	80	15.78	83	14.2	88	15.6	85
Maximum	17.32	89	17.78	84	17.33	82	17.27	84	17.67	90	17.31	90
Standard deviation	0.87	1.58	1.06	0.43	0.89	0.83	0.64	0.50	1.46	0.87	0.76	1.79

Table 5: Rearing performance of developed congenic multivoltine silkworm breeds

Breed	Denoted as	Fecundity (No.)	Cocoon yield /10,000 larvae by no.	Cocoon yield/ 10,000 larvae by weight (kg)	Cocoon weight (g)	Shell weight (g)	Shell %	Filament length (m)	Denier (d)	Reel-ability (%)	Raw silk (%)	Neat-ness (p)
MH1 (Donor)		475	9133	12.69	1.506	0.235	15.60	524	2.54	68.56	7.94	83
M.Con.1 x MH1	8W	511	8700	11.57	1.308	0.226	17.28	588	2.51	79.33	11.14	86
M.Con.4 x MH1	12Y	533	9300	14.43	1.538	0.268	17.42	640	2.41	74.48	10.11	88
M6DPE x MH1	21Y	508	7333	8.47	1.205	0.190	15.76	615	2.63	67.98	9.73	86
t stat		65.64**	14.51*	6.68NS	13.72*	10.12*	31.64**	40.92**	39.57**	22.48*	24.52*	130**

Values represent the mean of three seasons

* $P < 0.001$; ** $P < 0.0001$; NS - Non-significant

Improved Crossbreeds

The developed congenic multivoltine breeds (8W, 12Y and 21Y) were crossed with two well-known popular foundation crosses of Eastern India *viz.*, SK6 × SK7 and BCon1 × BCon4. Six crossbreed combinations were tested under the laboratory conditions. Notable increment in the rearing and reeling traits was observed in the crossbreeds as compared to the congenic breeds themselves, which can be attributed to the bivoltine component used in crossbreed development. In order to

shortlist the promising crossbreeds for field evaluation, multiple trait evaluation index (Mano *et al.*, 1993) was applied for rearing and reeling data (Table 6). Denier and renditta were exempted from the analysis as they are inversely related traits for reeling characteristics of the cocoon. The results indicated that 12Y × BCon1.BCon4 ranked first with cumulative evaluation index of 51.53 followed by 21Y × BCon1.BCon4 and 8W × SK6.SK7. Based on evaluation index and higher shell content, 12Y × BCon1.BCon4, 21Y × BCon1.BCon4 and 8W × SK6.SK7 were selected for field evaluation.

Table 6: Multiple trait evaluation of improved crossbreeds of developed congenic breeds

Crossbreed	Fecundity (no.)	Cocoon yield /10,000 larvae by no.	Cocoon yield /10,000 larvae by weight (kg)	Cocoon weight (g)	Shell weight (g)	Shell %	FL (m)	Denier (d)	Reelability (%)	Raw silk (%)	Renditta (kg)	Recovery %	Neatness	Cum MTEI	Rank
12Y × BCon1.BCon4	501	8356	15.41	1.781	0.346	19.43	702	2.30	71.80	9.10	10.98	76.47	85	51.53	1
21Y × BCon1.BCon4	526	9378	16.04	1.751	0.337	19.23	582	2.53	67.53	9.06	11.30	75.00	80	50.80	2
21Y × SK6.SK7	506	9244	15.78	1.720	0.336	19.55	651	2.41	73.51	10.00	10.27	77.14	80	50.41	3
8W × BCon1.BCon4	495	9355	15.79	1.605	0.327	20.38	647	2.62	73.61	9.33	10.71	77.41	75	50.21	4
12Y × SK6.SK7	472	9233	14.98	1.792	0.350	19.51	621	2.23	68.75	11.00	9.09	78.57	84	48.78	5
8W × SK6.SK7	510	8189	14.41	1.769	0.349	19.73	576	2.49	44.38	9.56	10.46	76.92	80	48.27	6

FL: Filament length; Cum MTEI: Cumulative multiple trait evaluation index.

Laboratory performance of improved crossbreeds

The selected crossbreeds were reared under the laboratory conditions for a year (2016-17) in all the seasons. Except for pupation, the test crossbreeds *i.e.*, 12Y × BCon1.BCon4, 21Y × BCon1.BCon4 and 8W × SK6.SK7 performed better than the control, Nistari × SK6.SK7 in all the rearing and reeling traits. The highest fecundity

Multi-location trials of improved crossbreeds

The improved promising crossbreeds, 12Y × BCon1.BCon4, 21Y × BCon1.BCon4 and 8W × SK6.SK7 along with the popular crossbreed (Nistari × SK6.SK7) were evaluated in the field conditions with the farmers in Eastern India. A total of 23400 DFLs consisting of test crossbreeds and 7800 DFLs of control were tested with

Table 7: Laboratory performance of improved crossbreeds of developed congenic breeds

Crossbreed	Fecundity (No.)	Cocoon weight (g)	Shell weight (g)	Shell %	Pupation rate (%)	Cocoon yield /10,000 larvae by no.	Cocoon yield /10,000 larvae by wt. (kg)	Yield/ 100 DFLs (kg)	Neatness (p)
8W × SK6.SK7	510	1.769	0.349	19.73	92	8189	14.41	57.64	80
12Y × BCon1.BCon4	506	1.720	0.336	19.55	94	9244	15.78	63.12	80
21Y × BCon1.BCon4	495	1.605	0.327	20.38	95	9355	15.79	63.16	75
Nistari × SK6.SK7 (Control)	382	1.366	0.209	15.30	96	9324	12.29	49.16	72

(510), cocoon weight (1.769 g) and shell weight (0.349 g) were recorded in 8W × SK6.SK7. Cocoon yield/10000 larvae by number (9355) and weight (15.79 kg), cocoon yield/100 DFLs (63.16 kg) and shell percentage (20.38) were the highest in 21Y × BCon1.BCon4; while, the highest neatness (80 p) was observed in 8W × SK6.SK7 and 12Y × BCon1.BCon4 (Table 7).

156 farmers covering West Bengal (11 crops), Odisha (7 crops), Assam (5 crop) and Jharkhand (7 crops). Data on overall performance of test crossbreeds from multi-location trials were documented and analyzed (Table 8).

The results reveal that 12Y × BCon1.BCon4 performed better with an improvement of 19.46 % cocoon yield over control, while 8W × SK6.SK7 exhibited better shell

content in West Bengal. In Jharkhand, 12Y × BCon1.BCon4 performed better with 10.50 % yield improvement over control and 21Y × BCon1.BCon4 performed better in cocoon weight, shell weight and shell content (Figure 2). 12Y × BCon1.BCon4 performed better in Odisha based on overall performance, cocoon yield and shell content. Whereas in Assam, 12Y × BCon1.BCon4 performed better for cocoon yield and shell content; 8W × SK6.SK7 with regard to cocoon and shell weights; Nistari × SK6.SK7 recorded higher realization potential as compared to test crossbreeds.

On the basis of overall performance, 12Y × BCon1.BCon4 fared better with regard to cocoon yield (55.33 kg/100 DFLs), shell weight (0.26 g), filament length (687 m), renditta (9.39), silk recovery (75 %) with the highest yield realization potential among the test hybrids (Table 8). The improvement over control with respect to cocoon yield/100 DFLs, shell weight, shell content, filament length and renditta were 17.15, 18.18, 8.44, 11.70 and 12.95 %, respectively. Based on overall rearing and reeling performance including yield realization

potential, 12Y × BCon1.BCon4 was identified as the most promising crossbreed suitable for rearing in Eastern India based on the field evaluation across different seasons (23400 DFLs/2years). The identified crossbreed viz., 12Y × BCon1.BCon4 yielded cocoons with similar shell content (~16 %) as that of Nistari × SK6.SK7 (~15 %). In general, shell content in a hybrid could be improved by utilizing better male components.

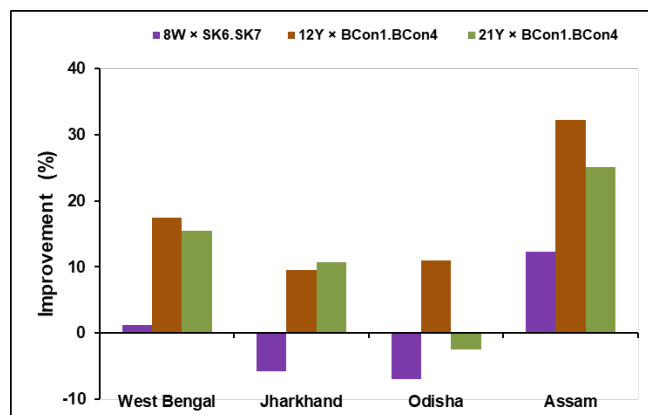


Figure 2: Cocoon yield improvement exhibited by 12Y x BCon1.BCon4

Table 8: Performance of newly developed improved crossbreeds during multi-location trials

Hybrid	State	Yield/ 100 DFLs (kg)	Cocoon weight (g)	Shell weight (g)	Shell (%)	Filament length (m)	Reela- bility (%)	Neat- ness (p)	Renditta (kg)	Silk recovery (%)	Realization potential (%)
8W × SK6.SK7	WB	45.73	1.51	0.26	17.20	705	74	83	09.64	76	79.11
	JHK	47.28	1.40	0.25	17.60	711	75	79	09.75	77	81.79
	ODS	55.09	1.56	0.26	16.80	618	69	85	10.28	77	95.30
	ASM	46.63	1.40	0.24	17.14	667	73	81	09.98	65	80.67
	Mean	48.52	1.47	0.25	17.20	675	73	82	09.91	74	83.94
12Y × BCon1.BCon4	WB	54.32	1.51	0.26	16.85	684	77	80	09.21	74	85.82
	JHK	54.97	1.50	0.25	16.23	667	74	80	09.90	77	86.85
	ODS	57.13	1.55	0.25	16.13	699	71	82	09.27	82	90.26
	ASM	54.90	1.52	0.24	17.62	668	72	80	09.20	66	86.74
	Mean	55.33	1.52	0.26	16.70	687	74	79	09.39	75	87.42
21Y × BCon1.BCon4	WB	53.46	1.48	0.26	17.10	673	81	80	08.80	75	84.47
	JHK	55.56	1.50	0.24	15.98	690	76	79	09.50	73	87.78
	ODS	52.76	1.67	0.26	15.80	653	72	83	10.41	82	83.36
	ASM	51.95	1.53	0.25	17.00	620	73	78	09.00	65	82.08
	Mean	53.19	1.54	0.25	16.50	659	76	80	09.43	74	84.04
N × SK6.SK7 (Control)	WB	46.27	1.41	0.22	15.70	638	72	78	10.68	76	93.84
	JHK	50.16	1.43	0.21	14.27	641*	71	75	10.86	79	101.82
	ODS	51.47	1.56	0.23	15.23	604	70	78	10.98	75	104.48
	ASM	41.51	1.34	0.22	16.41	576	72	78	10.06	62	84.26
	Mean	47.23	1.43	0.22	15.40	615	71	77	10.64	73	95.88
CD @ 5 %		6.01*	0.115*	0.08**	1.20*	54.06	NS	3.22**	0.886*	NS	

WB: West Bengal; JHK: Jharkhand; ODS: Odisha; ASM: Assam

New bivoltine male component

The aim of this experiment was to identify the 12Y-crossbreed combination especially for high shell content (>16 %). In order to explore the possibility of further improvement of shell content in 12Y-crossbreed, BFC1, a newly developed bivoltine foundation cross with high shell content (18.08 %) and survival (91.66 %) was utilized. The results revealed higher shell content (18-19 %) in the 12Y-crossbreed as compared to 12Y × BCon1.BCon4 (16.70 %). It also performed superior in

based on climatic conditions. In general, despite lower productivity and inferior silk quality of Nistari (indigenous multivoltine breed) and its crossbreeds, farmers rear them unwillingly for obtaining sustainable cocoon yields under adverse conditions. Multiple breeding attempts to identify suitable alternatives to Nistari crossbreeds with high productivity resulted in unsatisfactory outcome in the field. As a result, many multivoltine breeds and crossbreeds have been developed in India. The first hybrid for productivity improvement was the result of introduction of NB4D2 as male component and Nistari

Table 9: Performance of 12Y x BFC1 vs 12Y x BCon1.BCon4

Crossbreed	Hatching (%)	Pupation rate (%)	Yield / 10000 larvae by weight (kg)	Yield / 100 DFLs (kg)	Cocoon weight (g)	Shell weight (g)	Shell (%)	Neatness (%)
12Y x BFC1	95	91.24	14.93	59	1.573	0.298	18.94	83
12Y x BCon1.BCon4	93	90.33	13.84	55	1.522	0.266	17.47	80
Improvement (%)	2.15	1.01	7.88	7.27	3.35	12.03	8.41	3.75

Values represent the data of 2 favourable & 2 unfavourable seasons' crops

terms of cocoon yield (56-64 kg) and even recorded a cocoon wt. of 1.720 g and 0.336 g of shell wt. during the favourable seasons. Data on performance of 12Y × BFC1 and 12Y × BCon1.BCon4 was recorded for 2 favourable and 4 unfavourable seasons. The mean data depict the prominence of 12Y × BFC1 (Table 9) in terms of shell content (8.41 %) and cocoon yield/100 DFLS (7.27 %) and neatness (3.75 %) over that of 12Y × BCon1.BCon4. Currently, 12Y × BFC1 is being subjected for large scale field evaluation under Indian Silkworm Hybrid Authorization trials (2020-2022).

DISCUSSION

West Bengal is the major raw silk producer among the Eastern Indian states. Owing to the availability of mulberry leaves, high rainfall and fertile soils, West Bengal practices five crops schedule in an year. The crop seasons in West Bengal are categorized as favourable (November to March) and unfavourable (May to September)

x NB4D2 became instantly popular due to higher hybrid vigour and virtually ruled the industry for over 3 decades. However, this hybrid combination was highly susceptible to diseases and its utilization was confined only to the elite farmers (Narayanan *et al.*, 1967; Chandrasekharaiah and Jolly, 1986; Dandin *et al.*, 2004). Later, it was replaced by Nistari x SK6.SK7 and is presently being commercially exploited with sustainable cocoon yields, but with similar disadvantages (Nirmal Kumar, 2015). The subsequently developed Nistari x BCon1.BCon4 was also not preferred by the farmers over Nistari x SK6. SK7.

In this study, three promising crossbreeds viz., 12Y × BCon1.BCon4, 21Y × BCon1.BCon4 and 8W × SK6.SK7 which could serve as alternatives for Nistari based crossbreeds were identified. All the test hybrids showed higher shell content as compared to the control (Nistari × SK6.SK7) in both laboratory as well as field conditions indicating successful introgression of genes associated with higher shell

content from the donor parent (MH1) to the receptor parent (MCon1, MCon4 and M6DPE). Moreover, the evolved congenic multivoltine breeds (12Y, 21Y and 8W) developed by crossing, continuous backcrossing with receptor parent and sib-mating for seven generations by applying directional selection towards higher shell content might also have developed higher genetic plasticity. The resultant crossbreeds performed better with high shell content across the seasons and regions in coherence to results reported (Chattopadhyay *et al.*, 2001 a, b).

One of the objectives of the silkworm breeder is to recommend stable breeds/hybrids to the farmers for rearing under different environmental conditions. Silkworm breeds reared over a series of different environments exhibiting lesser variations are considered stable. According to Allard and Bradshaw (1964), performance of the breed/hybrid in a given environment indicates its superiority. As the majority of the economically important genetic traits of silkworms are qualitative in nature and phenotypic expression is greatly influenced by environmental factors, such as temperature, relative humidity, light and nutrition (Pillai and Krishnaswami, 1980; Zhang *et al.*, 2002; Ramesha *et al.*, 2010), it is essential to measure the degree of phenotypic differences in the economic traits under varied environmental conditions to understand the genetic steadiness. In the present study, the phenotypic expressions of rearing traits of four crossbreeds (with control) were studied in four states (Assam, Jharkhand, Odisha and West Bengal) characterized by varied climatic conditions. Among the crossbreeds, 12Y × BCon1.BCon4 exhibited higher and stable cocoon yield (55.33 kg/100 DFLs) compared to 21Y × BCon1.BCon4 (53.19 kg/100 DFLs), 8W × SK6.SK7 (48.52 kg/100 DFLs) and Nistari × SK6.SK7 (47.23 kg/100 DFLs) in all the states. This is also evidenced by positive and higher improvement of 12Y × BCon1.BCon4 in cocoon yield over the control in all the four states, whereas 8W × SK6.SK7 showed negative trend in Jharkhand and 21Y × BCon1.BCon4, in Odisha. The overall yield realization potential of 12Y × BCon1.BCon4 in the field conditions in comparison

to laboratory performance was also higher (87.42 %) as against that of 21Y × BCon1.BCon4 (84.04 %) and 8W × SK6.SK7 (83.94 %). The overall realization potential of Nistari × SK6.SK7 (95.88 %) was higher than all the test crossbreeds, which could be attributed to the higher adaptability of Nistari to the field conditions since it is being reared in Eastern India for >10 years (Nirmal Kumar, 2015). In this context, 12Y and its crossbreeds may require further time to genetically adapt to the field conditions in the region.

The selection of suitable parental breeds benefits the breeder to successfully amalgamate the desired traits and therefore, proper evaluation of breeding resources is crucial for the breeders (Mano *et al.*, 1993; Harjeet Singh and Suresh Kumar, 2008; Sivaprasad and Manjunath, 2021). In this study, the parents were selected based on the cumulative multiple trait evaluation index on rearing traits of economic importance. The multivoltine breeds which scored higher evaluation index (M6DPE: 62.73, MH1: 62.20, M.Con4: 61.38 and M.Con1: 54.90) have also recorded the higher shell content in comparison to the other multivoltine silkworm breeds. Therefore, the measure used has served the purpose of the experiment and the breeding method adapted. Contrary to it, the multiple trait evaluation index utilized to shortlist the crossbreeds did not show any similarities with regard to the shell content. This is majorly attributed to the involvement of bivoltine male component, which was crossed with the congenic multivoltine breeds. Multiple trait evaluation index method enables identification of superior breed or hybrid from an array of breeds, while considering cumulative effect of most of the yield and associated attributes. The method has been used extensively by the silkworm breeders in many studies (Nisar *et al.*, 2013; Nooruldin *et al.*, 2014). Khasru Alam *et al.* (2020) used multiple trait evaluation index for identification of suitable bivoltine hybrids with better productivity for Odisha.

Early breeding populations showed fluctuations in the rearing traits, which got stabilized after BC5 generation. These variations can be attributed to the

high heterogeneity gene-pool in the evolved breeds and difficulty in tracing the introgression of genes (Young *et al.*, 1988). Directional selection based on single cocoon shell assessment was the driving force in introgression of high shell content character in the evolved congenic breeds. Therefore, the current breeding programme could bring in aggregation of favourable gene/genes by the elimination of unfavourable gene/genes from the gene-pool by developing congenic breeds through directional selection. The stable performance of the congenic breeds and their crossbreeds across seasons over the control suggests that there was lesser interference of unfavourable gene/genes after synchronisation (Chattopadhyay *et al.*, 2001 c). A few researches reported varied expression by different breeds under different climatic conditions (Watanabe, 1928; Ueda and Lizuka, 1962). Seasonal studies made in Indian mulberry silkworm revealed that different hybrids expressed differently when tested under varied climatic conditions (Krishnaswami and Narasimhanna, 1974). The differences in fitness of silkworms in different seasons and regions have long been recognized in Japan and China and the outcome was identified as season- or region- specific breeds/hybrids to obtain sustainable cocoon yields (Hirobe and Ohi, 1954; Yokoyama, 1976; Xu Meng Kui *et al.*, 1990; He Yi *et al.*, 1991).

Present study identified three crossbreeds, 12Y × BCon1.BCon4, 21Y × BCon1.BCon4 and 8W × SK6.SK7 which yield with higher cocoon productivity and shell content than the ruling crossbreed (Nistari × SK6.SK7). 12Y × BCon1.BCon4 exhibited consistent and stable performance in the field with regard to cocoon yield and other important economic traits resulting in an additional income to the farmers. Newly evolved congenic multivoltine breed, 12Y exhibited consistent performance in the field with regard to cocoon yield potential (10-15 % improvement). However, the relatively lower shell content (15-16 %) from BCon1.BCon4 prompted to conduct further laboratory evaluation with other bivoltine male parents with higher shell content to develop a new 12Y crossbreed combination. As the selected bivoltine male parent (BFC1) possessed higher shell content and

higher survival, the resultant crossbreed, 12Y × BFC1 showed promising results with 18-20 % shell percentage and 56-62 kg/100 DFLs cocoon yield. The multivoltine × bivoltine hybrid combinations with desired shell content associated with higher survival thrive better in the field in Eastern India. The present laboratory and field testing results provide a choice to the farmers in Eastern Indian states between 12Y × BFC1 and Nistari × SK6.SK7. Commercial exploitation of improved crossbreed *i.e.*, 12Y × BFC1 is sure to enhance the silk productivity in Eastern India and gradually replace the Nistari based crossbreeds.

REFERENCES

- Allard R. B. and Bradshaw A. O. (1964) Implications of genotype environment interaction in applied plant breeding. *Crop Sci.*, **4**: 503-506.
- Chandrakanth N., Moorthy S. M. and Sivaprasad V. (2021) Molecular diversity between two indigenous silkworm races of *Bombyx mori* L. *Mun. Ent. Zool.*, **16** (2): 798-806.
- Chandrasekharaiah and Jolly M. S. (1986) Silkworm Breeding and Genetics. Proceedings of the Seminar on “Prospects and problems of sericulture in India, Vellore, India, 27-30 March, pp. 135-152.
- Chattopadhyay G. K., Sengupta A. K., Verma A. K., Sen S. K. and Saratchandra B. (2001 a) Utilization of congenic line in silkworm breeding. In: *Perspectives in Cytology and Genetics*, G. K. Manna and S. C. Roy (Eds.), **10**: 717-724.
- Chattopadhyay G. K., Sengupta A. K., Verma A. K., Sen S. K. and Saratchandra B. (2001 b) Transgression of shell weight-a multigenic trait, through development of congenic breed in tropical silkworm *Bombyx mori* L. *Sericologia*, **41** (1): 33-42.
- Chattopadhyay G. K., Sengupta A. K., Verma A. K., Sen S. K. and Saratchandra B. (2001 c) Esterase isozyme polymorphism, specific and nonspecific esterase, syngenic lines development and natural occurrence of a thermostable esterase in tropical silkworm *Bombyx mori* L. *Insect Biochem. Mol. Biol.*, **31**: 1191-1199.
- CSB (2020) *Report on functioning of Central Silk Board and performance of Indian silk industry*, Central Silk Board, Bengaluru, India, p. 18.

- Dandin S. B., Mal Reddy N., Basavaraja H. K., Suresh Kumar N., Kalpana G. V. and Joge P. G. (2004) Use of CSR breeds with Pure Mysore for higher productivity. *Indian Silk*, **43**: 8-10.
- Datta R. K. (1984) Improvement of silkworm races (*Bombyx mori* L.) in India. *Sericologia*, **24** (3): 393-415.
- Harjeet Singh and Suresh Kumar N. (2008) Selection of breeding resource material of bivoltine silkworm, *Bombyx mori* L. for breeding for high temperature tolerance. *Indian J. Seric.*, **47**: 20-28.
- He Yi, Sima Yang-hu, Jiang Da-xin and Dai Ping (1991) Breeding of silkworm varieties for summer and autumn rearing 'Xuhau' and 'Qiuxing' and their hybrids. *Canye Kexue*, **14** (4): 200-207.
- Hirobe T. and Ohi H. (1954) On the studies of heterosis in *Bombyx mori* L. *Japan J. Breed.*, **4**: 1.
- Khasru Alam, Misro S. K. and Sivaprasad V. (2020) Studies on evaluation and identification of suitable bivoltine hybrids (*Bombyx mori* L.) for better productivity in Odisha. *J. Pharmacogn. Phytochem.*, **9** (4): 990-994.
- Krishnaswami S. and Narasimhanna M. N. (1974) Large scale trials on bivoltine hybrids in Mysore state. *Indian J. Genet.*, **34**: 229-236.
- Krishnaswami S., Narasimhanna M. N., Surayanarayana S. K. and Kumararaj S. (1973) *Manual on sericulture - Silkworm rearing*, Food and Agriculture Organisation, United Nations, Rome.
- Li J., Moghaddam S. H., Du X., Zhong B. X. and Chen Y. (2012) Comparative analysis on the expression of inducible HSPs in the silkworm, *Bombyx mori*. *Mol. Biol. Rep.*, **39**: 15-23.
- Mano, Nirmal Kumar S., Rameshbabu M., Basavaraja H. K., Mal Reddy N. and Datta R. K. (1993) A new method to select promising silkworm breeds/combinations. *Indian Silk*, **31** (10): 53.
- Mukherjee P. (1994) Hybrid vigour in different crossing systems in silkworm, *Bombyx mori* L. In: *Silkworm breeding*, G. Sreerama Reddy (Ed.), Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, pp. 197-208.
- Mukhopadhyay T. K., Bhattacharya S. S. and Kundu J. K. (2013) Development of a new multivoltine breed (D+p) of silkworm (*Bombyx mori* L.) having better heterosis of its economic characters in the climate of West Bengal. *Int. J. Fauna Biol. Stud.*, **1** (1): 1-6.
- Narayanan E. S., Sonwalkar T. M. and Nataraja N. (1967) Studies in the variability of denier throughout the reelable length of the bave in the exotic and indigenous mulberry cocoons. *Indian J. Seric.*, **2** (1): 89-93.
- Nirmal Kumar (2015) Situation analysis and future strategy for multivoltine silkworm breeding. *Proceedings of Breeders' meet*, Central Sericultural Research and Training Institute, Mysore, India, 22nd September 2015, pp. 110-113.
- Nisar M., Chisti M. Z. and Khan M. A. (2013) Studies on the identification of summer specific silkworm *Bombyx mori* L. hybrids under temperate climatic conditions of Jammu and Kashmir. *Indian J. Intl. Acad. Res.*, **1** (3): 1-14.
- Nooruldin S., Bhat S. A., Malik M. A., Khan I. L. and Sahaf K. A. (2014) Comparative performance of silkworm, *Bombyx mori* L. hybrids during different seasons under Kashmir climatic conditions. *Green Farming*, **6** (6): 1392-1395.
- Pillai V. S. and Krishnaswami S. (1980) Effect of high temperature on the survival rate, cocoon quality and fecundity of *Bombyx mori* L. *Proceedings of Sericulture Symposium and Seminar*, Tamil Nadu Agricultural University, Coimbatore, India, 18-20th February, 1980, pp. 141-148.
- Ramesha C., Anuradha C. M., Lakshmi H., Sugnana Kumari S., Seshagiri S. V., Goel A. K. and Suresh Kumar C. (2010) Nutrigenetic traits analysis for identification of nutritionally efficient silkworm germplasm breeds. *Biotechnology*, **9**: 131-140.
- Sivaprasad V. and Manjunatha G. R. (2021) ROBEVA-Bm: A robust multivariate evaluation method for selecting silkworm genetic resources. *Sericologia*, **60** (3 & 4): 75 – 95.
- Ueda S. and Lizuka H. (1962) Studies on the effects of rearing temperature affecting the health of silkworm larvae and upon the quality of cocoons-1. Effect of temperature in each instar. *Acta Sericologia* (in Japanese), **41**: 6–21.
- Verma A. K., Suresh Kumar N., Saha A. K. and Nirmal Kumar S. (2016) Heterotic genetic interaction among high shell weight and high shell percentage multivoltine lines of silkworm *Bombyx mori* L. *J. Exp. Zool. India*, **19** (1): 249-255.
- Watanabe K. (1928) Further studies on the voltinism in the silkworm *Bombyx mori* L. *Bull. Seric. Expt. Stn. Jpn.*, **7**: 285-303.

Crossbreed of silkworm developed through congenic breeding
N. Chandrakanth *et al.*

Xu Meng Kui, Song Cui-e, Wang Zhang-e, Wang Yun-qin, Sun Yu-wu and Xu Wei-hua (1990) Breeding of silkworm varieties 'Suhua', 'Chunhui' and their hybrids for spring rearing. *Canye Kexue*, **16** (1): 5-13.

Yokoyama T. (1976) Breeding silkworm. *Science and Technology in Sericulture*, **15** (4): 58-61.

Young N. D., Daniel Z., Martin W. G. and Tanksley S. D. (1988)

Use of isogenic lines and simultaneous probing to identify DNA markers tightly linked to the Tm-2a gene in tomato. *Genetics*, **120**: 579-585.

Zhang Y. H., Xu A. Y., Wei Y. D., Li M. W., Hou C. X. and Zhang G. Z. (2002) Studies on feeding habits of silkworm germplasm resources for artificial diet without mulberry. *Acta Sericologia Sinica*, **28**: 333-336.



DETECTION OF MICROSPORIDIA (*NOSEMA* SPP. AND *VAIRIMORPHA* SPP.) FROM EXCRETA OF FROGS AND BIRDS, COLLECTED FROM MULBERRY FIELD

Ritsuko Murakami^{1*}, Kazuhisa Miyamoto¹ and Kenji Watanabe²

¹National Agriculture and Food Research Organization, 2-1-18 Kannondai, Tsukuba, Ibaraki, Japan.

²National Agriculture and Food Research Organization, 1-1-2 Owashi, Tsukuba, Ibaraki, Japan.

*Email: mritsuko@affrc.go.jp

ABSTRACT

Pebrine is a dreadful disease caused by microsporidian infection in silkworms (*Bombyx mori*), and it has been inflicting serious damage to sericulture across the world. Microsporidia had been detected from various insects in the fields, but invasion routes of microsporidia from fields to rearing places of silkworms were less known. Therefore, we made attempts to detect the source of microsporidial contamination of mulberry leaves in the field. In the process, samples of feces of frogs and birds dropped on mulberry leaves were subjected to polymerase chain reaction (PCR) and PCR products of microsporidia, such as *Nosema* spp. and *Vairimorpha* spp., were detected from the feces when extracted with chloroform after freezing at -30 °C and with thermal-shock treatments. Therefore, mulberry leaves soiled with animal feces should strictly be excluded from foliage feed lot supplied to silkworm rearing houses to prevent cross infectivity of microsporidians. This is the first report of its kind.

Key words: Bird, feces, frog, microsporidia, sericulture.

INTRODUCTION

Pebrine being the most awful disease affecting the growth and development of silkworm, *Bombyx mori*, all routes of microsporidian infection should be explored and monitored to formulate a fool proof system of disease management. It is the Fujiwara's method (Fujiwara, 1984) that has widely been adopted in Japan for pebrine inspection at various stages of silk crop. But, there always exists a possibility of cross-infectivity from the field and the invasion routes of microsporidia from fields to rearing rooms of silkworms were not fully explored. Microsporidia are intracellular parasitic fungi that infect various insects, fishes and mammals. The major hosts of microsporidia are insects (Nakamura *et al.*, 2019), and plenty of insects inhabit the mulberry fields. There were some reports on presence of microsporidia in rearing rooms of silkworms (Nozawa, 2012; Imura *et al.*, 2020),

and in the adult of cabbage worm (*Pieris rapae*) from mulberry fields (Kawarabata, 2003). However, there were some questions about invasion routes of microsporidia from fields to the rearing rooms and it is highly important to determine it for control of the disease. Therefore, in the present study, we explored the possible source and invasion routes of microsporidia from mulberry field to silkworm rearing room and also the trend of occurrence and variation in the intensity during different periods in the mulberry fields.

MATERIALS AND METHODS

Mass pebrine inspection of *B. mori* and extraction of microsporidian DNA

Microsporidian spores were collected by mass pebrine inspection according to the method by Fujiwara (1984),

from *B. mori* reared during September 2017. The microsporidia collected in distilled water, were centrifuged at x 16,000 g for 1 min. at 4 °C, replicated three times and were fixed in 2 % agarose with a phosphate buffer (pH 7.6). The agarose blocks were dehydrated with ethanol series and were replaced with t-butanol. Then the blocks were freeze dried and observed under LV SEM (JEOL) Scanning Electron Microscope (SEM). SEM images (Figure 1) depicted microsporidian spores of various shapes probably indicating different species. Therefore, total DNA was isolated from samples of mass pebrine inspection. The samples from fields were once frozen at -30 °C and, the frozen samples were boiled and were used for DNA extraction. DNA was extracted using phenol and chloroform.

Design of primers for microsporidia

For detection of microsporidia, polymerase chain reaction (PCR) method was used, and VN001F primer and VN001R primer (Kawakami *et al.*, 2001) are reported as universal primers for detection of microsporidia pathogenic to the silkworm, but the size of PCR product using VN001F primer and VN001R primer was 1,360 bp. However, the length was too long to detect microsporidia, efficiently. Therefore, new primer set was constructed using the above primer set to get PCR production with 400 - 600 bp and to detect various microsporidian species. To construct primers, total DNA was extracted from the mass pebrine inspection samples containing microsporidia as described by Hatakeyama and Hayasaka (2002), and PCR was performed using VN100F and VN001R primers. Then PCR products were cloned in pTac2 vector (Funakoshi, Tokyo), and the inserts in the vectors were sequenced. The inserts of 76 clones were sequenced, and the sequenced data were analyzed by ATGC software (Ver.6, GENETYX). PCR products of these primers hit with *Nosema antheraeae*, *N. bombycis*, *N. disstriae*, *N. fumiferanae*, *N. heliothidis*, *N. mylitta*, *N. pyrausta*, *N. racijplusiae*, *N. spodopterae*, *N. trichoplusia*, *N. tyriae*, *Nosema* sp., *Vairimorpha ceraces*, *V. imperfecta* and *Vairimorpha* sp. according to International Nucleotide Sequence Databases

(INSD). Microsporidia-F (5'-ACTTGTTCCGATAGTG TGTATGATGATTGATG-3') primer and Microsporidia-R primer (5'-TGTTGAAATTAATCATTATTCACAGCATCCATTGG-3') were designed by the sequences to detect common sequence of microsporidia from the fields, and microspores were detected in the PCR products with 483 bp. The PCR products were sequenced and hit the species (E-value = 0.0, Identity = 98.8 – 99.9 %) by search with INSD.

Detection of microsporidia by PCR

Mulberry leaves laid with corpses of insects, traces of soil and animal feces were harvested from mulberry fields, and these samples on the leaves were collected using distilled water. The collected samples were centrifuged at x16,000 g for 5 min at 4 °C, and DNA was extracted from the pellets by the methods as described above. Microsporidia were detected using Microsporidia-F primer and Microsporidia-R primer, and PCR was performed using KOD-Fx-Neo (TOYOBO, Osaka) with 55 °C anneal and extension for 1 min and cycled for 35 times. The PCR products were electrophoresed with 1 % agarose, and presence of microsporidian DNAs were ascertained in samples when the PCR products of 483 bp were detected.

Detection of microsporidia in feces on mulberry leaves from fields

More samples of animal feces were collected from mulberry leaves of two fields at Ibaraki Prefecture in Japan from September 2018 to October 2019. Feces samples were collected using distilled water and were precipitated by centrifugation. Microsporidian DNA was detected by the above PCR methods, and percentage of microsporidium detection (= number of feces samples detected with microsporidia / total number of samples x 100) was calculated.

RESULTS AND DISCUSSION

Out of various samples constituting corpses of insects, traces of soil and animal feces on the surface of mulberry

leaves in the fields, the PCR products of microsporidia were detected from feces of frogs and birds (Figures 2 and 3). Therefore, mulberry leaves with feces were collected every week from September 2018 to October 2019 (Figure 4). At Ibaraki Prefecture in Japan, mulberry sheds leaves from late October to November and further sprouts in May. Therefore, leaf sampling was not performed from late November of 2018 to April 2019. Results revealed higher percentage of microsporidian occurrence during 2018. In Japan, microsporidia were detected by mass pebrine inspection in female adult moths from 2015 to 2017, frequently (Hirokawa, 2018), and the intensity of detection decreased through 2018 to 2019. Therefore, frequency of microsporidium detection by mass pebrine inspection and by this study are not on contradiction. Moreover, it was interesting to note that the microsporidian occurrence was in comparatively lower percentage during 2019, after the passing of typhoon. This might be because the mulberry leaves getting washed by the heavy rains and simultaneous rinsing away of microsporidian spores.

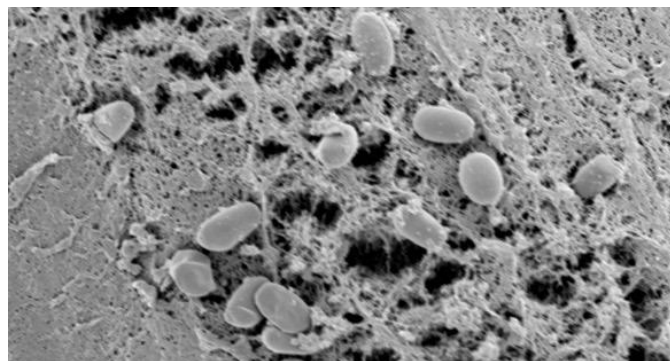


Figure 1: SEM image of microsporidia spores detected from *Bombyx mori*

Notably high percentage of over 50 % of microsporidia were detected during September 2018 (Figure 4) which stood much above than that detected from individual dragonflies (Nakamura *et al.*, 2021). Major hosts of microsporidia are insects in general, and particularly the order Lepidoptera. Microsporidia had been detected from various Lepidopteran insects, *viz.*, *Chilo suppressalis* (Hirose, 1979), *Spodoptera depravata* (Ishihara and Iwano, 1991), *S. exigua* (Yasunaga *et al.*, 1992), *S. litura*

(Nakamura *et al.*, 2019), *Tyria jacobaeae* (Canning *et al.*, 1999) and from insects belonging to other orders too (Ohta and Endo, 1978; Zhu *et al.*, 2011; Fries, 2010; Nakamura *et al.*, 2021). Since frogs and birds might eat many infected insects, there is a possibility of microsporidian concentration getting boosted in their feces, and hence, the percentage of detection might be higher than that from individual insect.



Figure 2: Samples of feces of frogs (A) and birds (B) spotted on mulberry leaf surface

PCR methods are used for detection of other pathogens, such as densovirus and nucleopolyhedroviruses also, and pathogens were detected sensitive (Ikuno *et al.*, 2004, How *et al.*, 2005). PCR methods were also useful for the detection of microsporidia from clinical stool specimens and extraction methods of microsporidian DNA are important (Muller *et al.*, 1999), but DNA had been extracted from microsporidia after spore germination (Hatakeyama and Hayasaka, 2002; Nakamura *et al.*, 2019). However, some microsporidian species were present in samples from mulberry leaves from fields, and spore germination of microsporidian requires specific conditions depending on microsporidian species. Therefore, in this study, we adopted PCR methods for microsporidian DNA extraction from feces after physical treatments, such as freezing and boiling. The thermal-shock method was useful for DNA release from spores of fungi (Fraczek *et al.*, 2019), and our results agreed with the report.

Microsporidia extracted from feces of frogs and of birds were mixed into artificial diet and fed to third instar

silkworms. But, they didn't develop any symptoms of the disease (data not shown). However, since DNA products of *Nosema* spp. and *Vairimorpha* spp. that infect *B. mori* (Canning *et al.*, 1999; Hatakeyama and Hayasaka, 2002; Kawarabata 2003), were detected from frog or bird feces collected from mulberry fields, mulberry leaves soiled with feces should be excluded from the supply lot to silkworm rearing houses.

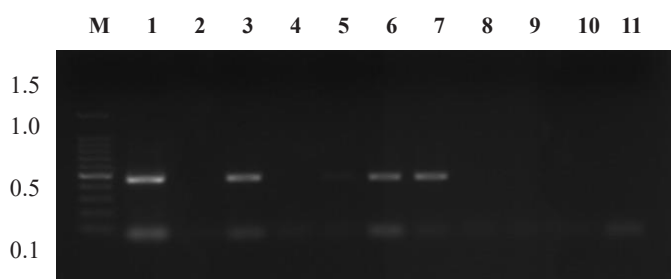


Figure 3: Electrophoresis of PCR products of frog (lane: 1-5) and bird feces (lane: 6-11)

PCR was performed using the extracted DNA, and PCR products of microsporidia were detected at lane 1, 3, 6 and 7 (483 bp); M: 100 bp DNA ladder marker

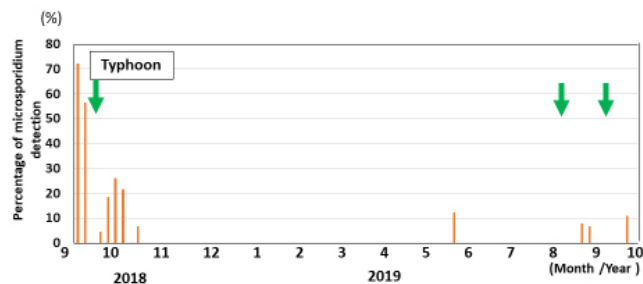


Figure 4: Variation in the percentage of microsporidia detected from feces of frogs and birds from mulberry fields at Ibaraki Prefecture in Japan

→ Passing of typhoon

ACKNOWLEDGEMENT

Authors are profoundly grateful to Mr. Koji Hashimoto, Dr. Masayuki Yonemura and Dr. Tetsuya Iizuka for providing scientific information as well as pebrine infected samples.

REFERENCES

- Canning E., Curry A., Cheney S. A., Lafranchi-Tristem N., Kawakami Y., Hatakeyama Y. and Iwano H. (1999) *Nosema tyriae* n. sp. and *Nosema* sp., microsporidian parasites of Cinnabar moth *Tyria jacobaeae*. *J. Invertebr. Pathol.*, **74**: 29-38.
- Fraczek M. G., Zhao C., Dineen L., Lebedinec R., Bowyer P., Bromley M., and Delneri D. (2019) Fast and reliable PCR amplification from *Aspergillus fumigatus* spore suspension without traditional DNA extraction. *Curr. Protoc. Microbiol.*, **54**: e89.
- Fries I. (2010) *Nosema ceranae* in European honeybees (*Apis mellifera*). *J. Invertebr. Pathol.*, **103**: S73-S79.
- Fujiwara T. (1984) Studies on the mass pebrine inspection of mother moth. *Tech. Bull. Seric. Exp. Sta.*, **120**: 113-160 (in Japanese).
- Hatakeyama Y. and Hayasaka S. (2002) Specific amplification of microsporidian DNA fragments using multiprimer PCR. *JARQ*, **36**: 97-102.
- Hirokawa M. (2018) Searching for a reliable and effective method for preserving silkworm genetic resources. *Sanshi-Konchu Biotec*, **87**: 14-41 (in Japanese).
- Hirose Y. (1979) Infection of microsporidia from *Chilo suppressalis* to *Bombyx mori* and other insects. *Acta Sericol.*, **112**: 275-279.
- How C., Li M., Gui Z., Xu A. and Guo X. (2005) PCR-based detection of densovirus infection in silkworm (*Bombyx mori*). *Int. J. Indust. Entomol.*, **11**: 135-138.
- Ikuno A. A., Margatho L. F. F., Harakava R., Akamatsu M. A., Martins E. M. F., Porto A. J. and Ferreira V. C. A. (2004) Direct application of the new PCR protocol for evaluation and monitoring of *Bombyx mori* infection by nucleopolyhedrovirus. *Arq. Inst. Biol.*, **71**: 309-315.
- Imura Y., Nakamura H., Nozawa M. and Hatakeyama Y. (2020) Latest status of silkworm-associated microsporidians via pebrine inspection revealed by phylogenetic analyses. *J. Insect Biotechnol. Sericology*, **89**: 63-71.
- Ishihara R. and Iwano H. (1991) The lawn grass cutworm, *Spodoptera depravata* Butler, as a natural reservoir of *Nosema bombycis* Naegeli. *J. Seric. Sci. Jpn.*, **60**: 236-337 (in Japanese).

- Kawakami Y., Iwano H., Hatakeyama Y., Inoue T., Canning E. U. and Ishihara R. (2001) Use of PCR with the specific primers for discrimination of *Nosema bombycis*. *J. Seric. Sci. Jpn.*, **70**: 43-48.
- Kawarabata T., (2003) Biology of microsporidians infecting the silkworm, *Bombyx mori*, in Japan. *J. Seric. Sci. Jpn.*, **72**: 1-32.
- Muller A., Stellermann K., Hartmann P., Schrappe M., Fatkenheuer G., Salzberger B., Diehl V. and Franzen C. (1999) A powerful DNA extraction method and PCR for detection of microsporidia in clinical stool specimens. *Clin. Diagn. Lab. Immunol.*, **6**: 243-246.
- Nakamura H., Hatakeyama Y., Arai R., Imura Y., Yakahashi Y. and Iwano H. (2019) Germination properties of spores on entomopathogenic microsporidia, *Trachipleistophora haruka* isolated from *Spodoptera litura*. *J. Insect Biotechnol. Sericology*, **88**: 27-30.
- Nakamura H., Kurimoto N., Imura Y. and Hatakeyama Y. (2021) The first isolation of microsporidia from dragonflies in Japan. *Jpn. J. Appl. Entomol. Zool.*, **65**: 29-34.
- Nozawa M. (2012) Pebrine disease and pebrine inspection of the silkworm. *Sanshi-Konchu Biotech.*, **81**: 149-152 (in Japanese).
- Ohta T. and Endo T. (1978) An investigation in infected microsporidia of field insect. *Tohoku J. Agric. Res.*, **21**: 283-284.
- Yasunaga T., Hunakoshi M., Kawarabata I., Aratake Y. and Iwano H. (1992) *Nosema bombycis* (Microsporidia: Nosematidae) detected from *Spodoptera exigua*. *Jpn. J. Appl. Entomol. Zool.*, **36**: 127-134 (in Japanese).
- Zhu F., Shen Z., Guo X., Xu X., Tao H., Tang X. and Xu L. (2011) A new isolate of *Nosema* sp. (Microsporidia, Nosematidae) from *Phyllobrotica armata* Baly (Coleoptera, Chrysomelidae) from China. *J. Invertebr. Pathol.*, **106**: 339-342.



SILKWORM (*BOMBYX MORI*) PUPAE PROTEINS: THE SOURCE OF HIGH VALUE AMINO ACIDS

Y. Thirupathaiah^{1*}, R. Ananthan², S. Manthira Moorthy¹, K. B. Chandrashekar¹,
M. Chandrasekharaiah³, V. Sivaprasad¹ and Pankaj Tewary¹

¹Central Sericultural Research and Training Institute, Mysuru 570008, Karnataka, India.

²National Institute of Nutrition, Tarnaka, Hyderabad 570007, India.

³National Institute of Animal Nutrition and Physiology, Bengaluru 560030, India.

*Email: reddytr@gmail.com.

ABSTRACT

Silkworm pupae are rich source of proteins composed of all essential amino acids required for human and animal health. The present study provides a comparative account of the amino acid profile of proteins extracted from fresh, fresh de-oiled and spent silkworm (*Bombyx mori*) pupae. The major amino acid components of silkworm pupae proteins were Glutamic acid (12.9 %) and Aspartic acid (9.65 %). The essential amino acid content as detected in silkworm pupae powder in the order of their proportion, were Leucine (6.91 %), Lysine (6.60 %), Phenylalanine (6.58 %), Valine (5.53 %), Threonine (4.48 %), Isoleucine (4.20 %), Histidine (3.79 %), Methionine (3.21 %) and Tryptophan (1.15 %). However, similar amino acid profile was obtained for de-oiled silkworm pupae powder as well but, certain amino acids measured slightly less in spent silkworm pupae proteins when compared with fresh silkworm pupae powder, indicative of microbial spoilage or loss during the reeling process. The process of de-oiling was proved to have no adverse influence on amino acid profile of silkworm pupae. The higher proportion of essential and high value amino acids in silkworm pupae proteins could be explored for supplementing human and animal nutrition and offer high scope for their commercial production.

Key words: Amino acids and nutrition, *Bombyx mori*, proteins, silkworm.

INTRODUCTION

Silkworm pupae have commonly been used as a traditional food item as well as animal feed in some parts of Asian continent for a long time because of its high nutritional value, particularly proteins and fat (Dong *et al.*, 2017). Silkworm pupae oil is well known as a rich source (>30 %) of omega-3-fatty acids (Pereira *et al.*, 2003; Thirupathaiah *et al.*, 2016). Moreover, the pupae of mulberry silkworm, *Bombyx mori* are mainly composed of proteins of about 50 to 55 % by dry weight and these proteins contain most of the essential amino acids necessary for human and animal health

(Rao. 1994; Zhou *et al.*, 1996) Whenever protein sources are considered from nutritional point of view, it is highly essential to look for its amino acid profile rather than functional characteristics of proteins. Amino acids have widely been used in food, pharmaceutical, medicine and chemical industry as flavor enhancers, nutritional supplements, feed additives, antioxidants, therapeutics, infusion solution for post-operative treatments and also precursors for the manufacture of polymers and cosmetics (Ivanov *et al.*, 2013). Worldwide, about 3 million tones of amino acids are being produced per annum, indicative of their enormous demand. These amino acids have been commercially produced from protein hydrolysates of

plant and animal source or through microbial fermentation (Park *et al.*, 2007).

Among the diversified animal products, particularly silkworm pupa, which is the by-product of silk-reeling industry, is yet to be properly explored for its high commercial value. The silkworm pupal protein hydrolysates have gradually been emerging as an attractive source of food, pharmaceuticals, medicines, cosmetics, chemical industry and animal feeds (Mentang *et al.*, 2013; Li *et al.*, 2018). Considering the huge availability of mulberry silkworm pupae that may be exploited for large scale production of amino acids with high economic returns, the present study was undertaken to analyze the amino acid profile of proteins of fresh, fresh de-oiled and spent silkworm pupae and further to explore the potentiality of sericulture industry for wider applications.

MATERIALS AND METHODS

Preparation of dried silkworm pupae powder and extraction of silkworm pupae oil

Both fresh and spent silkworm pupae powder preparation and oil extraction was carried out according to the process described by Thirupathaiah *et al.*, 2016. The de-oiled and non de-oiled pupae powder were used for analysis of amino acids.

Amino acid profile of silkworm pupae

The amino acid analyses for mulberry silkworm, *B. mori* pupae were carried out at National Institute of Nutrition (ICMR-NIN), Hyderabad with standardized hydrolysis method and determined using Biochrome Automated amino acid analyzer.

RESULTS AND DISCUSSION

Amino acid profile of fresh, fresh de-oiled and spent silkworm pupae (before oil extraction) was carried out. The major amino acids detected in silkworm pupae proteins were Glutamic acid (12.9 %) and Aspartic acid

(9.65 %) followed by Leucine (6.91 %), Lysine (6.60 %) and Phenylalanine (6.58 %) (Table 1). The of essential amino acids present in silkworm pupae powder in higher proportion, were Leucine (6.91 %) followed by Lysine (6.60 %), Phenylalanine (6.58 %) and Valine (5.53 %). Threonine (4.48 %), Isoleucine (4.20 %), Histidine (3.79 %), Methionine (3.21 %) and Tryptophan (1.15 %) were present in comparatively lower proportion. However, de-oiled silkworm pupae powder too displayed a similar amino acid profile and proportion. Whereas, certain amino acids were found to be slightly less in spent silkworm pupae proteins before oil extraction when compared with fresh silkworm pupae powder (Table 1). Results reveal that oil extraction did not result in loss of proteins/amino acids to a significant level. The meagre decrease observed in the content of certain amino acids might be due to the microbial spoilage of spent pupae and the resultant loss. Silkworm pupae powder contains all the nine essential amino acids, out of which three of them viz., Leucine (6.91 %), Lysine (6.60 %) and Phenylalanine (6.58 %) were detected in higher percentage.

Table 1: Amino acid profile of mulberry silkworm (*Bombyxmori*) pupae

Amino acid	Fresh pupae powder (g/100 g or %)	De-oiled pupae powder (g/100 g or %)	Spent pupae powder (before oil extraction) (g/100 g or %)
Glutamic acid	12.9	12.87	10.20
Aspartic acid	09.65	09.76	10.18
Leucine *	06.91	06.85	06.11
Lysine *	06.60	06.75	06.23
Phenylalanine *	06.58	06.59	06.34
Alanine	06.13	05.73	04.66
Tyrosine	05.86	05.87	05.16
Valine *	05.53	05.37	04.55
Glycine	05.52	05.55	04.50
Serine	05.50	05.35	04.13
Proline	04.85	04.43	02.97
Arginine	04.85	05.24	05.65
Threonine *	04.83	04.89	04.03
Isoleucine *	04.20	04.13	03.64
Histidine *	03.79	04.00	02.03
Methionine *	03.21	03.52	02.33
Cysteine	01.65	02.04	01.09
Tryptophan *	01.15	0.91	0.87

All values are average of three individually pooled samples, * essential amino acids.

The higher proportions of Glutamic acid (12.9 %) and Aspartic acid (9.65 %) present in silkworm pupae have great commercial value and could be explored in food and pharmaceutical industry. The salts of Glutamic acid and Aspartic acid have widely been used to improve the flavor of food. The Glutamic acid is also used as an ingredient in food supplements for muscle growth and treating various neuropathic diseases of humans. The essential amino acids *viz.*, leucine, lysine and phenylalanine present in higher proportion in silkworm pupae have been used as ingredients in food supplements for improving absorption of calcium, formation of collagen, cartilage and connective tissue in humans (Yeo *et al.*, 2013). Similarly, Tyrosine which is also abundantly available in silkworm pupae has wider range of applications in protein supplements to treat phenyl-ketonuria, attention deficit hyperactivity disorder (ADHD), narcolepsy and chronic fatigue syndrome. Tyrosine is also a precursor of melanin and used as precursor for the production of L-DOPA (Ivanov *et al.*, 2013). Moreover, some of these amino acids could not be produced cost effectively by microbial fermentation processes; therefore, extraction from silkworm pupae on commercial scale might provide an alternative option.

The animal feed industry is another largest consumer of amino acids, particularly Lysine, Methionine, Threonine and Tryptophan followed by other amino acids. All these essential amino acids are present in higher proportion in silkworm pupae powder and are known to improve the nutritional quality of animal feeds as against their occurrence in lower levels in grains. Supplementation of 0.5 % Lysine in animal feed improves the quality of the feed which is equivalent to adding 20 % of soybean meal. Therefore, the rich source of amino acids in silkworm pupae could be explored for production of amino acids used as ingredients in the human food/nutrition, pharmaceutical and animal feed industry which in turn is sure to enhance the economic returns of the farmers and entrepreneurs and ensure the constant growth of the sericulture industry as well.

REFERENCES

- Dong H. L., Zhang S. X., Tao H., Chen Z. H., Li X., Qiu J. F., Cui W. Z., Sima Y. H., Cui W. Z. and Xu S. Q. (2017) Metabolomics differences between silkworms (*Bombyx mori*) reared on fresh mulberry (*Morus*) leaves or artificial diets. *Sci. Rep.*, **7** (1): 1–16. DOI 10.1038/s41598-017-11592-4.
- Ivanov K., Stoimenova A., Obreshkova D. and Saso L. (2013) Biotechnology in the production of pharmaceutical industry ingredients: Amino acids. *Biotechnol. Equip.*, **27** (2): 3620-3626.
- Li X. I., Xie H., Chen Y., Lang M., Chen Y. and Shi L. (2018) Silkworm pupa protein hydrolysate induces mitochondria-dependent apoptosis and S phase cell cycle arrest in human gastric cancer SGC-7901. *Cells Int. J. Mol. Sci.*, **19**: 1013.
- Mentang F., Jintasataporn O. and Ohshima T. (2013) Fatty acid composition and sensory evaluation of the meat of broilers fed silkworm (*Bombyx mori* L.) pupa dietary supplementation. *Anim. Prod.*, **15** (1): 24-30.
- Park J. H., Lee K. H., Kim T. Y. and Lee S. Y. (2007) Metabolic engineering of *Escherichia coli* for the production of L-valine based on transcriptome analysis and insilico gene knockout simulation. *Proc. Nat. Acad. Sci. USA*, **104**: 7797-7802
- Pereira N. R., Ferrarese-Filho O., Matsushita M. and De Souza N. E. (2003) Proximate composition and fatty acid profile of *Bombyx mori* L. chrysalis toast. *J. Food Compos. Anal.*, **16** (4): 451–457. DOI 10.1016/S0889-1575 (03) 00016-4.
- Rao P. U. (1994) Chemical composition and nutritional evaluation of spent silkworm pupae. *J. Agric. Food Chem.*, **42** (10): 2201–2203. DOI 10.1021/jf00046a023.
- Thirupathaiah Y., Sivaprasad V., Bhuvaneswari E., Munirathnam Reddy M., Vineet Kumar and Chandrashekaraiah M. (2016) Extraction and characterization of mulberry silkworm, *Bombyx mori* pupae oil. *Indian J. Seric.*, **55** (1-2): 31-37.

Yeo Y., Ahn E. and Ryu S. (2013) Effect of pupa powder diet on muscle and blood amino acids composition in rats. *Kor. J. Phy. Edu.*, **52** (5): 807-818.

Zhou J. H., Sun X. B., Xu H. B., Li Y. Z. and Zhao J. H. (1996) Research progress on silkworm pupae. *Spec. Wild Econ. Anim. Pl. Res.*, **18** (1): 38-40.



HAEMOCYTE DYNAMICS IN THE SILKWORM, *BOMBYX MORI* L. DURING THE PROGRESSIVE INFECTION OF BmIFV

M. Mamatha and M. Balavenkatasubbaiah*

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

*Email: mbvsubbaiah@gmail.com

ABSTRACT

Silkworm diseases constitute the major constraint of Indian sericulture, which hamper productivity and quality of cocoons. Among silkworm diseases, infectious flacherie is a prominent one caused by the virus, *Bombyx mori* infectious flacherie virus (BmIFV). Total haemocyte count (THC) and differential haemocyte count (DHC) indicate the immunological status of an insect and there is a possibility of differential response by haemocytes in different breeds to microbial infection. Our earlier studies indicated CSR2 as highly susceptible and 5N as the most tolerant breed of silkworm against BmIFV infection. In the present study, an attempt was made to understand the haematological changes taking place in the haemolymph during the progressive infection of BmIFV in both the susceptible and tolerant breeds to further ascertain their susceptibility / tolerance level. Immediately after III moult, newly ecdysed IV instar (0 day of post inoculation - 0 DPI) larvae were per orally inoculated with an infective dose of BmIFV and larvae were reared up to 12 days of post inoculation (DPI). As the larval age progressed from 0 to 12 DPI, the THC increased in both the breeds. During the progressive infection of BmIFV, the THC got decreased in treated batches when compared to respective controls in both the breeds. However, 5N displayed more THC compared to CSR2 and the decrease in THC in response to BmIFV infection was at a slower rate compared to that of CSR2. Five types of haemocytes viz., prohaemocytes (PRs), plasmatocytes (PLs), granulocytes (GRs), spherulocytes (SRs) and oenocytes (OEs) were observed in the haemolymph of both the breeds. The PLs and GRs accounted for more than 50 % in the haemocyte population. As the larval age progressed from 0 to 12 DPI, the percentage of different haemocytes showed varying patterns in control and treated lots of both the breeds which are deliberated upon.

Key words: BmIFV, *Bombyx mori* L., differential haemocyte count, susceptible/tolerant breeds, total haemocyte count.

INTRODUCTION

Mulberry silkworm, *Bombyx mori* L. is an insect of economic interest and due to centuries of domestication, its natural resistance has been decreasing making it susceptible to various microbial (viral, bacterial, fungal and microsporidian) infections leading to different diseases and finally, cocoon crop loss. Among the viral diseases of silkworm, infectious flacherie is caused by

Bombyx mori infectious flacherie virus (BmIFV), which was first reported in Japan by Yamazaki *et al.* (1960). In India, Sato (1992) and Sivaprasad *et al.* (1993) reported the prevalence of infectious flacherie disease in different sericultural areas of southern districts of Karnataka. Later, silkworm breeds were screened to determine their comparative susceptibility to BmIFV (Hemanth Kumar,

2002; Mamatha, 2002; Mary Flora *et al.*, 2002). Mamatha and Balavenkatasubbaiah (2008 a) also studied the progressive morphological changes in the susceptible and tolerant breeds of silkworm infected with BmIF. Subsequently, they studied the biochemical changes during the progressive infection of BmIFV in the silkworm (Mamatha and Balavenkatasubbaiah, 2014) and identified midgut as the target tissue of BmIFV infection (Mamatha and Balavenkatasubbaiah, 2017 a) and reported the histopathological changes in the midgut of the susceptible/tolerant breeds of silkworm (Mamatha and Balavenkatasubbaiah, 2017 b). However, the information on the haematological changes during BmIFV infection is scanty which would throw some light on the immune system in the silkworm.

Haemolymph plays an important role in the processes of excretion, defense, molting and metamorphosis in insects. The total and specific haemocyte population indicates the immunological status of the insect. Nittono (1960) classified the haemocytes in the silkworm, *B. mori* L. into six types *viz.*, prohaemocytes, plasmatocytes, granulocytes, spherulocytes, imaginal spherulocytes (observed only at the stage of adult, but occasionally in pupa on the day before emergence) and oenocytes. However, Balavenkatasubbaiah *et al.* (2001) and Balavenkatasubbaiah and Nataraju (2005) reported five types of haemocytes *viz.*, prohaemocytes, plasmatocytes, granulocytes, spherulocytes and oenocytes in the silkworm. The chief defensive cells in *B. mori* haemolymph are the plasmatocytes and granulocytes which take part in phagocytosis, encapsulation and nodulation reactions in response to pathogen infection (Gupta, 1986; Krishnan *et al.*, 2000). The total haemocyte count and differential haemocyte count may indicate the susceptibility status of the insects. Hence, in the present study, the defensive mechanism during the progressive infection of BmIFV in the susceptible and tolerant breeds were probed and the results are discussed.

MATERIALS AND METHODS

The larvae of two silkworm breeds identified as susceptible

(CSR2) and tolerant (5N) against BmIFV (Mamatha and Balavenkatasubbaiah, 2008) were brushed *en masse* and reared following the standard rearing methods up to III instar. Immediately after III moult, newly ecdyced 4th instar larvae were per orally inoculated with an infective dose of BmIFV at $10^{-7.255}$ dilution of stock inoculum (LC50 dose of CSR2 for 12 days) by smearing on mulberry leaf @ 1ml/100 sq.cm leaf/100 larvae. The control batches were also maintained without any inoculation. The larvae were reared up to 12 days post inoculation.

From both treated and control batches, from 0 to 12 DPI, the haemolymph was collected in a pre-chilled eppendorf tube containing a few crystals of phenylthiourea by cutting the prolegs of larva. The collected haemolymph was stored at 5 °C for haemocyte counts. Six replications were taken for each treatment.

Estimation of total haemocyte count (THC)

The THC was estimated using haemocytometer following standard procedure (Cantwell, 1973). THC per mm³ of haemolymph was estimated according to the formula suggested by Jones (1962).

Estimation of differential haemocyte count (DHC)

The DHC (*i.e.*, the relative number of different types of haemocytes) was estimated by counting different haemocytes from a haemocyte population of 200 and finally expressed in per cent. Different haemocytes were identified as following based on their morphology as described by Nittono (1960) and also by referring to photographs (Figure 1) collected from literature through internet.

a) Prohaemocytes (PRs) are usually round or ellipsoidal cells, the plasma membrane is generally smooth.

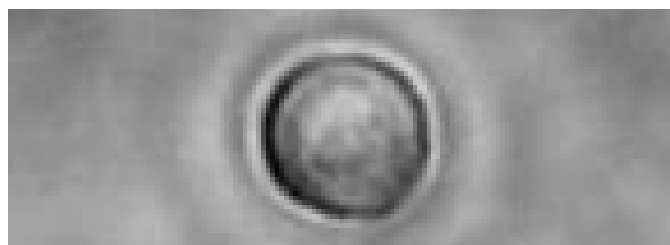
b) Plasmatocytes (PLs) are normally granular and the granules are few, smaller and finer than those of granulocytes. Plasmatocytes are usually prominent

in size and abundant in number. The plasma membrane of these cells may have numerous pseudopodia.

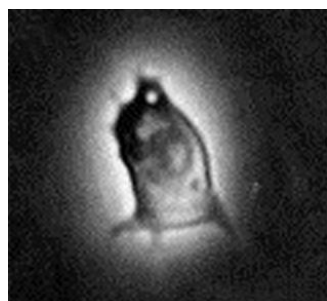
c) **Granulocytes (GRs)** are compact cells of variable size and shape. They are generally round or disc shaped. The cytoplasm contains many small round granules.

d) **Spherulocytes (SPs)** are round or ovoid cells and are characterized by large spherules.

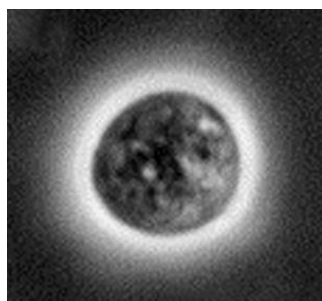
e) **Oenocytes (OEs)** are of variable shape and size with large amounts of superficially homogenous cytoplasm with characteristic inclusion crystals.



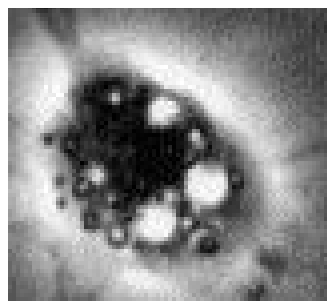
Prohaemocyte



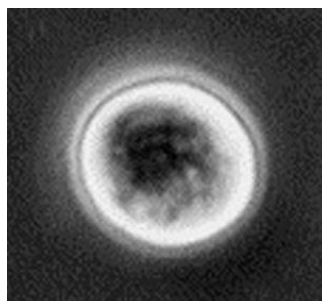
Plasmatocyte



Granulocyte



Spherulocyte



Oenocyte

Figure 1: Haemocytes present in the haemolymph of silkworm, *B. mori* L.

RESULTS

The THC in haemolymph of silkworm during the progressive infection of BmIFV in CSR2 and 5N breeds is presented in Table 1. As the larval age increased (0 day to 12 DPI), the THC also increased in these two breeds, both in control and treated batches. In CSR2 control batches, the THC in haemolymph was 5,575 / mm³ on 0 DPI and 11,083 / mm³ on 12 DPI whereas in treated batches, it showed an increase from 5,575 (0 DPI) to 8,225 / mm³ on 12 DPI. However, THC was less in treated batches when compared to respective controls. The per cent decrease with respect to control from 1 to 12 DPI was 3.43 to 25.66 (Figure 2). In the case of 5N, the THC was 7,358 / mm³ on 0 DPI and increased to 11,725 / mm³ on 12 DPI in control and from 7,385 (0 DPI) to 10,525 / mm³ on 12 DPI, in the treated group. Results also indicated that THC recorded in treated batches always remained comparatively lower than that of respective controls.

The percentage of prohaemocytes in the haemolymph of CSR2 and 5N breeds of silkworm during the progressive infection of BmIFV is presented in Table 2. In CSR2 control batch, on 0 DPI, the PRs % was 19.33 in haemocyte population and 20.75 % on 4 DPI. Afterwards, there was a gradual decrease of PRs % from 13.00 (5 DPI) to 8.82 (12 DPI). The same trend was also observed in BmIFV treated batch. However, when a comparison was made in relation to control, there was a decreased trend observed up to 6 DPI which then kept rising up to 12 DPI (Figure 3). In 5N control batch, there was a gradual decrease in PRs % from 18.83 (0 DPI) to 10.17 % (12 DPI) except on 5 DPI. The same trend was also observed in BmIFV treated batches except on 4 DPI. However, there was a decreasing trend observed during the progressive infection of BmIFV in treated batches compared to respective controls up to 12 DPI (Figure 2) except on 2, 4 and 6 DPI.

Table 3 presents an account of the percentage of plasmatocytes in the haemolymph of CSR2 and 5N breeds of silkworm during the course of infection of

BmIFV. In CSR2, as the age of larva increased from 0 to 12 DPI, the PLs % also increased from 13.98 to 16.73 % with fluctuations in both control and treated batches. The per cent increase of PLs in treated batches compared to control ranged from 13.22 (1 DPI) to 102.45 (11 DPI). On 12 DPI, the per cent increase was 95.27 (Figure 4). In the case of 5N control batch, as the age of larvae increased from 0 to 12 DPI, there were fluctuations of PLs % and in treated batches, PLs % increased from 12.67 to 16.27 on 12 DPI (Table 3). The per cent increase of PLs in treated batches compared to control was from 6.44 (1 DPI) to 43.56 (12 DPI).

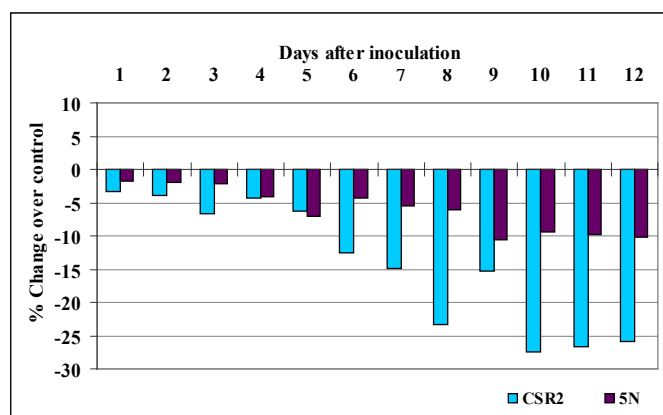


Figure 2: Changes in the total haemocyte count in CSR2 and 5N breeds of silkworm during the progressive infection of BmIFV

The results obtained in respect of the percentage of granulocytes in the haemolymph of both the experimental breeds during the progressive infection of BmIFV are presented in Table 4. In CSR2, as the age of larvae increased, the GRs % gradually increased from 48.33 (0 DPI) to 65.08 (12 DPI), whereas in the treated batches, the GRs % decreased from 48.33 (0 DPI) to 38.17 (12 DPI). But when compared to respective controls, the GRs % in BmIFV treated batches remained low from 1 to 12 DPI. The decrease was to the tune of 42.67 % on 12 DPI (Figure 5). In 5N also, as the age of larvae increased from 0 to 12 DPI, there was an increasing trend in GRs % both in control and treated batches. The GRs % increased from 47.67 to 62.50 (12 DPI) in control batches and from 47.67 to 57.90 in treated batches. A comparison between

respective control and treated batches shows decrease in GRs % in BmIFV inoculated batches. The decrease was to the extent of 3.02 % on 1 DPI and 7.36 % on 12 DPI (Figure 5). When a comparison was made between the breeds, there was no much variation of GRs % in controls but in treated batches, there was a variation on 5 and 7 DPI.

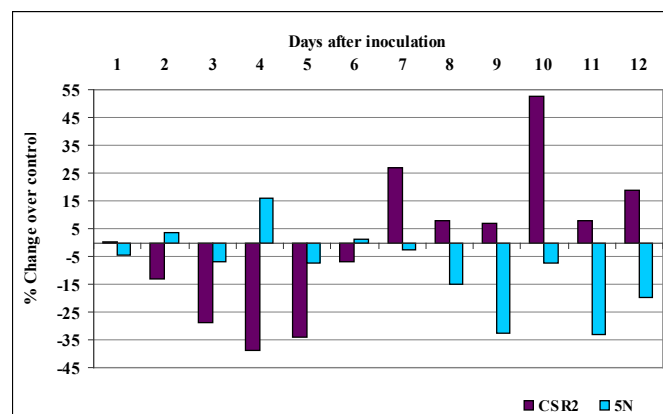


Figure 3: Changes in the prohaemocytes (%) in CSR2 and 5N breeds of silkworm during the progressive infection of BmIFV

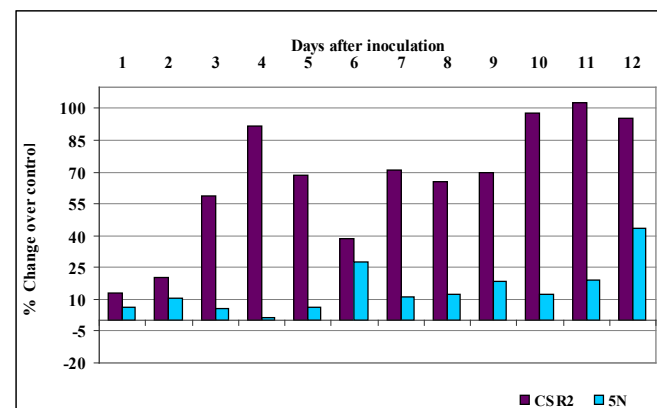


Figure 4: Changes in plasmatocytes (%) in CSR2 and 5N breeds of silkworm during the progressive infection of BmIFV

Table 5 depicts the status of spherulocytes in the haemolymph of treated as well as control batches of CSR2 and 5N breeds. The percentage of SPs decreased as the age of larvae increased from 0 to 12 DPI in both the breeds. In the case of CSR2, the SPs % gradually decreased from 15.15 (0 DPI) to 8.17 (12 DPI). In the case of treated batches also, the SPs % decreased from

15.15 to 12.83 (12 DPI) during the progressive infection of BmIFV. But when compared to respective controls, there was a fluctuation in the trend of SPs % (Figure 6). In 5N control batches, the SPs % decreased from 13.50 (0 DPI) to 10.83 (12 DPP) with fluctuations. In treated batches, there was not much variation in SPs % (13.50 % on 0 DPI and 13.17 % on 12 DPI), but when compared to respective controls, in this breed also, there was no variation in the fluctuation trends of SPs % (Figure 6).

The percentage of oenocytes in the haemolymph of CSR2 and 5N breeds of silkworm during the progressive infection of BmIFV is presented in Table 6. The percentage of OEs fluctuated both in control and treated batches of CSR2 breed. The percentage of OEs was less compared to other haemocytes both in control (1.08 to 6.75 %) and treated batches (1.43 to 6.83 %). In the case of 5N also, the percentage of OEs was less in control (3.33 to 7.67 %) and treated batches as well (2.40 to 7.47 %).

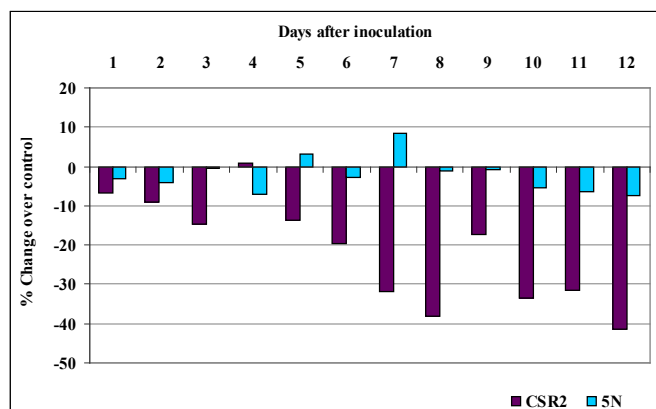


Figure 5: Changes in granulocytes (%) in CSR2 and 5N breeds of silkworm during the progressive infection of BmIFV

DISCUSSION

Insect innate immune system comprises of humoral and cellular defense responses. Humoral defenses include antimicrobial peptides, the cascades that regulate coagulation and melanization of haemolymph, and the production of reactive intermediates of oxygen and nitrogen. Cellular defenses refer to haemocyte-mediated

responses. Haemocytes play an essential role in defending insect against invading parasites and pathogens by effective physiological mechanisms of phagocytosis, encapsulation and other related defense processes.

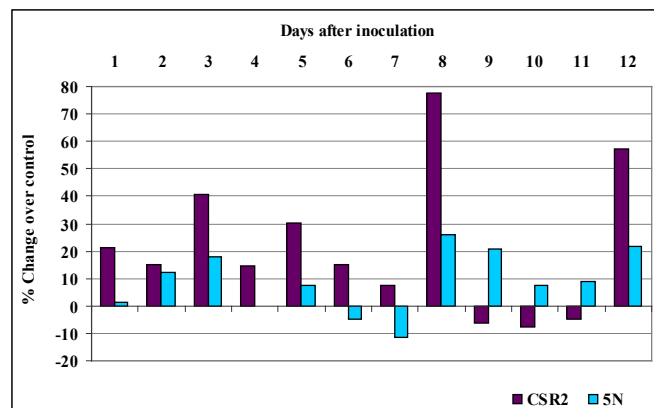


Figure 6: Changes in spherulocytes (%) in CSR2 and 5N breeds of silkworm during the progressive (%) infection of BmIFV

The experimental breeds exhibited a significant difference in their initial THC, it being less in the susceptible breed (CSR2) and higher in the tolerant (5N) breed. As the larval age increased from 0 to 12 DPI, there was a corresponding hike in the THC in control and BmIFV treated batches of both the breeds. But, the treated lots exhibited relatively lower THC than that of respective controls. The decrease in THC was to the tune of 25.88 % in CSR2 and 5.96 % in 5N on 12 DPI. The observation of high THC in tolerant breed during progressive infection points to the possibility of a correlation between the tolerance of breed to disease and THC. Earlier reports also presented a similar observation of decrease in THC at a slower rate in the tolerant breed during the infection of BmNPV (Balavenkatasubbaiah *et al.*, 2001). In the present study, the decrease in total haemocyte count in treated batch compared to respective controls was in agreement with the earlier studies of Narayanan and Jayaraj (1976) and Hung *et al.* (1993). They reported drastic reduction in the number of haemocytes during various microbial infections due to fungi, bacteria and viruses and parasitic infections. According to Witting (1962), increase in circulating haemocytes is the instant cellular immune response in some insects and the response also depends

on the type and dose of the pathogen. Koundinya *et al.* (2007) reported the increase in THC in the bacteria infected larvae of selected bivoltine breeds. Begum *et al.* (1998) had reported that the response of haemocytes of *P. ricini* to deltamethrin brought about morphological and pathological changes resulting in cell breakdown and decrease in total haemocyte counts. Wigglesworth (1959) and Crossley (1979) reported that the haemocytes are known to be involved in intermediary metabolism, such as protein synthesis, transport of nutrients, phenol metabolism and growth stimulation.

Based on Jones classification (Jones, 1962), in the present study also, five types of haemocytes *viz.*, prohaemocytes, plasmacytes, granulocytes, sperulocytes and oenocytes were observed in the silkworm, *Bombix mori* L.

Divergence in haemocyte profile of lepidopteran larvae was reported by Lackie (1988) and Ratcliffe (1993) and most of the cellular defense responses involve plasmacytes and granular cells. According to them, the plasmacytes and granulocytes accounted for more than 50 per cent of the haemocytes in circulation in the larval stage of lepidoptera. The present observations are in unison with this. Beaulaton (1979) suggested that prohaemocytes in *B. mori* differentiates into plasmacytes which in turn differentiated into granulocytes and sperulocytes. The granulocytes, are primarily involved in defensive mechanisms and in the present study, a gradual decrease of granulocytes was observed in BmIFV treated batch. This was in agreement with the findings of Balavenkatasubbaiah *et al.* (2001).

Table 1: Total haemocyte count in haemolymph of CSR2 and 5N breeds of silkworm during the progressive infection of BmIFV

Total haemocyte count (Cells/mm ³ of haemolymph)								
DPI	CSR2		't' value	5N		't' value	CSR2	CSR2 Treated
	Control	Treated		Control	Treated		Control v/s 5N Control 't' value	v/s 5N Treated 't' value
0	5,575 ±144	5,575±144	0.000	7,358±265	7,358±265	0.000	14.467**	14.467**
1	6,567±438	6,342±365	0.993 NS	8,243±183	8,102±297	0.966 NS	8.651**	9.153**
2	7,467±183	7175±184	1.647*	8,496±119	8,333±211	2.751*	11.538**	10.142**
3	8,325±94	7,775±234	1.280*	8,883±289	8,688±236	5.346**	4.498**	6.736**
4	8,733±240	8,358±372	2.331*	9,267±147	8,877±382	2.0743*	4.638**	2.380*
5	8,792±297	8,242±398	9.652**	8,892±143	8,258±74	2.711*	0.742 NS	0.100 NS
6	9,667±223	8,450±335	3.270**	9,917±151	9,483±288	7.412**	2.276*	5.736**
7	10,183±481	8,658±240	4.174**	11,183±342	1,0575±104	6.947**	4.150**	17.981**
8	10,717±379	8,208±188	6.252**	11,525±234	10,833±137	14.518**	4.445**	27.648**
9	11,258±252	9,533±306	15.881**	11,942±163	10,675±108	10.661**	5.584**	8.613**
10	11842±211	8,600±118	7.210**	12,092±169	10,950±349	32.853**	2.269*	15.608**
11	11,592±248	8,492±159	12.432**	11,892±169	10,733±154	25.768**	2.451*	24.784**
12	11,083±254	8,225±121	7.786**	11,725±260	10,525±273	24.844**	2.451*	18.831**

NS: Non-significant; *Significant at 5 % level; **Significant at 1 % level.

Table 2: Prohaemocyte count in the haemolymph of CSR2 and 5N breeds of silkworm during the course of BmIFV infection

Percentage of Prohaemocytes (Cells/mm ³ of haemolymph)								
DPI	CSR2		‘t’ value	5N		‘t’ value	CSR2	CSR2 Treated
	Control	Treated		Control	Treated		Control v/s 5N Control ‘t’ value	v/s 5N Treated ‘t’ value
0	19.33±1.37	19.33±1.37	0.000	18.83±3.37	18.83±3.37	0.000	0.337 NS	0.337 NS
1	17.50±2.35	17.55±1.21	0.046 NS	18.00±2.00	17.17±3.130	0.550 NS	0.397 NS	0.280 NS
2	19.67±2.66	17.13±1.88	1.909*	18.00±1.79	18.67±2.34	0.554 NS	1.274 NS	1.255 NS
3	16.83±2.93	12.00±1.55	3.575**	16.67±2.25	15.50±2.43	0.862 NS	0.111 NS	2.976*
4	20.75±1.54	12.67±1.63	8.818**	18.08±1.36	21.00±1.79	3.181**	3.182**	8.427**
5	18.67±3.34	12.33±1.21	4.364**	20.00±1.55	18.50±3.16	1.043*	0.887 NS	4.461**
6	13.00±2.28	12.08±1.20	0.871 NS	12.83±1.94	13.00±1.67	0.159 NS	0.136 NS	1.090 NS
7	13.67±1.97	17.34±3.44	2.274*	14.00±1.90	13.67±1.97	0.298 NS	0.299 NS	2.274*
8	13.12±1.90	14.17±1.60	1.034 NS	14.27±0.91	12.12±1.97	2.423*	1.336 NS	1.975 NS
9	9.67±1.21	10.34±1.50	0.858 NS	13.83±0.75	9.33±1.21	7.730**	7.157**	1.283 NS
10	9.92±1.96	15.15±2.50	4.041**	12.15±2.16	11.25±1.54	0.831 NS	1.877 NS	3.259**
11	8.82±1.02	9.50±1.05	1.144*	9.83±1.83	7.92±1.63	1.915*	1.18 NS	2.005 NS
12	8.82±2.37	9.50±0.84	0.667 NS	10.17±1.60	8.17±1.33	2.353*	1.157 NS	2.080 NS

NS: Non-significant; *Significant at 5 % level; **Significant at 1 % level.

Table 3: Plasmacyte count in the haemolymph of CSR2 and 5N breeds of silkworm during the course of BmIFV infection

Percentage of Plasmacytes (Cells/mm ³ of haemolymph)								
DPI	CSR2		‘t’ value	5N		‘t’ value	CSR2	CSR2 Treated
	Control	Treated		Control	Treated		Control v/s 5N Control ‘t’ value	v/s 5N Treated ‘t’ value
0	13.98±3.59	13.98±3.59	0.000	12.67±0.82	12.67±0.82	0.000	0.876 NS	0.876 NS
1	14.87±1.31	16.83±0.75	3.189**	13.66±1.50	14.53±1.51	1.248*	1.490*	3.341**
2	16.83±2.93	20.25±1.08	2.681*	13.31±2.29	14.67±1.37	1.248*	2.324*	7.842**
3	14.58±1.36	23.16±1.61	9.997**	13.58±1.39	14.33±1.37	0.945 NS	1.263*	10.260**
4	12.33±1.97	23.64±2.90	7.911**	13.50±1.64	13.67±1.51	0.183 NS	-1.115*	7.484**
5	16.47±1.42	27.75±1.25	14.555**	14.83±2.32	15.76±1.41	0.833 NS	1.472*	15.547**
6	18.50±3.39	25.67±1.86	4.537**	12.67±1.63	16.17±1.33	4.071**	3.796**	10.172**
7	14.62±1.45	25.00±3.41	6.868**	13.17±2.14	14.62±1.45	1.374*	1.374*	6.868**
8	16.32±1.41	27.00±4.00	6.163**	13.67±0.82	15.36±2.76	1.439*	3.985**	5.871**
9	16.14±2.16	27.43±4.86	5.2010**	12.50±1.87	14.83±2.32	-.919*	3.116**	5.732**
10	16.51±1.16	32.68±3.14	11.817**	14.70±1.04	16.51±1.16	2.858*	2.859*	11.818**
11	16.91±1.11	34.23±1.87	19.468**	13.17±0.75	16.51±1.05	6.320**	6.823**	20.184**
12	16.73±1.17	32.67±1.51	20.504**	11.33±1.63	16.27±1.28	5.828**	6.588**	20.329**

NS: Non-significant; *Significant at 5 % level; **Significant at 1 % level.

Table 4: Granulocyte count in the haemolymph in CSR2 and 5N breeds of silkworm during the course of BmIFV infection

Percentage of Granulocytes (Cells/mm ³ of haemolymph)								
DPI	CSR2		't' value	5N		't' value	CSR2	CSR2 Treated
	Control	Treated		Control	Treated		Control v/s 5N Control 't' value	v/s 5N Treated 't' value
0	48.33±2.94	48.33±2.94	0.000	47.67±2.25	47.67±2.25	0.000	0.441 NS	0.441 NS
1	52.03±2.59	48.50±0.84	3.175**	49.67±1.21	48.17±2.32	1.405 *	2.025 NS	2.025 NS
2	51.42±2.15	46.83±2.64	3.295**	52.50±1.87	50.33±2.94	1.416*	0.930 NS	0.930 NS
3	55.67±2.58	47.50±3.21	4.856**	50.83±1.47	50.67±1.51	0.193 NS	3.980 **	3.980 **
4	48.33±3.98	48.73±5.10	0.151 NS	49.67±1.75	46.17±1.72	3.490**	0.751 NS	0.751 NS
5	48.83±3.92	42.17±2.48	3.519**	47.50±2.43	49.00±3.69	0.832 NS	0.708 NS	0.708 NS
6	49.25±3.66	39.67±4.32	4.147**	52.33±1.75	50.83±2.79	2.208*	1.863*	5.320**
7	56.95±2.04	38.83±2.99	12.241**	52.50±2.88	56.95±2.04	3.086**	3.086*	12.241**
8	60.17±2.79	37.33±4.23	11.046**	54.17±1.60	53.50±4.23	0.360 NS	4.572**	6.622**
9	59.67±2.58	49.33±2.73	6.732**	56.00±1.90	55.50±3.94	0.280 NS	2.803*	3.152**
10	62.17±2.14	41.25±1.47	19.732**	54.22±1.79	51.33±1.63	2.915*	6.987**	11.225**
11	62.25±2.09	42.67±1.97	16.709**	61.00±1.67	57.00±2.61	3.162**	1.143*	10.750**
12	65.08±2.20	38.17±3.97	14.524**	62.50±1.64	57.90±3.07	3.236**	2.304*	0.850 NS

NS: Non-significant; *Significant at 5 % level; **Significant at 1 % level .

Table 5: Spherulocyte count in the haemolymph in CSR2 and 5Ns breed of silkworm during the course of BmIFV infection

Percentage of Spherulocytes (Cells/mm ³ of haemolymph)								
DPI	CSR2		't' value	5N		't' value	CSR2	CSR2 Treated
	Control	Treated		Control	Treated		Control v/s 5N Control 't' value	v/s 5N Treated 't' value
0	15.15±1.46	15.15±1.46	0.000	13.50±1.64	13.50±1.64	0.000	1.838*	1.838*
1	11.71±1.19	14.17±0.98	3.899**	12.48±2.18	12.67±1.75	0.163 NS	0.763 NS	1.830*
2	11.00±0.63	12.67±1.21	2.988*	10.53±2.36	11.83±1.83	1.066*	0.469 NS	0.928 NS
3	10.42±2.46	14.67±2.88	1.570*	11.58±1.91	13.67±1.37	2.174*	0.918 NS	0.769 NS
4	11.83±1.47	13.53±2.56	1.409 NS	11.71±1.19	14.17±0.98	3.899**	0.236 NS	1.133*
5	12.17±1.47	15.82±3.59	2.310*	11.33±1.86	12.17±1.47	0.860 NS	0.860 NS	2.310*
6	13.27±2.20	15.25±1.47	1.835*	14.50±1.64	13.77±1.90	0.715 NS	1.101*	1.511*
7	12.37±0.95	13.27±2.10	0.955 NS	14.00±1.26	12.37±0.95	2.527*	2.527*	0.955 NS
8	8.67±1.03	15.39±2.63	5.824**	10.83±2.04	13.67±1.86	2.512*	2.316*	1.308*
9	10.32±2.06	9.67±1.51	4.622**	12.83±1.33	15.51±2.08	2.654*	2.510*	5.571**
10	8.83±1.72	8.17±2.14	0.594 NS	14.73±0.77	15.84±1.42	1.681*	7.667**	7.330**
11	8.00±0.89	7.60±1.64	0.520 NS	12.67±3.00	13.84±1.96	0.799 NS	3.662**	5.978**
12	8.17±1.72	12.83±2.99	3.305**	10.83±1.60	13.17±2.71	1.814*	2.771*	0.201 NS

NS: Non-significant; *Significant at 5 % level; **Significant at 1 % level.

Table 6: Oenocyte count in the haemolymph in CSR2 and 5N breeds of silkworm during the course of BmIFV infection

DPI	Percentage of Oenocytes (Cells/mm ³ of haemolymph)							
	CSR2		‘t’ value	5N		‘t’ value	CSR2	CSR2 Treated
	Control	Treated		Control	Treated		Control v/s 5N Control ‘t’ value	v/s 5N Treated ‘t’ value
0	3.20±1.02	3.20±1.02	0.000	7.33±1.03	7.33±1.03	0.000	6.976**	6.976**
1	3.88±1.40	2.95±1.37	1.168 NS	6.20±2.12	7.47±1.37	1.231 NS	2.237*	5.713**
2	1.08±0.20	3.12±0.49	9.357**	5.67±1.37	4.50±2.88	0.8962 NS	8.127**	1.159 NS
3	2.50±1.41	2.67±2.73	0.133 NS	7.33±1.17	5.83±2.14	1.508 NS	6.449**	2.236*
4	6.75±0.76	1.43±0.68	12.760**	6.58±1.11	7.00±0.89	0.714 NS	0.303 NS	12.115**
5	3.87±1.83	1.93±1.04	2.242*	6.33±1.75	4.58±1.91	1.655 NS	2.382*	2.983*
6	5.98±1.80	5.00±2.53	0.776 NS	7.67±1.03	6.23±1.77	1.715 NS	1.987*	0.979 NS
7	2.40±1.37	5.57±1.72	3.525**	6.33±2.34	2.40±1.37	3.555**	3.556**	3.525**
8	1.72±0.72	6.12±1.52	6.396**	7.07±0.91	5.35±2.38	1.649 NS	11.304**	0.664 NS
9	4.22±2.74	3.23±1.06	0.820 NS	4.83±2.56	4.83±1.37	0.000	0.403 NS	1.705 NS
10	2.57±2.24	2.74±1.47	0.158 NS	4.21±0.68	5.08±2.58	0.804 NS	1.715 NS	1.935 NS
11	4.03±2.15	6.00±1.25	1.939 NS	3.33±2.07	4.73±0.59	1.597 NS	0.575 NS	2.245**
12	3.35±2.39	6.83±0.98	3.304**	5.17±1.94	4.50±1.52	0.663 NS	1.446**	3.162**

NS: Non-significant; *Significant at 5 % level; **Significant at 1 % level.

Variations in the susceptibility of insect species to pathogen invasion may result from several factors, including the efficiency of cellular and humoral defense reactions (Vilcinskas and Go^otz, 1999). The effective physiological mechanisms of phagocytosis, encapsulation, and other related defense mechanisms were primarily due to the availability of circulatory immune cells particularly plasmatocytes and granulocytes. As haemocytes respond very instantly against adversaries, it is expected that by using haemocyte catalogue as indicator, impact of several biotic and abiotic factors can be evaluated (Rajitha *et al.*, 2013). Present investigation tried to analyze cellular immunopotency in *B. mori* larvae during the progressive infection of BmIFV by quantifying total and differential haemocytes in susceptible and tolerant breeds. 5N was having more THC compared to CSR2 at all instances and the decrease in THC and GRs % in treated batch was at a slower rate compared to that of CSR2 indicating the higher tolerance of 5N than CSR2. Our earlier investigation on larval mortality (Mamatha

and Balavenkatasubbaiah, 2008 b) and histopathological changes (Mamatha and Balavenkatasubbaiah, 2017 b) during the progressive infection of BmIFV in CSR2 and 5N breeds also indicated the higher susceptibility of CSR2 against BmIFV infection.

ACKNOWLEDGEMENT

First author wishes to express her sincere thanks to the University Grants Commission, New Delhi, India for providing Rajiv Gandhi National Fellowship to carry out this Research work and University of Mysore, Mysore, India for permitting her to carry out the work at Central Sericultural Research and Training Institute, Mysore, India. She is also thankful to the CSRTI, Mysore for providing laboratory facilities and encouragement. The authors are thankful to Mr. J. Justin Kumar, Technical Assistant, Silkworm Pathology, CSRTI, Mysore for his help in data compilation.

REFERENCES

- Balavenkatasubbaiah M. and Nataraju B. (2005) Haemocyte changes during the progressive infection of *Beauveria bassiana* in different breeds of silkworm (*Bombyx mori* L.). *Madras Agric. J.*, **92** (7-9): 431-437.
- Balavenkatasubbaiah M., Nataraju B., Thiagarajan V. and Datta R. K. (2001) Haemocyte counts in different breeds of silkworm, *Bombyx mori* L. and their changes during progressive infection of BmNPV. *Indian J. Seric.*, **40** (2): 158-162.
- Beaulaton J. (1979) Haemocytes and haemopoiesis in silkworms. *Biochemie.*, **61**: 157-164.
- Begum R., Gohain R. and Hazarika L. K. (1998) Detoxification of Deltamethrin by the haemocytes of *Philosamia ricini* Boisid (Lepidoptera: Saturniidae). *Proceedings of National Seminar on Life Sciences*, Dibrugarh University, Assam, India, pp. 113-118.
- Cantwell G. E. (1973) Methods for determining the level of *Nosema* infection in honeybees. In: *Insect diseases*, G. E. Cantwell (Ed.), Marcel Dekker, New York, No. 2, pp. 539-542.
- Crossley A. C. S. (1979) Biochemical and ultrastructural aspects of synthesis, storage and secretion in haemocytes. In: *Insect haemocytes*, A. P. Gupta (Ed.), Cambridge University Press, Cambridge, pp. 423-473.
- Gupta A. P. (1986) Arthropod immunocytes: Identification, functions of vertebrate B and T lymphocytes. In: *Haemocytic and humoral immunity in arthropods*, A. P. Gupta (Ed.), John Wiley, New York, pp. 33-59.
- Hemanth Kumar L. (2002) Screening of promising bivoltine hybrids of silkworm, *Bombyx mori* L. for their susceptibility to BmNPV and BmIFV. *M.Sc. Dissertation*, University of Mysore, Mysore, India.
- Hung S. Y., Boucias D. G. and Vey A. J. (1993) Effect of *Beauveria bassiana* and *Candida albicans* on the cellular defense response of *Sopodoptera exigua*. *J. Invertebr. Pathol.*, **61**: 179-187.
- Jones J. C. (1962) Current concepts concerning insect hemocytes. *Amer. Zool.*, **2**: 209-246.
- Koundinya P. R., Ponnuvel K. M., Mohan B. and Sinha R. K. (2007) Bacterial induced immunity studies in selected bivoltine silkworm (*Bombyx mori*) germplasm accessions. *Annual Report*, 2006-07, Central Sericultural Germplasm Resources Centre, Hosur, India, pp. 137-138.
- Krishnan N., Mohanan M., Chaudhuri N. A., Mitra P., Saratchandra B. and Roy A. K. (2000) Role of 3, 4-dihydroxy phenyl alanine in the nodulation response of silkworm, *Bombyx mori* L. to bacterial infection. *Curr. Sci.*, **79** (7): 1011-1016.
- Lackie A. M. (1988) Haemocytic behavior. *Adv. Insect. Physiol.*, **21**: 85-178.
- Mamatha M. (2002) Screening of promising multivoltine hybrids of silkworm, *Bombyx mori* L. for their susceptibility to BmNPV and BmIFV. *M. Sc. Dissertation*, University of Mysore, Mysore, India.
- Mamatha M. and Balavenkatasubbaiah M. (2008 a) Comparative study on progressive morphological changes in the susceptible and tolerant breeds of silkworm infected with BmIFV. *Indian J. Seric.*, **47** (1): 64-69.
- Mamatha M. and Balavenkatasubbaiah M. (2008 b) Identification of productive bivoltine breeds tolerant to BmIFV (*Bombyx mori* Infectious Flacherie Virus). *Uttar Pradesh J. Zool.*, **28** (3): 297-305.
- Mamatha M. and Balavenkatasubbaiah M. (2014) Biochemical changes during the progressive infection of BmIFV in the silkworm, *Bombyx mori* L. *Int. J. Plant Animal Env. Sci.*, **4** (2): 372 - 378.
- Mamatha M. and Balavenkatasubbaiah M. (2017 a) Identification of target tissue(s) of BmIFV infection in the susceptible/tolerant breeds of silkworm, *Bombyx mori* L. through immunodiffusion test. *Sericologia*, **57** (1): 45-52.
- Mamatha M. Balavenkatasubbaiah M. (2017 b) Histopathological changes during the progressive infection of BmIFV in the susceptible/tolerant breeds of silkworm, *Bombyx mori* L. *Sericologia*, **57** (3): 158-163.
- Mary Flora C. A., Sivaprasad V., Balavenkatasubbaiah M., Nataraju B., Thiagarajan V. and Datta R. K. (2002) Comparative susceptibility and histopathology of infectious flacherie virus in different breeds of silkworm, *Bombyx mori* L. In: *Advances in Indian Sericulture Research, Proceedings of National Conference on Strategies for Sericulture Research and Development*, November, 16-18, 2000, S. B. Dandin and V. P Gupta (Eds.), Central Sericultural Research and Training Institute, Mysore, India, pp. 323-327.

- Narayanan K. and Jayaraj S. (1976) Metamorphic changes in haemocytic picture of the citrus butterfly, *Papilio demoleus* L. (Lepidoptera: papilionidae). *J. Bombay Nat. Hist. Soc.*, **73**: 283-286.
- Nittono Y. (1960) Studies on the blood cells in the silkworm, *Bombyx mori* L. *Bull. Seric. Expt. Stn.*, **16**: 261-266.
- Rajitha G., Savithri G. and Sujathamma P. (2013) Haemocyte population dynamics in fifth instar silkworm *Bombyx mori* L. inoculated with *Beauveria bassiana* (Bals.) Vuill. *Int. J. Agric. Sci. Res.*, **3** (2): 265-276.
- Ratcliffe N. A. (1993) Cellular defense responses of insects: Unresolved problems. In: *Parasites and pathogens of insects*, Beckage N. E., Thompson S. N. and Federici B. A. (Eds.), Academic Press, San Diego, Canada, **1**: 267-304.
- Sato T. (1992) *Report on the Silkworm Pathology*, Bivoltine Sericulture Technology Development Programme, Japan International Cooperative Agency (JICA), Central Sericultural Research and Training Institute, Mysore, India.
- Sivaprasad V., Nataraju B. and Balavenkatasubbaiah M. (1993) Study on the prevalence of non-occluded viral diseases of silkworm, *Bombyx mori* L. *Annual Report, 1992-1993*, Central Sericultural Research and Training Institute, Mysore, India, p.76.
- Vilcinskas A. and Go"tz P. (1999) Parasitic fungi and their interactions with the insect immune system. *Adv. Parasitol.*, **43**: 267-313.
- Wigglesworth V. B. (1959) Insect blood cells. *Annu. Rev. Entomol.*, **4**: 1-16.
- Witting G. (1962) The pathology of insect blood cells. A review. *Am. Zoologist*, **2**: 257-273.
- Yamazaki H., Sakai E., Shimodaira M. and Yamada T. (1960) Studies on the infectious flacherie (F-type) of silkworm, *Bombyx mori*. *Bull. Seric. Exp. Stn.*, **61**: 1-28.



EMPLOYABILITY OF SERICULTURE PG DIPLOMA HOLDERS IN EAST AND NORTH-EAST INDIA

**G. R. Manjunatha*, Lalrinnungi, Kiran Kumar R. Patil¹,
J. Parameshwarnaik and V. Sivaprasad**

Central Sericultural Research and Training Institute, Central Silk Board, Berhampore 742101, India.

¹Department of Agricultural Economics, University of Agricultural and Horticultural Sciences,
Shimoga 577225, India.

*Email: mgr.dvg@gmail.com

ABSTRACT

Central Sericultural Research and Training Institute, Berhampore (CSRTI-BHP) has been rendering services of R&D; technical, technological and extension support to the silk industry in Eastern and North-Eastern India since 1943. Besides, CSRTI offers Post Graduate Diploma in Sericulture (PGDS), a structured training course in affiliation with the University of Kalyani, Kalyani since 2007-08 as per the MoA held between them. The duration of the course is 15 months. Applications for the course are invited through regular media advertisements / correspondence. Majority of these students are sponsored by the Department of Sericulture (DoS) of various state governments across India. The students are trained in sericulture for its promotion in their respective states. In recent days, the students' intake to the course was found to be more as compared to past years. Thus, the current study was proposed to investigate the employability of the PGDS graduates from CSRTI. Primary data pertaining to the employability was elicited from 98 PGDS graduates (2013-2017) using structured questionnaire in the form of Google-doc via social media. Descriptive statistics, chi square test of independence and logit regression were performed to draw logical conclusion. The study indicated that the employment generation potential of PGDS holders was maximum (63 %) and majority of them are serving as extension officers in sericulture sector (81 %). The graduates from Assam, Mizoram, Jammu & Kashmir, West Bengal, Jharkhand and Madhya Pradesh were employed cent per cent. The employability of PGDS graduates was found to have significant association with marital status, category, merit position in graduation & team work skills. The sample had been correctly classified to the extent of 88 per cent using logit model. Majority of the un-employed graduates suggested for job reservation to alma-maters in CSB recruitments.

Key words: Employability, logit, North-East, PG Diploma, sericulture.

INTRODUCTION

Sericulture in India plays an important role in poverty alleviation. Compared to other agricultural crops, sericulture provides year-round employment and higher income to the rural farm families. In India, sericulture is practiced by about 1.2 million families and the industry

provides employment to approximately 9.2 million persons in rural and semi-urban areas across various activities of silk production chain (Anonymous, 2020). Of these, a sizeable number of workers belong to the economically weaker sections of the society, especially

women with a participation rate of around 55 %. The advent of technologies and education has created a wide range of job opportunities in both public and private sectors. The Department of Sericulture (DoS), Central Silk Board, Silk Export Promotion Council, FAO, NABARD, ICAR, SAUs (State Agricultural Universities), Nationalized banks *etc.* are the major public sector avenues and in addition, private consultancy is also gaining glaring importance.

Employability refers to skills and abilities required to find employment, remain employed or obtain new employment as and when required (Crossman and Clarke, 2010). Employability has been conceptualized as a set of achievements that increases graduates' likelihood of finding employment opportunities and guarantees them success in their chosen occupation, which would eventually benefit the workforce, community, economy and graduates themselves (York, 2004). Currently, the concept of employability of graduates is used as a benchmark to measure the quality of higher education globally forming an integral part of policies and strategies related to higher education (Teichler, 2009).

A gamut of factors, such as socio-economic status, nature of degree programme and different skills acquired influences the graduates in obtaining jobs. The mix of academic qualifications, vocational skills and personal skills are the selling skills for the entry level jobs (Rajkumar, 2011). Kay Wardle said that employer usually looks for a desired degree in relevant subject, work experience and transferable skills (communication, teamwork, problem solving, flexibility/adaptability, self-awareness, commitment and commercial awareness) in job seekers. In this context, bio-sciences subject fits the same pattern of employer response (Julie and Helena, 2006). Besides, geographic position also plays an important role in the job search because it will have influence on exposure to the aspirants regarding job opportunities.

Institute enrol the students (input) and transform them through teaching and learning which is reflected in the

students' performance and their employability (output). In order to ensure their potentiality, universities/institutes should conduct research on the level of employability of their graduates, as well as the skills they require to succeed in the workplace (Alibaygi *et al.*, 2013).

CSRTI-Berhampore is a premier research station established in the year 1943, involved in research and developmental activities to promote silk production in the Eastern and North-Eastern India. Through its remarkable research breakthrough, overall development of sericulture sector has been achieved in the region. It focuses on Research, Extension and Human Resource Development (HRD). To develop skilled and technical manpower related to pre-cocoon and post-cocoon activities, various training activities in the form of structured and non-structured courses are being tailored and offered. Post Graduate Diploma in Sericulture (PGDS) is one such structured training course affiliated to the University of Kalyani-Kalyani since 2007-08.

The PGDS is a 15 months course divided into two semesters of six months duration each (theory & practical) and another three-months for preparation of dissertation, for execution of syllabus covering all the aspects of mulberry sericulture. The eligibility for pursuing PGDS is graduation (B.Sc./M.Sc. in Biological Sciences/Sericulture/Agriculture and B.Tech.) from a recognised college or university. The course also includes 15 days exposure visit per semester to major mulberry & non-mulberry sericulture areas. The syllabus including practical components was revised during 2018-19. The syllabus comprises of topics *viz.*, introductory sericulture, mulberry production, crop protection, cocoon & seed production, silkworm breeding, mulberry breeding, plant physiology, post cocoon technology & by-product utilization, extension management and seri-entrepreneurship, seri-economics, statistics & computer application. The students are evaluated through examinations at the end of each semester (theory & practical) following internal & external evaluation systems. In addition, students are allowed for three months course work in the form of dissertation/intensive

practical training under the supervision of experienced faculty in various sericulture disciplines. The students have to submit final report being evaluated by the selected external examiner. The students on successful completion are awarded PGDS and those who are top scorers (preferably first three) are felicitated by the Central Silk Board (CSB-Bengaluru) by conferring Gold Medal or cash award (Anonymous, 2019). The applications for the course are invited through regular media advertisements/ and official correspondence to Department of Sericulture of different States in East and North-East. Majority of these students are sponsored by the DoS of various State Governments. The students are taught by the experienced scientific personnel working in CSRTI-Berhampore and other CSB units, and freelancers as honorary faculty. The students are trained in sericulture for its promotion in their respective states.

In recent days, the students' intake to the course was found to be increased significantly (13 in 2017 & 40 in 2019) as compared to previous years probing researcher to envisage into the details of employment and ability of the course to enhance human capital formation (Anonymous, 2019). In this context, the study attempted to investigate the employment potentiality of PGDS graduates from CSRTI-Berhampore.

METHODOLOGY

Primary data pertaining to the employment status of PGDS holders in last quinquennial period was elicited (during 2013 to 2017) using a pre-tested structured questionnaire (Annexure - I). The questionnaire was prepared in the form of Google doc (<https://forms.gle/dZ6CuPiQBFh5WveH9>) following the design of complete enumeration and sent to the graduates (n=105) through social media (WhatsApp, e-mail *etc.*). The data collected from in-service candidates were considered as non-response for study since they were a few. The year-wise response rate of the graduates was as given below:

Academic Year	Graduates (No.)	Responded (No.)
2012-13	26	22
2013-14	28	28
2014-15	15	13
2015-16	23	22
2016-17	13	13
Total	105 (M=48; F=57)	98 (M=46; F=52)
M= Male; F= Female		

A total of 21 variables (Qualitative & Quantitative) were considered for the study as enlisted below:

Variable	Details & Scaling	Variable	Details & Scaling
Eligibility for job	Others = 0; PGDS = 1	Locality	Rural = 0; Urban = 1
Gender	Male = 0; Female = 1	Educational Status before PGDS	B.Sc. = 0; M.Sc. = 1
Age	<30 = 0; >30 = 1	Employment	Un- empl. = 0; Self = 1; Private = 2; Govt. = 3
Marital Status	Others = 0; Married = 1	Year of joining job	2014 to 2018
Family Background	Agric./Seri. = 1; Non-Agri. = 0	Nature of job	Admin = 0; Extension = 1; Research & Training = 2; Others = 3
Category	Gen. = 0; OBC = 1; SC = 2; ST = 3	Annual Income (lakh)	<3 = 0; 3-5 = 1; >5 = 2
Rank in Graduation (%)	<60 = 0; 60-70 = 1; >70 = 2	Working in Sericulture sector	No = 0; Yes = 1
Rank in PGDS			
Communication skill			
Problem solving skill			
Team work skill			
Creativity skill			
ICT Skill			

The following statistical analyses were performed using MS-Excel, SPSS & R statistical packages.

Tabular analysis with descriptive statistics & percentages was performed to summarise the results of PGDS graduates employability.

Chi square (χ^2) statistic was used to test the independence of attributes governing employability of the graduates

using contingency table of order $r \times c$ ($r=1,2,\dots,i$ & $c=1,2,\dots,j$). Rows were two (employed or not) and columns were 2 to 5 based on attributes considered for the study. The hypothesis of attributes are independent (H_0) and are tested with a maintained hypothesis (H_1) (Rangaswamy, 2010). The attributes considered were eligibility degree, gender, age, family background, marital status, category, merit in graduation/PGDS & skills to ascertain the association with employability.

$$\text{The test statistic } \chi^2_{(r-1,c-1)} = \sum_r \sum_c \frac{(O_{ij} - E_{ij})^2}{E_{ij}}$$

where, O_{ij} = observed frequency of $(i, j)^{\text{th}}$ cell & E_{ij} = expected frequency of $(i, j)^{\text{th}}$ cell

When the expected frequency in a cell of (2×2) contingency table is small (say < 5), Yates' or Dandekar's corrections were employed for the continuity of χ^2 distribution.

Coefficient of contingency was used to measure the strength of association between the attributes pertaining to employability when the null hypothesis (H_0) was rejected in a χ^2 test.

$$C = \sqrt{\frac{\chi^2}{n + \chi^2}} \text{ where, } n \text{ is the size of the sample; } 0 \leq C < 1$$

If C is near to 1, it indicates a high degree of association while $C = 0$ indicates complete dissociation.

Logistic regression was employed to establish the functional relationship between dependent binary or dichotomous variable (PGDS holder employed or not) and one or more nominal independent variables. The independent variables or attributes preferred (Table 4) for logit analysis was based on significance of χ^2 at chosen level of 5 % (Gujarati, 2003). The relationship between dependent variable (Y) and independent variables (x_i) is linear and the model is written as:

$$Y = \alpha + \beta_i x_i + \varepsilon$$

where, α is the intercept; β_i is the regression coefficient of i^{th} variable and ε is random error $\sim N(0, \sigma^2)$

When the relationship between dependent/ response and predictor / independent variables is non-linear, the model is

$$Y = \ln \left[\frac{P_1}{1-P_1} \right] = \alpha + \beta_i x_i + \varepsilon$$

where, P_1 is the probability of graduate being employed ($Y=1$) for given x_i ($i=1,2,\dots,p$)

$$P_1 = \frac{\exp(\alpha + \beta_i x_i)}{1 + \exp(\alpha + \beta_i x_i)}$$

or

$$\text{logit}(P_1) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_p x_p$$

where, α and β_i are model parameters.

x_i are independent variables, such as Eligibility for job; Marital status; Category; Graduation rank & Team work skills (Table 5).

The best fit logit model was validated with parameters, such as minimum value of -2 log likelihood, Chi-square test of significance and Nagelkerke R^2 value and correct classification % between observed & predicted values of employability.

RESULTS AND DISCUSSION

The general information on PGDS graduates during 2012-13 to 2016-17 is presented in Table 1. A total of 98 (93 %) out of 105 graduates responded through social media. Among the graduates responded, 53 per cent were found female and the rest were male. Majority (97 %) of the respondents belonged to the age group category of < 35 years, 63 per cent were found unmarried, 55 per cent belonged to schedule tribe category & 52 per cent

Table 1: Profile of PGDS graduates of CSRTI Berhampore (2013-17)

#	Particulars	2013	2014	2015	2016	2017	Total
A	Graduates (N)	26	28	15	23	13	105
B	Responded (n)	22	28	13	22	13	98 (93.33)
I	Age						
	<30	7	9	4	15	12	47 (47.96)
	30-35	15	18	9	6	1	49 (50)
	>35		1		1		2 (2.04)
II	Gender						
	Female	7	14	8	13	10	52 (53.06)
	Male	15	14	5	9	3	46 (46.94)
III	Marital Status						
	Married	12	14	5	5		36 (36.73)
	Unmarried	10	14	8	17	13	62 (63.27)
IV	Residential State						
	Arunachal Pradesh					3	3 (3.06)
	Assam		6	5	6		17 (17.35)
	Jammu & Kashmir		1				1 (1.02)
	Jharkhand			1			1 (1.02)
	Madhya Pradesh	1					1 (1.02)
	Maharashtra				1		1 (1.02)
	Manipur	9	13	4	6	5	37 (37.76)
	Meghalaya	7					7 (7.14)
	Mizoram				3	2	5 (5.1)
	Nagaland	2	1	3	6	3	15 (15.31)
	Sikkim	2					2 (2.04)
	Tripura		7				7 (7.14)
	West Bengal	1					1 (1.02)
V	Category						
	General	7	10	4	3	2	26 (26.53)
	OBC	2	7	3	3		15 (15.31)
	SC		1		1	1	3 (3.06)
	ST	13	10	6	15	10	54 (55.1)
VI	Family Background						
	Agriculture/Sericulture	11	17	6	9	8	51 (52.04)
	Non-Agriculture	11	11	7	13	5	47 (47.96)
VII	Annual Income (lakh)						
	<3	9	13	6	12	9	49 (50)
	3 to 5	13	13	7	9	4	46 (46.94)
	>5		2		1		3 (3.06)
VIII	Locality						
	Rural	11	22	7	12	7	59 (60.2)
	Urban	11	6	6	10	6	39 (39.8)
IX	Educational Status before PGDS						
	B.Sc.	21	21	6	12	9	69 (70.41)
	M.Sc.	1	7	7	10	4	29 (29.59)
X	Merit in PGDS (%)						
	<60 (C)	1			1		2 (2.04)
	60-70 (B)	7	1	4	10	2	24 (24.49)
	> 70 (A)	14	27	9	11	11	72 (73.47)
XI	Merit in Graduation (B.Sc./M.Sc.) (%)						
	<60 (C)	7	7	3	5	1	23 (23.47)
	60-70 (B)			3	5	1	9 (9.18)
	> 70 (A)	15	20	8	12	11	66 (67.35)

Note: Values within brackets in the last column indicate % to the total (n=98).

hailed from rural area having background of sericulture & agriculture, majority of the diploma holders were the graduates of Bachelor's degree (70 %) and found to have secured first class (>70 %) in their UG (B.Sc.) /PG (M.Sc.) programmes and even the same trend has been observed in Diploma. Students enrolled for PGDS programme belonged to different states of the country. More number of students were from Manipur (38 %) followed by Assam (17 %) and Nagaland (15 %). This clearly indicated the potentiality of PGDS course in providing wide range of opportunity to graduates to get expertise in sericulture cut across geographical regions of the country.

Regarding employment of PGDS graduates, 62 (63 %) graduates were employed and the rest of 37 % were found un-employed (Figure 1). Out of 62, 90 % of graduates were employed in Public sector undertakings and PGDS served as basic eligibility for employment of 65 per cent of the graduates. Majority of them are serving as extension officers in sericulture sector (81 %) (Table 2). Cent per cent of the graduates from Assam, Mizoram, Jammu & Kashmir, West Bengal, Jharkhand and Madhya Pradesh were employed (Figure 2), followed by Nagaland (73 %), Tripura (57 %), Sikkim (50 %), Manipur (48 %) and Arunachal Pradesh (33 %). This clearly reveals the potential of this course (graduates) in generation of jobs.

Table 2: Employment status of PGDS graduates of CSRTI-Berhampore (2013-17)

#	Particulars	2013	2014	2015	2016	2017	Total
I	Employed						
	Public or Govt. Sector	13	15	8	16	4	56 (90.32)
	Private	2		2	1	1	6 (9.68)
	Year of joining the job						
	2014	8			1	1	10 (16.13)
	2015	4	4	1	1		10 (16.13)
	2016	2	6	2	2		12 (19.35)
	2017	1	5	6	8		20 (32.26)
	2018		2	1	2	5	10 (16.13)
	Eligibility criteria for joining the job						
	BSc.	1	4	2	2	3	12 (19.35)
	MSc.		2	4	3	1	10 (16.13)
	PGDS	8	13	5	7	7	40 (64.52)
	Nature of job						
	Administration	4	5	2	4		15 (24.19)
	Extension	9	6	6	12	3	36 (58.06)
	Research & Training	1	2	1		1	5 (8.06)
	Others	1	2	1	1	1	6 (9.68)
II	Working in Sericulture sector						
	Yes	12	13	7	15	3	50 (80.65)
	No	3	2	3	2	2	12 (19.35)
	Employed: Yes (62; 63.26 %) & No (36; 36.74 %)						

Note: () indicates % value to the total (n=62)

The variables, such as eligibility degree, gender, age, family background, marital status, caste, merit in graduation/PGDS & skills were considered to know the association with employment of PGDS graduates, using Chi-square statistic (Table 4). The strength of association between the associated attributes was measured using contingency coefficient. The eligibility qualification (0.40), caste (0.33), teamwork skills (0.297), merit in graduation (0.29) & marital status (0.19) of the graduates were found significantly associated with employment at 5 % level. It revealed that these five attributes are crucial in obtaining jobs. Usually, a graduate having qualifications, such as desired degree, merit & technical skills are absorbed in any sector subjected to availability of vacancies. On the whole, the skill of PGDS graduates pertaining to communication, problem solving, computer literacy, team work and creativity were also recorded using the 3 point scale as average, good and excellent. Table 3 indicated that most of the graduates fall under the category of excellent & good (88 %) as perceived by the respondents themselves. This reflected that the PGDS graduates are trained even in acquiring soft skills which are crucial in obtaining jobs.

found to have significant association with employability, using Chi square test. The resultant logit regression is $Y = 0.005 + 6.261E + 8PGDS + 11.76 \text{ married} + 0.123OBC + 7.09ST + 30.40\text{rankB} + 13.71\text{rankA} + 18.57 \text{ good_TWS} + 297.88 \text{ excellent_TWS} + e$. The model was found to be the best fit with -2 log likelihood of 44.73, significant chi-square statistic, Nagelkerke R^2 of 0.68 and 87.80 % of correct classification between observed & predicted values.

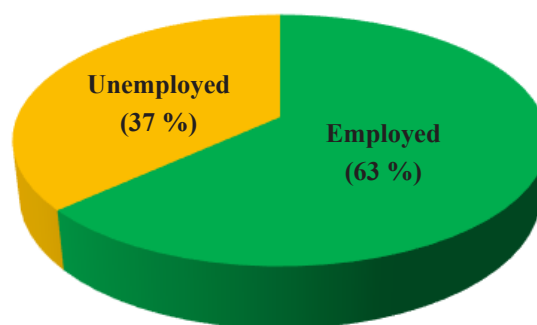


Figure 1: Employment status of PGDS graduates of CSRTI Berhampore (2013-2017)

Table 3: Skill status as perceived by PGDS graduates (2013-17)

Skill	Excellent	Good	Average
Communication (speaking & writing)	11	81	6
Problem solving (Assessing)	9	77	12
Teamwork (co-ordination & leading)	16	71	11
Creativity (new ideas during group work)	10	75	13
Computer or ICT (work execution)	8	72	18
Average	10.80 (11.02 %)	75.20 (76.73 %)	12.00 (12.24 %)

The probability of being employed was studied using logit model. The employment of PGDS graduates was considered as dependent variable and is a binary variable (Employed =1 and otherwise=0). The eligibility degree, category, marital status, merit in graduation and teamwork were considered as independent variables as they were

The employability of PGDS graduates was found to have significant association with marital status, caste, merit position in graduation and team work skills (Table 5). Considering exp (B) values, the employability of graduates was found 11 times higher in the case of married (age & girls) as compared to unmarried, 7 times

more in the case of schedule tribe compared to other categories, 14 times more with merit A in graduation than the rest, 30 times higher with merit B in graduation as compared to rank C and 294 times more among the graduates having excellent work skill than others & 18 times higher in the case of graduates with skill rated as good compared to those who are average skilled.

This clearly revealed that the success rate of employment of PGDS holders was higher in the case

of those possessing attributes, such as marriage, skill, caste reservation and academic achievements. It might be due to the existing Indian culture, wherein women get married earlier to male counterpart. Majority of the graduates who are employed belonged to female category and are married. They fall under ST reservation with merit of first class in all the degrees pursued by them. The similar kind of results were evident in the case of Bogdan *et al.*, 2016 and Tee *et al.*, 2019.

Table 4: Association of variables with PGDS graduates' employment (Yes =1 & No=0)

Variable	Details	Pearson's Chi. Square Stat	Co-efft. of Contingency (C)
Eligibility degree for job	Others = 0; PGDS = 1	18.43**	0.40**
Gender	Male = 0; Female = 1	0.32	0.06
Age	<30 = 0; >30 = 1	0.21	0.05
Marital status	Others = 0; Married = 1	3.60*	0.19*
Family background	Agric./Seri. = 1 Others = 0	1.04	0.10
Category	Gen. = 0; OBC = 1; SC = 2; ST = 3	12.05*	0.33**
Rank in graduation (%)	<60 = 0; 60-70 = 1;	8.95*	0.29*
Rank in PGDS (%)	>70 = 2	2.23	0.15
Communication skill		0.31	0.06
Problem solving skill	Fair = 0;	1.02	0.10
Team work skills	Good = 1;	9.48**	0.30**
Creativity skills	Excellent = 2	0.55	0.07
ICT Skills		2.06	0.14

Level of significance: * (P≤0.05); ** (P≤0.01)

The factors, such as less job vacancies in the State Department of Sericulture (especially in Manipur, Meghalaya, Nagaland and Tripura) and willingness of graduates to pursue higher studies were found to be the major factors responsible for unemployment (37 %). Out of 36 unemployed graduates, 21 graduates were self-employed connected to family business & farming, 6 were pursuing higher studies and 9 were found unemployed. This highlighted the fact that un-employment among PGDS holders was found to be minimum and might be due to their poor soft skills (regarding communication, leadership, ICT, task handling, creativity *etc.*) and poor academic performance. The same result was evidenced in the study of Tee *et al.* (2019) regarding employability of Chinese graduates.

During the study, the PGDS graduates were asked to offer suggestions to improve the employability of the course. The suggestions offered are summarised as below.

- **Encourage campus interviews:** Invite the business concerns (private/public) to campus to organize on-campus selection of candidates having expertise in the sericulture sector.

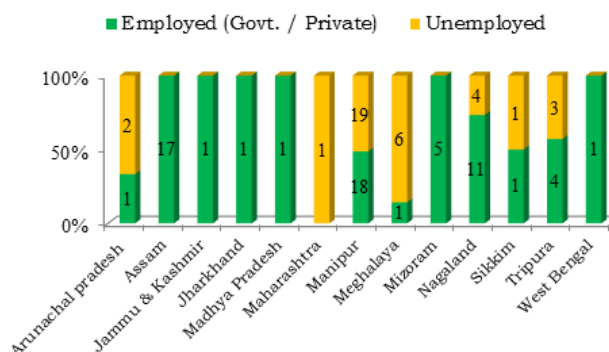


Figure 2: State-wise employment status of PGDS graduates of CSRTI Berhampore (2013-2017)

Table 5: Estimation of factors responsible for PGDS graduates' employment

Variable	Indicator	B (Estimates)	Std. Error	Prob. Z value	Exp (B)
Eligibility degree for job	PGDS = 1	19.567	2305.123	0.993	6.261E+8
Marital status	Married = 1	2.465	1.136	0.030*	11.760
	OBC = 1	-2.097	1.519	0.167	0.123
Category	SC = 2	-20.701	9529.826	0.998	0.000
	ST = 3	1.959	1.062	0.065	7.090
Rank in graduation	B (60-70 %) = 1	3.415	1.226	0.005**	30.403
	A (>70 %) = 2	2.618	1.128	0.020*	13.710
Team work skills	Good = 1	2.922	1.231	0.018*	18.576
	Excellent = 2	5.687	2.046	0.005**	294.883
Constant		-5.325	1.892	0.005**	0.005

Level of significance: * ($P \leq 0.05$); ** ($P \leq 0.01$); 2log likelihood = 44.73; chi-square = 57.11; probability (chi-square) = 0.00; Nagelkerke $R^2 = 0.683$; Correct classification % with predicted values = 87.80 %.

- **Job reservation for alma-maters/own graduates in CSB:** In most of the organizations or Institutes, some percentage of posts will be reserved for their alma-maters who have excelled in academics. Even in the CSB's recent recruitment, preference had been given to sericulture graduates. On similar lines, defined proportion of posts should be preferred for PGDS graduates.
- **Expansion of sericulture:** The extensive sericulture is anticipated to increase job opportunities not only in primary sector but also in secondary and tertiary sectors of the economy. Especially for aspiring graduates, it provides an opening to have their own start-ups (soil to silk).

Conclusion: The finding of the study indicated that the employability of sericulture PG diploma graduates was 63 % and majority of them are serving as extension officers in sericulture sector (81 %). The graduates belonging to Assam, Mizoram, Jammu & Kashmir, West Bengal, Jharkhand and Madhya Pradesh were employed cent per cent. The employability of PGDS graduates was found to have significant association with marital status, caste, merit in graduation and team work skills as indicated in the results of logit regression. Less job vacancies in the State Department of Sericulture (especially in Manipur, Meghalaya, Nagaland & Tripura) and graduates willing to pursue higher studies were accounted the major factors responsible for unemployment (37 %). Conduct of on-campus interviews and providing reservation for alma-maters in CSB recruitments emerged as the major suggestions by the graduates. The outcome of the study could be utilized by policy makers in formulation of effective policies having relevance on human capital formation related to sericulture sector.

REFERENCES

- Alibaygi A. H., Barani S. and Karamidehkordi E. (2013) Employability determinants of senior agricultural students in Iran. *J. Agric. Sci. Tech.*, **15** (4): 673-683.
- Anonymous (2019) *Annual Report*, Central Sericultural Research and Training Institute, Berhampore (2019-20), pp. 92-93.
- Anonymous (2020) *The National Silk Policy-2020*, Central Silk Board, Bangalore, pp. 1-66.
- Bogdan O., Richard P. and Raluca M. D. (2016) A logit model for the estimation of educational level influence on unemployment in Romania. *MPRA Paper No. 81719* (<https://mpra.ub.uni-muenchen.de/81719/>)
- Crossman J. and Clarke M. (2010) International Experience and graduate employability: Stakeholder perceptions on the connection. *High. Educ.*, **59** (5): 599-613.
- Gujarati N. D. (2003) *Basic Econometrics*, United States Military Academy, West point, p. 600.
- Julie A. and Helena M. (2006) *Employability for students*, Higher Education Academy Education Subject Center, Bristol, p. 6.
- Rajkumar P. (2011) Employability skills in Chennai Retail Market, India. *Acta Universitatis Danubius*, **7** (5): 16-30.
- Rangaswamy R. (2010) *A textbook of Agricultural Statistics*, New Age International Publishers, pp. 2-527.
- Tee P. K. (2019) Factors Influencing Employability of Chinese Graduates in Malaysia Upon Returning to China. *Asia Proceedings of Social Sciences*, **4** (1): 118-121.
- Teichler U. (2009) *Higher Education and the World of Work: Conceptual Frameworks, Comparative Perspectives, Empirical Findings*, Sense Publishers, B.V., pp. 21-309.
- York M. (2004) Employability in the Undergraduate Curriculum: Some Student Perspectives. *Eur. J. Educ.*, **39** (4): 409-427.

Annexure - I

1)	Name of PGDS graduate	:	
2)	Sex	:	a) Male [] b) Female []
3)	Marital status	:	a) Married [] b) Unmarried []
4)	Age	:	a) <30 [] b) 30-35 [] c) >35 []
5)	Religion	:	a) Hindu [] b) Muslim [] c) Christian []
6)	Caste	:	a) Gen [] b) OBC [] c) SC [] d) ST []
7)	Residential State & Contact Number	:	
8)	Family background	:	a) Agriculture/sericulture [] b) Non-Agri. []
9)	Educational status before joining to PGDS & marks obtained	:	a) B.Sc. [] b) M.Sc. [] & i) <60 [] ii) 60-70 [] iii) 71-80 [] iv) >80 []
10)	Year of joining PGDS	:	a) 2013 [] b) 2014 [] c) 2015 [] d) 2016 [] e) 2017 []
11)	Year of passing PGDS & Marks obtained (%)	:	a) 2014 [] b) 2015 [] c) 2016 [] d) 2017 [] e) 2018 [] i) <60 [] ii) 60-70 [] iii) 71-80 [] iv) >80 []
12)	Are you employed in	:	a) Public or Govt. [] b) Private [] c) Self [] d) Other []
13)	Designation & Address	:	
14)	When did you join to the job?	:	a) 2014 [] b) 2015 [] c) 2016 [] d) 2017 [] e) 2018 []
15)	Job eligibility criteria	:	a) B.Sc. [] b) M.Sc. [] c) PGDS []
16)	Nature of work	:	a) Admin. [] b) Extension [] c) Research & Training [] d) Others []
17)	Pay Scale [Rs.]	:	
18)	Annual Income [Lakh]	:	a) <3 lakhs [] b) 3-5 lakhs [] c) >5 lakhs []
19)	Are you working in sericulture sector	:	a) Yes [] b) No []
20)	If No, why [pl. mention]	:	
21)	Are you un-employed	:	a) Yes [] b) No []
22)	If yes, reason[s] is/are	:	a) Higher studies [] b) Not interested [] c) Lack of opportunity [] d) Low salary structure [] e) Others, if any mention _____
23)	How is your communication skill <i>wrt</i> reading and writing?	:	a) Excellent [] b) Good [] c) Average []
24)	How is your problem solving capacity <i>wrt</i> assess the situations and giving solutions?	:	a) Excellent [] b) Good [] c) Average []
25)	How is your teamwork <i>wrt</i> coordination and leading?	:	a) Excellent [] b) Good [] c) Average []
26)	How is your creativity <i>wrt</i> new ideas during group work?	:	a) Excellent [] b) Good [] c) Average []
27)	How is your computer / ICT skill <i>wrt</i> work execution?	:	a) Excellent [] b) Good [] c) Average []
28)	Offer one or two valid suggestions to improve the employability through PGDS course	:	a) _____ b) _____ c) _____



Report

FOREST INSECT INDUSTRY FOR LIVELIHOODS SUPPORT TO THE FOREST DEPENDENT PEOPLE AND ITS SIMULTANEOUS IMPACT ON COLLABORATIVE CONSERVATION OF TROPICAL FORESTS IN INDIA: AN ANALYSIS

Narendra Kumar Bhatia

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

ABSTRACT

In the growing literature at the interface of the topics *viz.*, rural livelihood improvement of forest dependent people and conservation of natural forests in India, two contesting issues stand out: (1) How and to what extent joint forest management (JFM), being people-centric, principal forest management strategy in India do contribute to forest conservation and poverty alleviation, and (2) Why and how adoption of a multi-agency linked collaborative forest management (CFM) system can be a better strategy to reassure the delivery of livelihood functions of the forests to their dependents and concomitantly foster its impact on collaborative forest conservation in India. This article summarizes and evaluates these domains of thought and discuss why and how Forest Insect Industry can be a better livelihood option or a long lasting solution for livelihood support to the forest dependent people and simultaneously contribute towards collaborative conservation of their tropical forests in India.

Key words: Biodiversity, forest dependent people, forest insect enterprise, institutional linkage, joint forest management, poverty.

1. INTRODUCTION

Poverty is the biggest of all the problems and its alleviation is the greatest challenge for all developing countries. India is a nation with over 330 million poor people¹ (Thampi, 2012), a number that has barely declined over last three decades of development. Recent estimate indicates that out of the total population living in the rural parts of all States and Union Territories of India, 25.7 per cent is living below the poverty line (Sharma, 2019). India is also the home to the largest number of the hungry people in the world, ranking 94th out of 107 countries in 2020 (Global Hunger Index, 2020); and

despite a strong economic growth, the latest GHI (27.2) still remains more or less near to that of 1996 (22.6).

Forests in India play a crucial role to support livelihood activities of 833 million rural people by one way or other, but for about 200 million² people who exclusively live in 1.73 lakh fringe villages³, forests are the only source for their livelihood (Nayak *et al.*, 2012). From 1850 to 1920, as much as 33 million ha of forest was cleared (Williams, 2002), but even today, forest with 7,12,249 sq km covering 21.67 % of the total geographical area is still the second largest land use in India (FSI, 2019). High population density of India *i.e.*, 382 person/km²,

is twelve times higher than that of the USA and per capita forest availability (0.057 ha) is 11 times lower than the world average (0.64 ha) (Census, 2011; ICFRE, 2012). Moreover, India with 2.5 % of world's geographical area, supports 16 % of the world's population and 18 % cattle population of the world (ICFRE, 2012). Therefore, there is a tremendous human and cattle⁴ pressure on the Indian forest.

Further, 59.72 per cent (412,625 km²) of the total forest in India is distributed in 188 tribal districts where poverty is more than 50 % (FSI, 2009). Eighty four per cent of India's tribal and ethnic minorities live in forested areas, where natural, physical, social, and human capitals are very low (Mehta and Shah, 2003). Studies have shown that majority of forest dependent regions in India are poverty ridden (Shah and Guru, 2004), and one such study indicated that fifteen out of the twenty poorest regions in India remained in the list of poorest region right from 1983 to 2000 (Shah, 2010).

On the other hand, recent data of International Monetary Fund (IMF) shows that India overtakes Japan to become third-largest economy in purchasing power parity (PPP) in 2011 after US and China (Banerji and Shah, 2012). Moreover, a US based intelligence report released in December 2012 predicted that by 2030, surging India would straddle global commerce and will dominate the world economy. However, report also cautions that existing inequalities between rural and urban sectors would further widen due to infrastructural and educational deficiencies (NIC, 2012). In India, youth bulges are very high and in next 10-15 years, the country will be challenged very high to find jobs for its large youth population. Unfortunately, rural development strategies often neglect forests because they are mistakenly viewed as being outside the mainstream of agricultural development (UNEP, 2011).

In India, poverty in forested area is a natural phenomenon and if forests are not managed properly to generate additional income in addition to what people are getting

now from collection of traditional non-timber forest products (NTFPs), the forest dependent people will be forced to leave their forest and family behind to find modern livelihood avenues in urban areas that will put an extreme pressure on families who are bound to be separated by economic forces. Secondly, forests may lose their sheer, shine and significance due to discriminate logging by non-forestry people in lack of local resistance. These compelling situations of Indian forest, its people, and their state of incessant poverty have forced forest managers to find out ways and means to increase economic return from unit area of the forest.

This paper deals with the state, scale, and constraints of the Joint Forest Management (JFM) in India, which is in vogue since two decades and now, is losing its credibility in several parts of the country. Paper also elaborates why and how multiagency linked collaborative forest management (CFM) system should be prioritised in place of JFM to realise incentive linked conservation practices with involvement of forest dependent people in India. This study underlines the significance of small and medium forest-based enterprises (SMFEs) and focuses on the emerging role of Forest Insect Industry (FII) in livelihood security and forest management. This paper explains how these arguments can be considered to accommodate India specific viable FII in CFM for poverty alleviation in forested area. Some questions are also raised about true potential of NTFPs in poverty alleviation and forest conservation. The paper concludes with a recommendation to convert people-centric JFM system of India into a multiagency linked CFM practice and proposes to link forest insect industry as a viable livelihood component in such adoptive model of CFM to alleviate poverty in forested area and concomitantly foster its impact on conservation of terrestrial biodiversity. Arguments in this communication are intended to provide forest managers and policy-makers with necessary inputs to consider Forest Insect Industry as amiable commercial vehicle in CFM and pursue the different stakeholders to contribute their full institutional strength to implement an incentive linked forest management strategy in India.

2. Participatory forest management and its livelihood delivery

The poor are said to rely on forests to maintain their well-being (Byron and Arnold, 1999) and in some cases, it serves as a source of income improvement (Ruiz-Perez *et al.*, 2004). Poor people living in and around the forests are the ones who are most dependent on forests for their livelihood and forests have both, potentials and limitations with regard to poverty alleviation capabilities (Angelsen and Wunder, 2003). High incidence of poverty in forested areas and high dependency of the poor on forests, suggest a leading role for forestry in poverty eradication (FAO, 2012 a). Forest can help in poverty mitigation and avoidance by serving as source of subsistence, seasonal employment opportunity, and safety nets (Sunderlin *et al.*, 2005).

Community forestry is a crucial institutional vehicle for assuring and improving the livelihood benefits of forests (Sunderlin *et al.*, 2003). Governments around the world are decentralizing their environmental policy (Agrawal *et al.*, 2006) to reflect the current international trend of participatory forest management (Dove 1995; Victor *et al.*, 1998; Arnold 2001). Nearly every central government in Latin America, sub-Saharan Africa, South and Southeast Asia claims to have decentralized the governance of forests and wildlife (Agrawal, 2004).

2.1 Joint Forest Management (JFM): its state, scale, and constraints in India

Consequent upon some innovative experiments in society's involvement in forest management, models for participatory forest management have been evolving in India since 1980s. National forest policy, 1988 (MoEF, 1988) and its subsequent resolutions emphasised the need for people's participation in protection and management of forest in India, and on 1 June 1990, the concept of JFM was implemented. Ministry of Environment and Forest, Govt. of India issued further guidelines in February 2000, which inter-alia included uniform nomenclature and legal backup to the Joint forest management committees⁵

(JFMCs) along with extension of JFMCs to good forest area with focus on management of NTFPs. Another set of guidelines were issued in December 2002 on setting up conflict resolution mechanism with Gram panchayat and Panchayati Raj Institution (PRI⁶) to ensure their support in forest management (ICFRE, 2012).

JFM regime evolved gradually in India and after a slow start with 4 million ha in 17 states during 1998, it now involves 22 million participants under 106479 JFMCs in 28 states that are managing 22.02 million ha forest (Planning Commission, 2011). Presently, State forest department (SFD) solely administer sixty-five per cent of the total forests, while remaining twenty-seven per cent are being managed by JFMCs (Thampi, 2012). From 2006, there has been a downward correction in the number of registered JFMCs and their forest area under management (ICFRE, 2012). JFM as a policy, prevents commercial exploitation of forest for industry purposes and makes provisions to substantiate the subsistence requirement of the local people by giving high priority to environmental security. Under JFM, State forest department has nominal responsibility; however, local people share both, the management responsibility of degraded forest, and the benefits out of their management activity. JFM in different states are governed differently.

2.2 Why efficiency of JFM is reducing in India?

JFM is now losing its shine and currency in India, and years after its purposive implementation, it is now debated that JFM has been failing to live up to the expectation of people due to not accommodating the democratic representation of the local people at various level of decision-making, and rather JFM has been reducing decision-making role of the communities (Sarin *et al.*, 2003). Second, the views of local community are kept aside or often excluded in decision-making processes, and the failure to recognize the legitimate interests of forest dependent people leads to conflicts that harm the long-term goal of JFM. Third, it is also argued that JFM fell into a trap of project-mode implementation to lure

international funding and external assistance to support large JFM projects (Nayak, 2002). Fourth, in most of the states, JFM program is extremely dependent on government funding that raise many serious questions about its sustainability (Thampi, 2012). Fifth, there are government initiatives that provide a legal basis for participatory forestry, but the absence of a law recognising the management rights of the communities heighten their level of insecurity (Fisher, 2011). Sixth, participation of JFMCs in forest protection and management in India depends on government's call (Thampi, 2012) and, seventh, many believe that JFM itself is not sufficient to address the complex and multi-dimensional nature of poverty among forest communities (MoEF, 2006). However, in spite of all these shortcomings, JFM being people-centric conservation efforts, is the principal forest management strategy in India today. But the challenge is now, how to empower the local communities to ensure that potential benefits from forest conservation accrue to them?

Conservation and livelihood are often found to be of contradicting goals and pose divergent problems. There is a conflict between conservation policies set by the state and the right of the people (Moeliono, 2006). Local community's perception of problems of natural resource management and their priority is different from that of the external development agencies (Matta and Alavalapati, 2006). Moreover, forests are complex, both as ecosystems and resources of diverse needs of the society and different stakeholders have different priorities and perceptions about forest management. Some have direct dependency on forests for fuel, food, fodder, medicines and building materials *etc* or simply as a source of income, while others are interested in conservation, because forests provide ecosystem services. Therefore, to fulfil the diverse needs of the society, we need divergent people to manage the forest. There has been some paradigm shift in forest management, now forest preservation has changed to a mode of sustainable utilisation of forest, and state controlled forest management is shifting towards shared

forest management with involvement of communities and other stakeholders.

3. Why collaborative forest management (CFM) should be prioritized over JFM?

The question is whether poverty in poor region is high due to the social identity of its people being tribal and marginalised or whether poverty is more due to their forest dependency and physical isolation from the main land. This question was analysed in a case study of southern Orissa, one of the poorest regions of India, and it was found that the forest-based nature stands more of a significant reason than its tribal characteristics (Shah, 2010). Forest-based economic initiatives at local-level requires technical and institutional innovations for local capacity building up, so as to manage resources sustainably through income generating activities (FAO, 2011). In forest areas, massive demographic and land-use shifts are taking place because of migration, population growth, and urbanization. Therefore, for making living in the fast changing world, forest dependent people would require adoptive learning and multi-agency collaboration as a way to deal with uncertainty and complexity by sharing management power and responsibility (Fisher *et al.*, 2007). Now, collaboration has taken root in national forest planning to provide expanded opportunities for stakeholder participation (Cheng and Mattor, 2006).

CFM is a partnership for natural resource management, involving local people as main stakeholders (Borrini-Feyerabend *et al.*, 2004). According to Carter *et al.* (2003); Recognition by local people that forests are being degraded and their willingness to involve with forest authorities are the *prerequisites* of CFM; Creating a workable partnership between key stakeholders to manage the forest is the basic *concept* of CFM; Ensuring sustainable use of forest resources to improve livelihood of involved people and to increase forest cover by expanding their participation are the *goals* for CFM, and; Increased awareness of participating agencies, adoptive planning, availability of service provider, collective conflict resolution, possibility of innovative adoption,

collective approach and changed attitude of the local people and participating agencies are the *essence* of CFM. In addition, to make CFM a success, exchange of ideas and information between user groups and the government counterparts that provide technical support and advice is essential (Tesfaye *et al.*, 2012).

Integration of different institutions with local community can better identify the hidden livelihood opportunity in different forest areas and their viable linkages can increase the confidence of local people by changing their attitude towards forest management. Attitude, which means the evaluative dimension of a concept (Ajzen and Fishbein, 1977), is the major antecedent of people's behaviour in relation to natural resources management (Tesfaye *et al.*, 2012). In many studies, positive attitude of the local people correlated to their perception of benefits and costs in the context of community linked conservation efforts in Nepal (Mehta and Heinen, 2001) and India (Matta and Alavalapati, 2006). CFM is a dynamic approach for sustainable and equitable forest management that works in partnership with all stakeholders. Its transparent decision-making processes and judicious human and natural resource utilisation ensure diverse interests of many forest users.

Government policy initiatives to reduce poverty in forested area can be better realized through CFM, because it accommodates institutional linkages for multi governance to achieve better delivery of livelihood function of forest to their dependents. However, in contrary to CFM, JFM does not support a democratic way of work execution and depends largely on unilateral decisions of the state forest department (SFD). Secondly, it is mostly the degraded forests, which are designed for the local communities in a trend of "little trees for little people" (Warner, 2007) and do not provide any economic benefits to the forest communities or necessitates much effort to achieve it. Moreover, given the wide variation in resource position as well as in culture and terrains of the forest areas, community involvement in forest management is necessarily location-specific, so emphasis must be on carrying forward such programmes that are

locally rooted and have worked well in the past (Planning Commission, 2012).

Many governments in developing countries have prioritized CFM over traditional forest management systems (Abdus Salam *et al.*, 2006). Collaborations can also be legally mandated, *e.g.* National forest management act of United State requires involvement of public in all phases of forest planning (Selin and Chavez, 1995). However, enabling community participation in forest management and planning is a complex undertaking, it is complex because participation of local community unfolds a dense context of social, economic, political and cultural institutions and arrangements (Agrawal *et al.*, 2006).

4. Why and how small and medium forest-based enterprises (SMFEs) should be integrated with CFM to alleviate poverty?

NTFPs are natural products of SMFEs that serve a complementary role in household economy of poorer groups within the community (Falconer 1990; Arnold and Ruiz-Perez, 1998) and their roles become more critical when other incomes are low. There is a strong link between poverty and dependence on NTFPs, and since NTFPs diversify the income sources of poor people, they are more important for low-income groups than to high-income people (Jodha 1986; Hecht *et al.*, 1988; Pimentel *et al.*, 1997). Further, NTFPs production rarely competes with important agricultural activities, because they are usually collected in lean period when labour requirement for agriculture is comparatively low (Belcher and Kusters, 2004). Benefits of the SMFEs not only accrue to its gatherers, but intermediaries are also benefited through different market linkages. Neuman and Hirsch (2000) elaborated three main reasons why SMFEs can be an important economic strategy for poor people: One, it requires low capital investment; two, tropical forests that are the most important supplier of NTFPs are often occupied by the poorest segments of the society; and three, in most cases, those forest dwellers do not have any alternative sources of income. In most of the developing

countries, SMFEs employ millions of the poor people that often make 80-90 per cent of the total enterprise numbers and creates more than 50 per cent of forest-related jobs (Hobley, 2008). NTFPs provide about 40 % of the total forest revenues and share 55 % of the total forest based employment in forested area (Prasad, 2006). According to an estimate, women and children gather 67 % and 13 % of the total NTFPs, respectively that provides 20-24 % of their total household income (Thampi, 2012).

SMFEs play a critical role in community forestry and offer high potential for poverty reduction than large forestry industries. Even though throughout the world, SMFEs have been both overlooked and poorly regulated by governments and despite to growing importance of NTFPs in poverty reduction, there is no institutional mechanism that has the approach, reach or the capacity to take a long-term view of the sector (FAO, 2012 a). Moreover, SMFEs seldom assume a priority in forestry sector or in economic development policies (MacQueen, 2008). What the primary gatherers of NTFPs are getting today, is a very small fraction of the total potential value embedded in NTFPs (Planning Commission, 2012).

The NTFPs sector is suffering from a host of problems, such as poor returns to its gatherers, market distortions, low technology, and institutional inadequacy (Thampi, 2012). Inappropriate policies have not only led to over-exploitation of species in the wild, but have also reduced the benefits and generated new forms of inequality. Existing NTFPs legislation and policies is a complex and confusing mix of measures developed over a long period with poor coherence and coordination (FAO, 2011). Further, recent studies on NTFPs harvest and trade have suggested that NTFPs as a major source of income can be a little bit problematic business and the prominent reasons cited for, are: markets are frequently unstable (Padoch, 1992); both locally and regionally, trade is often controlled by the elite (Ribot, 2000); access to NTFPs is socially mediated and inequitable (Kumar, 2002); most NTFPs occur at low densities (LaFrankie, 1994); their potential for trade is usually low with only a few species being traded (Saw *et al.*, 1991); NTFPs

collection suppresses forest regeneration (Momberg *et al.*, 2000); and have more adverse ecological effects than expected (Padoch, 1992) and also fetches low economic returns (Godoy *et al.*, 1995). Therefore, to derive potential livelihood functions of commercial NTFPs, integration of multiple agencies to manage forest resources is a crucial requirement.

Sustainable SMFEs can bring about positive economic, social, and environmental impacts by making significant contribution to economic development (FAO, 2011). Some major characteristics of SMFEs include; by nature, they are location specific, so their adoption should be based on the availability of resource, labour, and markets; these seasonal enterprises are mostly small, often household-based, and predominantly rural and use simple technologies that require more labour but low capital investment; SMFEs are easily accessible to low-income and socially disadvantaged groups of people, especially women and provide an impetus to the local economy; SMFEs have certain micro-economic characteristics that generate a 'multiplier effect' to increase its economic benefits in rural economies by promoting domestic consumptions that improve terms of trade (Elson, 2010); many rural people who develop SMFEs may eventually use their surplus income for better health and education besides increased participation in social and political activities. Communities that grow economically tend to be more active in political decision-making.

5. Forest insect industry (FII) and its emerging role in poverty alleviation and forest management

In recent years, numerous actions for sustainable exploitation of forest resources have been undertaken (Muafor *et al.*, 2012), but only a few actions deal with commercialisation of forest insect (De Foliart, 1992). Most studies on tropical forest insects focus on their distribution, abundance and the environmental goods and services they provide to humans (Barbault, 1995; Hunter, 1999). Many people and some forest managers still consider insects mainly as a pest; however, they tend a bit less aware of the poverty alleviation potential of commercial forest

insects. Forest insect industry (FII) is a labour-intensive activity to achieve significant socio-economical benefits and does not require any major capital investment or land ownership. FII is more suitable for women and children living in forest fringe areas and in the buffer zones around protected forests. Several tree based insect products *viz.*, silk, honey, wax, lac, dyes, manna, *etc.* can be linked and commercialised with forest conservation activities in many developing countries to provide livelihood services of different economic scales to forest dependent people, even in deep tribal helmet.

Many forest insects are popular foods in different cultures all over the world, but only a few are commercialized (de Beer and McDermott, 1996). Moreover, women and children mostly collect all the insects consumed by humans from forest (FAO, 2012 b). In Sub-Saharan Africa, edible insects and their trades make significant contribution to the livelihood earnings of many forest dependent people (Vantomme *et al.*, 2004). The most commonly eaten forms of insects are larvae and pupae and about 1700 insect species are reported to be used as human food (Johnson, 2010). Coleopterans, Hymenopterans, Orthopterans and Lepidopterans account for more than eighty per cent of the total edible forest insect species, worldwide (Ramos-Elorduy *et al.*, 1997). Apart from the contribution of forest insects in food security, investigations have indicated that they contribute significantly to livelihoods earnings in both rural and urban areas (Stack *et al.*, 2003). Forest insect collection, their processing, transporting and marketing provides many business opportunities to an undetermined number of poor people around the world (Johnson, 2010). In Central Africa, caterpillar of *Imbrasia* species that feeds on the leaves of sapele tree, *Entandrophragma cylindricum* are dried and sold for up to US\$14 per kg (Vantomme *et al.*, 2004).

In southwest Cameroon, many forest dwellers are engaged in commercial beetle collection from different forest trees *viz.*, *Vernonia amygdalina* Delile, *Vernonia conferta* Benth, *Carapa grandifolia* Sprague and *Nobotonia mannii* Benth and are earning a complementary household income by beetles trading

through intermediaries led marketing chain, which are further exported to Europe, Asia and America, through internet business negotiations. Among all forest beetles, white forms of *Goliathus goliatus*, *Fornasiero spartacus* and blue *Stephenocrates preussi* are the most expensive specimens that attract very high pricing. Forest beetle collection has a nominal impact on forests insect ecology, because most often they are collected on a very small scale (Muafor *et al.*, 2012).

Further, in Papua New Guinea (PNG), the Queen Alexandra's birdwing butterfly (*Ornithoptera alexandrae*) is exploited for the rural household income. The Papua New Guinean government has created an Insect Farming and Trading Agency (IFTA) that controls its conservation and trading and assures livelihood delivery of this forest insect to the local people. The caterpillars of birdwing butterfly feed only on *Aristolochia diehlsiana* vines found in lowland rainforest of northern PNG. Dead specimens in good condition command more than US\$2000. IFTA's yearly sales is about US\$400,000 worth of insects to collectors, scientists, and artists around the world and generates substantial livelihood earnings for the poor people. In PNG, the Queen Alexandra's bird wing butterfly has acted as a flagship insect species for forest conservation and has been attracting external funding for maintenance and establishment of forest reserves. In PNG, the local people have now learned the significance of maintaining the forests to increase their household incomes (Cranston, 2009) and have generated a viable model of participatory forest management through FII.

The mopane worms (MWs), or edible larvae of Saturniid moth, *Imbrasis beilina* are another forest insect species of mopane woodland in the southern Zimbabwe, Botswana, and the northern Transvaal, which is collected from *Colophospermum mopane* tree to supplement the income of forest dependent people (Bradley and Dewes, 1993). Stack *et al.*, 2003 analysed the livelihood function of MWs in Southern Africa and found that that all categories of households in Zimbabwe, except religious groups, takes advantage of MW collection as a free forest resource. Normally, MWs are collected by women and are used as food or sold for cash income to

pay school fees or to purchase small items like kitchen utensils and clothing. Their livelihood analysis suggested the need for a technical and institutional innovation in mopane harvesting and trading to maximise its poverty reducing efficiency in different forest areas of Africa.

In Java, Indonesia, larvae and pupae of Asian weaver ant, *Oecophylla smaragdina* (Hymenoptera: Formicidae), which is called 'Kroto', is collected by the poor people from *Archidendron pauciflorum*, *Artocarpus* spp., *Mangifera indica*, *Lansium domesticum*, *Nephelium* spp., *Syzygium aqueum*, *Tectona grandis*, etc. throughout the year for additional income. Kroto is used as songbird food and fishing bait, and in Jakarta, which is the main outlet for kroto in West Java, about 100 kg of kroto are sold every day (Holldobler, 1983). In Thailand and Philippines, larvae and pupae of *O. smaragdina* ants are eaten (Cesard, 2004) and in Bastar region of Chhattisgarh, India, its larvae are used as medicine for treatment of rheumatism and stomach infections (Oudhia, 1998). In addition to livelihood and medicinal function, *O. smaragdina* is also used as a natural control agent against insect pests of many tropical crops. Commercial collection of *O. smaragdina* does not affect its species richness in the natural forest, because ants have a quick population recovery that is normally completed in 17-24 days (Paimin and Paimin, 2001).

Further, in northeast Thailand, around 3000 poor families are engaged in rearing of house crickets, *Acheta domesticus*, as a sideline business activity, which is providing an year round income of US\$130 to US\$1600 a month per family. Farmed crickets are exported to cricket-consuming nations like Laos and Cambodia and are sold in city markets of Bangkok to earn livelihood by poor people (Johnson, 2010).

In addition, bamboo borer caterpillar, *Omphisa fuscidentalis*; sago grubs, *Rhynchophorus ferrugineus*; grasshoppers, *Acridium* spp.; dung beetles, *Heliocopris bucephalus*; vespa wasps, *Vespa* spp.; silkworm species viz., *Samia cynthia*, *Antheraea proylei*, *A. assama* etc. are

the other important forest insects, which are collected by poor for food or for trade to earn cash income in different world regions. Location specific Forest Insect Industries can safely be integrated with CFM as a livelihood component to alleviate poverty in many developing countries.

6. India specific forest insect industry and their livelihood delivery under CFM

Commercial forest insects and their products have been traditionally associated with many tribal communities in India as a part time livelihood activity that provides a substantial source of seasonal earnings for many people in forested area. However, throughout India, forest insect industry has neither been linked with any large-scale forest management activity nor it has been tried as a forest conservation strategy to reduce poverty in forested area. Moreover, most of the forest managers don't take required steps about manipulation of forest vegetation or harvest practices to maximize or sustain the population of forest insect to derive their livelihood function.

State forest department (SFD) may take initiatives to link FII with forest dependent communities along with different institutional linkages to devise a workable model of adoptive collaborative forest management system. Forest managers can choose FII as one of the strategic priorities to increase contribution of forest to improve earnings of poor people in forested area and concomitantly foster its impact on shared forest management. In addition, owing to inconsistent livelihood delivery of many traditional NTFPs in India, FII can be a better livelihood option rather than sole reliance on NTFPs and commercialization of forest-based insect enterprises can add employment opportunities for bulging youth population in rural India, especially hilly inhabitation in Himalayas.

Among many forest insects, wild silkworms, forest honeybees, and lac insects have great promise in CFM. A brief account on how these FIIs can be a beneficial adaptation in various geographical regions of India is provided as under:

6.1. Integration of forest based sericulture (FBS) with CFM to reduce poverty in forest area

Natural Silk, a protein fibre drawn out of silkworm cocoon marks class and excellence to rich people but for poor families who rear the silkworms and the reelers and weavers who finish it into eco-friendly textiles, silk means - a natural source of livelihood. According to Yokoyama (1963), the term, "Sericulture" is used to denote both the industry concerned with silkworm rearing and the science, which provides technical basis for the industry. Commercial silk producing insects of order Lepidoptera are classified into mulberry and non-mulberry section. In India, non-mulberry or wild silk is called *Vanya* Silk that includes tropical tasar or Indian tasar silkworm, *Antheraea mylitta* Drury, temperate oak tasar silkworm, *Antheraea proylei* J., muga silkworm, *Antheraea assama* Ww and wild eri silkworm, *Samia cynthia* Drury. All the *Vanya* silkworm species are polyphagous where tasar and muga silkworms are reared outdoor on different forest tree species, but mulberry and eri silkworms are reared indoor. India, owing to immense climatic diversity coupled with wide-ranging ecological habitats, produces all the five varieties of silk, where tropical tasar and muga silkworms are prerogative to India (Jolly *et al.*, 1979). Geographically, Asia is the main producer of silk that shares over 95 % of the total global output.

Among all Forest Insect Industries in India, forest-based sericulture is the largest human-insect interaction in terms of associated insect and forest tree species and number of poor families linked with and the forest area that it relates. Silkworm larvae are reared or grown naturally in an ecological interaction on different forest trees in or outside the natural forest. Production process of FBS is divided into pre and post-cocoon sectors. Pre-cocoon sector is forest-based and on-farm activity dealing with the protection and management of the forest host tree species for silkworm-rearing activity to produce cocoons for raw silk production, whereas reeling, spinning (yarn production from cocoon), and weaving comprise the post-cocoon and off-farm activity. On the demand and supply front, India is the second largest producer of silk in the world next to China (68600 MT) and shares

32.83 % (35820 MT) of the global raw silk production (109111 MT) (ISC, 2021). The global silk market is projected to be valued at USD 16.94 billion by 2021, at a compound annual growth rate (CAGR) of 7.8 % from 2016 to 2021, but the country continues to import no less than 6,000 Tonnes of silk every year from China (The Hindu, 2017). In 2018-19, mulberry silk contributed 70.46 % (25,239 MT) and Vanya silk, 29.54 % (10,581 MT) of the total raw silk production (CSB, 2020). Among different vanya silks varieties, eri, tasar and muga silkworms accounted for 68.1 % (7204 MT), 29.65 % (3136.40 MT), and 2.27 % (240.50 MT), respectively. In comparison to 2018-19, the highest growth of 5.22 % (155.8 MT) was recorded in tasar sector, followed by 4.26 % (294.4 MT) in eri, and 3.04 % (7.1 MT) in muga silk sector during 2019-20 and the overall progress of vanya silk was 4.52 % (457.30 MT) during the last year. Projected growth of raw silk production in India is about 4.5 % for 2010-2015 and 5.0 % for 2015-20 and domestic demand is expected to grow by 3.5 % and 4.0 % during the corresponding period (NFP, 2011).

In India, FBS can be an ideal livelihood avenue for forest dwellers due to its low gestation and high economic return feature and can provide vibrancy to rural economy by satisfying the equity concern of tribal women in their society (CSB, 2012). However, shrinkage of forest property in wake of man induced destructive proportion of utilizing natural resources has slowly been paralyzing the efficiency of several nature based man's occupation, and Forest Insect Industry (FII) is not an exception. Efficiency of FBS can be enhanced by training the forest communities in skills necessary for scientific rearing of different forest silkworm species. State Forest Department can link JFMCs with State Department of Sericulture (DOS) for transfer of technology (ToT) and to seek other extension support and; Central Silk Board (CSB⁷) for location specific R&D, extending training support through Regional Training and Research Stations (RTRS) and supply of silkworm seed through National Silkworm Seed Organization (NSSO) of CSB that manages seed production and co-ordinate silkworm

seed demand and supply at national level. Involvement of credible NGOs is also necessary to ensure fair marketing of cocoon or finished yarn on competitive prices through viable market linkages; because, in Vanya Silk Sector, there is no competitive marketing like mulberry sector, and State operated marketing agencies are some time blamed for institutional corruptions. Therefore, SFD, DOS, CSB, and NGOs can work together as a coherent entity to promote an effective model of CFM for unified goal of managing the forest for well-being of the poor people in forest areas of the country.

Relevant details of potential forest silkworm species are discussed below.

6.1.1. Tropical tasar silkworm, *A. mylitta* Drury

Forest rearing of *A. mylitta* D. uniquely suits to the forest dwellers in India and being a treasured tradition, it constitutes a way of tribal's life in tropical forest area of Bihar, Jharkhand, Chhattisgarh, Madhya Pradesh, Orissa and touching the fringes of West Bengal, Andhra Pradesh, Uttar Pradesh and Maharashtra (CSB, 2012). *Antheraea* species have built up different forms of ecological population called eco race in all tropical moist deciduous, semi evergreens, dry deciduous and tropical dry deciduous forests in India (Rao, 2001) and 64 ecoraces have been recorded (Rao *et al.*, 2003). Among different ecoraces, Daba of Chota Nagpur plateau in eastern India, Raily of district Bastar in Chhattisgarh state, Sukinda and Bogai of Odisha, Sarihan and Laria of Jharkhand, Bhandara of Maharashtra and Andhra local in Andhra Pradesh are the important commercial ecoraces of *A. mylitta* D. (Rao *et al.*, 2003).

In nature, *A. mylitta* D. is found on 45 different forest tree species being primary, secondary, and tertiary host tree species. However, *Shorea robusta* Roxb., *Terminalia arjuna* Bedd., *T. tomentosa* W.&A., *Lagerstroemia parviflora* Roxb., *L. speciosa* Pers., *T. chebula* Retz., *T. belerica* Gaertn. and *Anogeissus latifolia* Wall. are the main host tree species (Suryanarayana *et al.*, 2005) that are distributed in tropical and sub tropical forests of

India. Egg, larva, pupa, and adult are the four stages of *A. mylitta* D. Larval period varies from 30-35 days in first crop (July-Aug), 40-45 days in second crop (Sept-Oct), and 50- 60 days in third crop (Nov-Jan). In addition to forest rearing, *A. mylitta* D. also thrive naturally and tribal people collect cocoons in January when they are easily seen on leafless trees. One family can at least earn ₹13000 per annum through cultivation of tropical tasar silkworm in the forest (MoEF, 2004), and if integrated package of rearing is followed, this earning can be increased to ₹21937 (Srivastav and Thangavelu, 2005). *A. mylitta* D. produces high quality natural silk that has some peerless qualities *viz.*, controlling blood cholesterol, antibacterial functions, and UV absorption properties (Akai, 1998). Huge availability of Vanya silkworm's host trees (131.48 lakh ha) and large number of associated tribal families (2.35 lakh) can provide an effective base for community based CFM in India, however, presently, 95 % of the total forest tasar flora (11.16 m ha) is still unexploited in India (Ojha and Panday, 2004), which constitute a huge scope for tropical tasar linked CFM in India.

6.1.2. Temperate oak tasar silkworm, *A. proylei* J.

Temperate oak tasar silkworms, *A. proylei* J., *A. frithi*, and *A. compta* that feed on different species of oak *viz.*, *Quercus serrata*, *Q. dealbata*, *Q. griffithii*, *Q. incana*, *Q. himalayana* and *Q. semecarpifolia* (Singh and Singh, 1998) produce finer variety of tasar silk. In India, oak tasar silkworm rearing started in 1970s, when *A. proylei* J. was evolved by crossing *A. roylei* of India and *A. pernyi* of China. Oak forests (2.5 m ha) in India are distributed along the western sub-Himalayan range at 700-1500 m in Uttarakhand, Himachal Pradesh, Jammu and Kashmir, West Bengal, Manipur, Meghalaya, Sikkim, Assam, Arunachal Pradesh, Mizoram and Nagaland (Jolly, 1970), but only 1 % of the total oak forests are being used for rearing of oak tasar silkworms (Singh and Mishra, 2003).

In north-eastern states of India, rearing of oak silkworm is the major Forest Insect Industry that play a crucial role in its rural economy (Unni *et al.*, 2009) and on an average, a farmer gets ₹4598.00 per annum

(Kant *et al.*, 2004). Paucity of superior quality silkworm seed and lack of adequate extension support are the main constraint for development of oak tasar in India that is still in infancy and hence, requires some concrete actions from SFD to link forest dwellers with DOS, CSB, and credible NGOs to increase its commercial viability. Oak dominating forests in India can generate livelihood opportunity for 1.5 lakh poor people and thus arrest their migration from sub Himalayan region.

6.1.3 Muga silkworm, *A. assama* Ww.

A. assama Ww. is a semi domesticated multivoltine forest silkworm species endemic to north-east India and Indo-Burma region (Ahmed *et al.*, 1998; Hazarika *et al.* 1998). Muga silkworms produce attractive golden hue silk that is famous for its lustre, UV resistance, and tensile strength properties. After *A. yamamai*, the Japanese tasar silkworm, muga silk is the second most expensive silk in the world. In the entire world, muga silkworms are confined only to the natural forest in Brahmaputra valley of Assam and foothills of east Meghalaya and about 30000 families are engaged in muga culture. Primary host trees of *A. assama* Ww. include *Litsea polyantha*, *L. citrata* and *Machilus bombycina*, whereas *L. salicifolia*, *Cinnamomum glaucescens*, *C. glanduliferum*, *Actinodaphne obovata*, *Michelia champaca*, *Magnolia sphenocarpa*, *Zanthoxylum rhetsa*, *Gmelia arborea*, *Celastrus monosperma* and *Actinodaphne angustifolia* are the secondary host trees. When *A. assama* Ww. feeds on Mejankari (*Listaea citrata*) leaves, it produces a special kind of silk, known as mejankari silk, which, is admired for its durability, lustre, and creamish white shade (Jolly *et al.*, 1974). Life cycle of *A. assama* Ww. lasts for 40-50 days in summer and 110-120 days in winter, and normally 4-5 crops are taken in an year. The average holding of muga plantation by a farmer in Assam is less than half an acre, but it is intact as such since last 20 years (Chakravorty, 2004).

Literature survey indicates that *L. monopetala*, a primary food plant of *A. assama* Ww. is uniformly distributed throughout Uttarakhand state at 800-2700 m. Khatri *et*

al. (2004) have conducted experimental rearings of *A. assama* Ww. and harvested 3470 cocoons from 100 DFLs (one disease free laying contains about 200 eggs). This study indicates that *A. assama* Ww. can be promoted by SFD through institutional linkages with DOS, CSB and NGOs in Uttarakhand state also where, only 14.02 % of the total reported area (53 485 km²) is under agriculture and majority of the people are forest dependent. Muga silkworm rearing is very remunerative and a farmer can earn ₹37500 from 150 trees by conducting two crops in an year. This income can be doubled, if cocoons are converted into yarns (Singh and Sinha, 2000).

6.1.4 Eri silkworm, *Samia cynthia* Drury

Wild eri silkworm, *Samia cynthia* D. syn. *Philosamia cynthia* Grote is a univoltine or bivoltine wild silkworm found on different forest tree species viz., *Heteropanax fragrans*, *Manihot utilissima* and *Evodia fragrance* in Assam, Manipur, Bihar, West Bengal, Odisha, Andhra Pradesh and Karnataka, and 1.5 lakh poor families are engaged in eri sector. Eri culture in north-eastern states of India is mainly practiced for protein rich pupae; a delicacy for the tribals, and the silk produced is treated as by-product.

Eri silkworm is the only wild silkworm that is domesticated indoor up to an altitude of 1525 m and larval period lasts for 30-35 days. Host tree leaves are hung over the tray, where larvae climb and feed on the leaves. Cocoon filament of eri silkworm is neither continuous nor uniform in thickness, that is why it is only hand reeled and produced silk is used indigenously for preparation of chaddars (wraps) by the tribals. Eri silk can be blended with cotton, wool, jute, or mulberry silk for jackets, suiting materials, furnishings, *etc.* Owing to polyphagous nature, hardy breed characteristics and indoor nature of rearing, eri silkworm rearing can be integrated with CFM all over India.

6.1.5. Forest based sericulture and Indian Forest (Conservation) Act, 1980

Recognising the role of FBS in livelihood support to the

poor families and its contribution towards forest conservation, Government of India issued guidelines for vanya silkworm rearing under Forest (Conservation) Act, 1980. According to this ruling, plantation of forest trees on which vanya silkworms could be reared, without undertaking a monoculture plantation shall be traded as forestry activity and no prior permission of the Central Government under Forests (Conservation) Act, 1980 is required provided that such plantation should not involve any felling of the trees and while undertaking such plantations, at least three species should be planted, of which no single species shall cover more than 50 % of the total planted area (MoEF, 2004).

6.1.6 Forest silkworm and forest ecosystem

In FBS, silk products are anthropogenic utilization of ecological interactions between wild silkworms and their host trees. Insect eating green tree leaves in forest is an integral part of forest ecosystem. Population build-up of insect is regulated by biotic, abiotic, density dependent, and density independent factors, and if natural regulatory mechanisms like parasites, predators and pathogens are active, insects do not attain the status of pests and their population remains below economic injury level (EIL). There is no record that any saturniid has ever caused an outbreak in forest. Functionally, annual primary production is an indicator of healthy forest ecosystem and forest productivity is the function of leaf area index (LAI). However, relationship between LAI and photosynthesis is not linear, because due to self-shading, some leaves of the tree canopy receive so little light that their rate of respiration exceeds the rate of photosynthesis that declines the function of net primary production against LAI. High leaf availability and corresponding increase in gross photosynthesis at high leaf area index is offset by increased respiration (Odum, 1975).

Silkworms are reared on forest host trees in small compact patches at outskirts of the forests once a year for 30-60 days and the host trees suffer a temporary photosynthetic loss, but the total production of forest stand is not likely to be affected. The foliage loss after silkworm feeding

allows understory trees and other ground flora to get much light that compensates temporary photosynthetic loss of partially defoliated host trees by forest silkworm species. Since the secondary foliage grows in 30-45 days after silkworms' feeding, it compensates not only the foliage loss but also in exceeding the total LAI in comparison to un-damaged trees. The secondary foliage being thinner than the primary foliage has better photosynthetic efficiency in comparison to the older leaves that were consumed by the silkworms. Further, the increased longevity of newly grown leaves on silkworm fed trees extends the usual leaf fall period and this extended period of leaf on crown provides a positive photosynthetic gain to the host tree. Therefore, as far as the foliage loss is concerned, new foliage offsets it and apparently, no loss takes place in annual primary production of forest due to silkworm feeding. Moreover, the roots of host trees grow more vigorously by utilising increased nutrient contents due to enhanced microbial activity on larval faecal materials at the forest floor. Vanya silkworms are forest insects and have no adverse effect on growth and increment of the forest (Bhandari, 2003).

6.2. Integration of forest based apiculture (FBA) as a livelihood component in CFM

Honeybees are important pollinators that ensure functioning of many ecosystems. According to FAO (2009), honeybees pollinate one third of all the plant products consumed by the humans. In US, Berenbaum (2007) estimated that bees pollinate over 90 crops for a value of more than US\$15 billion in an year. All the four species of honeybees viz., *Apis cerana*, *A. mellifera*, *A. florea* and *A. dorsata* are found in India, however the major portion of honey is contributed by forest bee, *A. dorsata* (Sivaram *et al.*, 1993), but the commercial exploitation of forest bee is very limited (Sivaram and Anita, 2000). In forest, *A. dorsata* build single comb attached to the branches of many forest tree species and their nests are up to one meter wide (Rouquerte, 1995). It is estimated that around two million *A. dorsata* colonies are available in forests all over India (Thomas *et al.*, 2001) that can be exploited to

create an additional income for forest dependent people.

Beekeeping is not a labour-intensive activity and can easily be accommodated in the daily routine of the forest dependent people. Bee keeping has high earning potential where one can earn ₹1.7 lakh from 100 bee colonies @ 20.11 kg honey per hive and according to Sivaram (2012), if these colonies are put under diversification plan, this profit can be further increased up to ₹3.19 lakh per year. Beeswax is twice costlier than honey; bee-collected pollen, propolis, bee-venom, and royal jelly are several times costlier than beeswax; and all these are in great market demand. Honey can be easily stored, sold, or consumed in the times of need.

Forests are known to provide organic honey, nectar, pollen, and propolis of high quality without any insecticidal residue that can be sold at premium prices in western markets through viable market linkages under CFM. In India, forest dependent people apply a very crude and destructive method of honey hunting to earn their livelihood and contribute 45.85 % of the total honey production (85000 MT) (Sivaram, 2012). They crush and squeeze the comb along with larvae and pollen grain that makes honey turbid and fetch low market price. Thus, 40-50 % forest bees discontinue their breeding cycles every year due to unscientific honey harvesting. Sometimes the honey hunters use fire to facilitate honey collection that may constitute a source of forest fire. So, proper training to forest honey hunters may enable safe honey extraction from forest.

FBA can be promoted through collective action of SFD, JMFCs, FRI (Forest Research Institutes), and NBB (National Bee Board) in an adoptive CFM module, where forestry people and apiculture scientists can work together for safe honey extraction in forestry sector. FBA can increase the customary use of forest resources for equitable benefits sharing that can further contribute to forest conservation and poverty alleviation in forested area of the country. The important areas of interventions are - capacity building for improved honey production, adoption of improved technologies for migratory bee

keeping, nucleus stock maintenance, processing, and quality control of bee products. Further, beekeeping can also be introduced as a special scheme in reforestation programmes by paying special attention to use native melliferous forest tree species to provide a rich and varied source of nectar and pollen for forest honeybees. Secondly, bee-reserves can be established with exclusive access for beekeepers, as has already been done in United Republic of Tanzania (MNRT, 1998).

6.3. Integration of forest based lac culture (FLC) in CFM to alleviate poverty in tropical India

Lac is the only known commercial resin of animal origin secreted by female scale insect *Laccifer lacca* Kerr (Hemiptera: Lacciferidae). Lac is an eco-friendly non-toxic product that has many industrial applications, like natural dye, oil painting, candy coatings, leather finishing, electrical insulation, glue for glass and metals, hair spray, coating of pills and processed food *etc.* Stick lac, seed lac, shellac, button lac, garnet lac and bleached lac are the different forms of the lac. India is the principal lac producing country in the world, with 20,000 metric tones of raw lac produced annually, which fulfils 60 % of the world demand. In India, Jharkhand, Chhattisgarh, West Bengal, Uttar Pradesh, Madhya Pradesh, Maharashtra, Bihar, and Odisha are the major lac producing states that contribute 90 % of the total lac production.

Lac insects are reared on *Butea monosperma*, *Ziziphus mauritiana*, *Schleichera oleosa*, *Acacia catechu*, *A. arabica* and *A. auriculiformis*, which can be raised and utilized for rearing within 5-6 years of plantation. Like forest silkworms, lac insects are also a pest on their host trees, but they enjoy a privilege for not being treated as pest, because insect's damage is temporary and provides money to poor people. Six months duration of life cycle of lac insect passes through egg, nymph, pupa, and adult stages. Crimson-red first instar nymph called crawlers start secreting resin from the glands distributed under cuticle, throughout the body, except mouthparts, breathing spiracles, and anus. The resin secreted is semi-solid that hardens on exposure to air

into a protective covering. After life cycle is completed and next generation is about to begin, the resin encrusted branches are scraped off, dried, and processed for various lac products. A portion of brood lac is retained for the purpose of inoculation to new trees. To produce 1.0 kg of lac resin, around 300,000 lac insects give up their life.

Lac cultivation is simple that does not require any large investment and needs only part-time attention. The mean lac productivity varies from 1-10 kg per tree depending on host tree species and climatic conditions. Average net profit from one tree is ₹109 for *B. monosperma*, ₹202 to 1060 for *Z. mauritiana*, and ₹1320 for *S. oleosa* per crop cycle (Sharma *et al.*, 2006). Lac cultivation is an important source of livelihood earnings for many forest dependent people and also helps to protect forest and improves biodiversity. In some cases, its contribution can be as high as 30-55 % to the total annual cash flows (CSTRD, 2012) and in Jharkhand, 20-38 % of total income of poor tribals are contributed by lac cultivation (Sharma *et al.*, 2006).

Transfer of technology (ToT) to deep tribal areas and timely supply of the superior quality brood lacs are the important interventions to augment lac production in India; and this can be ensured through institutional linkage of JFMCs with lac related R&D institute *i.e.*, Indian Lac Research Institute, Ranchi. Presently, only 15 % of the available lac host trees are being utilized for lac cultivation, so there is a vast potential for lac linked CFM in India.

6.4. Forest insect industry and insect biodiversity

Insects constitute more than fifty per cent of total biodiversity in tropical forests (Novotny *et al.*, 2006) and have enormous economic value in terms of ecological services they provide to humans. In a study, the total annual value of insects' services in United State amounted to more than US\$ 57 billion (Losey and Vaughan, 2006), and if such a study is extended to entire world, the total value of insect services would be staggering. In comparison to the most temperate ecosystems, tropical forests are characterized by extraordinarily high insect diversity (Godfray *et al.*, 1999; Novotny *et al.*, 2002) and their rate of degradation

and destruction are higher than any other biome (Sala *et al.*, 2000). Combination of these two facts indicates that the potential loss of insect diversity in tropical forests through anthropogenic actions is enormous.

Diversity in the life style of an insect shows its capacity to adjust in different ecological conditions. For example, biodiversity of tasar silkworm reveals its potentiality and the genetic adaptability through interaction with environment to struggle and sustain in varying ecological niches. Overall, forest insect industry has a favourable impact on the conservation of insect in tropical forest and woodland. For example, Holden (1991) observed a reduced frequency of bushfires in caterpillar harvesting areas of Zambia, and villagers sought to protect the sustainability of insect populations in natural forests. It is also reported that a few edible insects enhance their habitat in specific ways, *e.g.* leaf-cutter ants in South America cultivate fungus gardens that convert cellulose into carbohydrates and in Africa, termites increase local plant species diversity, because some plants can only grow on termite mounds (De Foliart, 1997). Forest insect industry promotes conservation of insects in forest ecosystem by maintaining and encouraging the forest reserves by utilising the forest buffer zone and, FII also helps in maintaining the heterogeneity of landscape by promoting the concept of land sparing outside the forest reserves area (Samways, 2007).

7. Why to accommodate forest insect industry in CFM

7.1. Improved incentives encourage participation of local people in CFM

Forest insect industry has tremendous potential to contribute in household income of many forest dwellers in developing country, but to link conservation with livelihoods requires an implementation model. Incentive linked conservation model acts as driving force for conservation and encourages the local communities to participate in forest management by providing them a direct stake in conservation efforts (Salafsky and Wollenberg, 2000).

Such incentives become most attractive, when they are derived from sustainable use of forest biodiversity without threatening its resource base. Forest insect industry is a good option to realise these benefits, because it gives quick rewards and use renewable forest resources. Second, FII is technically simple and easily adoptable. Third, it encourages women participation and does not produce any chemical effluents in the whole production process. Fourth, FII can serve a safety net function by creating employment for the rural people to avoid poverty, whereas some of the poor people may grow out of poverty through continuous household earnings.

7.2. Institutional linkages may encourage multi-governance mechanism under CFM

Community based conservation is conceived and implemented only at the local level and community institutions are only one layer in a multi-level world (Berkes *et al.*, 2006), however, local community can be used as an abridged label for decentralized governance that starts from ground level. Institutional linkages between communities for multi-level governance is an important aspect for co-management, because such linkages provide ways to deal with governance (Kooiman, 2003); have multiple objectives (Brown *et al.*, 2005) and deliver multiple knowledge systems to create a network for learning and execute joint problem solving (Carlsson and Berkes, 2005).

7.3. CFM encourages democratic way of functioning

Integrating the goals of forest conservation with livelihood requires capacity building, which can effectively be addressed in CFM. Working together of different agencies addresses several socio-economical issues and may decelerate tribal migration from forested area. Institutional linkages under CFM encourage democratic decision-making process and all the stakeholders have space and capacity to make them heard. Second, they communicate and transfer their knowledge and skills in multiple directions. Third, they act together to manage a conflict and Fourth, there is a shared and intentional

social learning and experimentation in forest management process, planning, and decision-making that clearly reflects a link to the desired future (Fisher *et al.*, 2007).

7.4. Scope to integrate FII in CFM

In India, about 13 million ha forest is available with silkworm related forest flora as dense, open, and scrub forest (Srivastav and Thangavelu, 2005) that can be utilised to expand economic benefits of forest based sericulture (FBS) to a large number of forest dependent people.

Forest sericulture, apiculture and lac culture can serve as alternatives for Shifting or Jhum cultivation (slash and burn cultivation) that is practised by 4.433 lakh families as a livelihood activity that involves 3869 km² forest area annually in north-eastern states of India (Tripathi and Barik, 2003). Earlier, shifting cultivation cycle was for 15-20 years, but it has now reduced to 2-3 years only and is causing large-scale deforestation and inflicting heavy loss of insect biodiversity. If Jhum cultivating poor tribals are linked with location specific forest insect industry under CFM module, the problem of shifting cultivation and its associated ecological losses can be reduced.

Edible insects collected from forest are generally clean and free from chemicals and they are the cheapest source of protein compared to animal meat and fish and contribute to sustainable management of insect habitats. In India, edible insects are largely consumed in north-eastern region and there is almost no entomophagy in other parts of India. However, there exists a very good scope to widen economic potential of edible insects for a large number of poor people in all the forested area through their collection or by commercial rearing for cash income through evolved market linkages with insect consuming countries. Rapid reproduction rate and high fecundity feature of forest insects are the preferable commercial traits to use them in forest insect industry.

Forest management strategy that could promote dual product systems for example, eri silkworms for natural silk fabric and pupae as food; honey, beeswax, propolis,

bee-venom, and royal jelly as a commercial product and honeybee brood as food, *etc.* should be prioritised in CFM.

8. Potential critics about efficiency of NTFPs in poverty alleviation and conservation of forest

Since 1980s, the hope for conservation of tropical forests was put to NTFPs, but its livelihood delivery potential has been questioned. Neuman and Hirsch (2000) raised a wide range of constraints that suppress straight relationship between increased sales of NTFPs and corresponding income increase of their gatherers. They also hold an opinion that even in situations of increasing prices and expanding markets of NTFPs, the economic situations of the primary producers do not change, because commercial use of NTFPs is driven by cash demands from poor households. Further, NTFPs appear to be critical in the subsistence of the rural poor that often saw a strong income equalising effect between poor and wealthier classes, but NTFPs rarely provide a means for the poor to actually move up to the wealthier classes and achieve due socio-economic advancement. Ultimately, it appears that commercial exploitation of NTFPs contributes little to address the structural origins of poverty in forested area.

Further, to what extent commercialisation of forest product can improve the income of its gatherers have also been questioned and the issue of sustainable supply of NTFPs is not easily answered. According to Dove (1993), it is likely that the largest parts of the benefits of any newly developed forest product will eventually fall in the hands of larger merchants and not in the hands of poor people in forested area, because exploitative relationships appear to be more evident in cases where intermediaries are available at the point of primary production and governing a marketing chain of forest products. Wilkie and Godoy (1996) propose a model where little commercial contacts exist with the outsiders to avoid possible exploitation through intermediaries. Wiersum (1997) defines forest management as the process of making and implementing decisions about the use and maintenance of forest resources. But, proper implementation of the decisions under CFM system may be influenced or hindered

by unfavourable circumstances, such as rent seeking activities by the outside parties, inadequate policies, corruption of government official, and the like. If these kinds of conditions occur, CFM system is likely to be replaced by unwise harvesting of the forest resources and more often than not, these changes will have a declining effect on the presence of forests in the landscape. Further, the proposition that commercialisation of NTFPs will boost conservation of forests has also been questioned.

9. Conclusions

This article has summarized the knowledge with respect to two central questions at the interface of livelihoods, forests, and conservation: To what scale JFM is contributing to forest conservation and what are the problems of JFM in delivering the livelihood functions of forests to forest dependent people in India. Secondly, why collaborative forest management (CFM) can be a better option than JFM for an effective forest management to provide a better livelihood opportunity to poor people in forested area. We know that we have just touched the surface of a vast topic and this article does not address all the points that are relevant to this topic.

With respect to the first question, it is recognised that even today, JFM is the principal forest management strategy in India, but its forest management potential and livelihood delivery is declining due to lack of institutional linkages for multilevel governance and want of incentives for community involvement. It is recommended that the vast institutional base of JFM in India can be better utilised for location specific institutional linkages to realise the commercial potential of SMFEs to promote the growth of incentive linked forest management strategy in India. With respect to the second question, it is concluded that owing to complex, multidimensional and dynamic nature of poverty; forests and forestry alone will not eradicate rural poverty. Secondly, livelihood oriented forest conservation initiatives require a strategic mix of organizational collaborations for local capacity building to diversify the livelihood options for forest dependent people. Therefore, State Forest Department will have

to join other organizations beyond the forestry sector to reduce poverty in forested areas, because associative relation between different agencies with local community can better identify the hidden livelihood opportunity in a given forest area and their viable integration can change the attitude of local communities by demonstrating them the real potential of forests in terms of improved earnings.

Further, this study underlines the important functions of small and medium forest-based enterprises and cited the emerging roles of forest insect industry in forest based rural economy of developing countries. This investigation identified many livelihood and ecological functions that different forest silkworms, honeybees, and lac insects can play in nature preservation, and the positive impacts that these FII can have on the lives of humans. Recognizing the substantial contribution of these commercial forest insects in improving the livelihood earnings of forest dependent communities, forest based sericulture, forest beekeeping and forest lac culture can be integrated as the livelihood component in CFM. Such initiative by forest managers and policy makers will make forest-edge communities to be aware of the precious value of forest insects in their life and the need to safeguard them and by learning about the role of these commercial forest insects in forest ecosystems, people will better understand and appreciate the value of forests.

NOTE

- ¹ As per Census 2011, total population of India is 1210 million, equal to the combined population of USA, Brazil, Indonesia, Pakistan, Bangladesh, and Japan.
- ² There is no census figure for forest dependent population in India. Different estimates put the figures from 200 million (ICFRE, 2012) to 400 million (MoEF, 2009).
- ³ There are 6.41 lakh total villages in India as per the 2011 census.
- ⁴ Livestock population of India is 530 million as per the 18th Livestock Census, 2007 (MoA, 2010). Thirty eight % of livestock depend on fodder derived from forest by direct grazing or by harvesting.

⁵ JFMCs are village-level institutions of forest communities constituted democratically for the protection and development of forests and sharing of the benefits arising out of the managed forests, including NTFPs.

⁶ PRIs form the third tier of the decentralised three-tier governance structure mandated under the Constitution. Among the 29 functions recommended for decentralization, three relate to forestry, viz., social forestry, fuel wood plantations and NTFPs. The Panchayats are local self-government bodies and considered central to the development of villages. Gram (village) panchayat is the lowest strata of governance in India consisting of 5,000 populations belonging to one or several adjacent villages popularly known as Panchayati Raj Institution. Above village panchayat, exists Panchayat samiti at Block level (Block consist of 50-90 villages depending on the population). Above panchayat samiti, exists Jilla Parishad or District Council.

⁷ Central Silk Board (CSB) is a statutory and autonomous body under the administrative control of Ministry of Textiles, Govt of India. CSB is an apex body, with responsibility of overall development of silk industry and sericulture in India.

ACKNOWLEDGEMENT

We wish to thank anonymous reviewers for insightful comments they made on drafts of this article. We take full responsibility for any errors or omissions that might remain in the finished product.

REFERENCES

- Abdus Salam M. D., Noguchi T. and Pothitan R. (2006) Community forest management in Thailand: current situation and dynamics in the context of sustainable development. *New For.*, **31**: 273–291.
- Agrawal A. (2004) Environmental politics and institutional choices: Forestry and wildlife policies in the developing world, 1980-2005. *Book manuscript* presented at the CHAOS seminar, University of Washington, Seattle, June 8-9, 2004.
- Agrawal A., Yadama G., Andrade R. and Bhattacharya A. (2006) Decentralization and environmental conservation: Gender effects from participation in Joint Forest

- Management. *CAPRI Working Paper No. 53*, International Food Policy Research Institute, Washington, USA. <http://www.ifpri.org/sites/default/files/publications/CAPRIWP53.pdf>
- Ahmed R. Z., Choudhury S. N. and Bhattacharya P. R. (1998) Variation in cocoon characteristics of muga silkworm (*Antheraea assama* Westwood) reared on *som* (*Persea bombycina* Kost) collected from different places of upper Assam, India. *Sericologia*, **38** (4): 699-702.
- Ajzen I. and Fishbein M. (1977) Attitude-behaviour relations: A theoretical analysis and review of empirical research. *Psychol. Bull.*, **84** (5): 888-918.
- Akai H. (1998) Global scenario of wild silks. *Indian Silk*, **37** (6&7): 18-20.
- Angelsen A. and Wunder S. (2003) Exploring the forest-poverty link: key concepts, issues and research implications. *Occasional Paper 40*, CIFOR, Bogor, Indonesia. http://www.cifor.org/publications/pdf_files/OccPapers/OP-40.pdf
- Arnold J. E. M. and Ruiz Perez M. (1998) The role of non-timber forest products in conservation and development. In: *Incomes from the forest: methods for the development and conservation of forest products for local communities*, Wollenberg E. and Ingles A. (Eds.), CIFOR, Bogor, Indonesia, pp. 17-41.
- Arnold J. E. M. (2001) *Forest and People: 25 Years of Community Forestry*, Food and Agriculture Organization of the United Nations, Rome. <http://www.fao.org/docrep/012/y2661e/y2661e01.pdf>
- Banerji D. and Shah R. (2012) India overtakes Japan to become third-largest economy in purchasing power parity. *The Economic Times, Economy*. http://articles.economictimes.indiatimes.com/2012-04-19/news/31367838_1_ppp-terms-india-s-gdp-power-parity
- Barbault R. (1995) Biodiversity: stakes and opportunities. *Nat. Resources*, **31** (3): 18-26.
- Belcher B. and Kusters K. (2004) Non-timber forest product commercialisation: Development and conservation lessons. In: *Forest Products, Livelihoods and Conservation: Case Studies of Non-Timber Forest Product Systems*, Volume 1- Asia, Kusters K. and Belcher B. (Eds.), CIFOR, Bogor, Indonesia, pp. 1-21.
- Berenbaum M. R. (2007) The birds and the bees: How pollinators help maintain healthy ecosystems. *Testimonial before the subcommittee on Fisheries, Wildlife and Oceans, Committee on Natural Resources*, U. S. House of Representatives, 26 June 2007. http://www7.nationalacademies.org/ocga/testimony/How_Pollinators_Help_Maintain_Healthy_Ecosystems.asp
- Berkes F., Hughes T. P., Steneck R. S., Wilson J. A., Bellwood D. R., Crona B., Folke C., Gunderson L. H., Leslie H. M., Norberg J., Nystrom M., Olsson P., Osterblom H., Scheffer M. and Worm B. (2006) Ecology - Globalization, roving bandits, and marine resources. *Science*, **311**: 1557-1558.
- Bhandari R. S. (2003) Impact of tasar culture on forest. In: *Proceedings of the National Workshop on Vanya Silk Culture and Forestry*, Rana A. K., Bisht N. S., Khatri R. K., Khanna D., Siddiqui A. A. and Babulal (Eds.), Forest Research Institute, Indian Council of Forestry Research and Education, New Forest, Dehradun, India, pp. 33-36.
- Borrini-Feyerabend G., Pimbert M., Farvar M. T., Kothari A. and Renard Y. (2004) *Sharing power: Learning by doing in co-management throughout the World*, IIED and IUCN/CEESP/CMWG, Cenesta, Tehran.
- Bradley P. and Dewees P. (1993) Indigenous woodlands, agricultural production, and household economy in the communal lands. In: *Living with Trees: Policies for Forestry Management*, Bradley P. N. and McNamara K. (Eds.), The World Bank, Washington DC, pp. 63-137.
- Brown K., Mackensen J., Rosendo S., Viswanathan K., Cimarrusti L., Fernando K., Morsello C., Siason I. M., Singh S., Susilowati I., Manguiat M. S., Bialluch G. and Perrin W. F. (2005) Integrated responses. In: *Ecosystems and Human Well-being*, Volume 3, Chopra K., Leemans R., Kumar P. and Simons H. (Eds.), Island Press, Columbia, Washington, pp. 425-464.
- Byron R. N. and Arnold J. E. M. (1999) What futures for the people of the tropical forests? *World Dev.*, **27** (5): 789-805.
- Carlsson L. and Berkes F. (2005) Co-management: Concepts and methodological implications. *J. Environ. Manage.*, **75**: 65-76.
- Carter J., Steenhof B., Haldimann E. and Akenshaev N. (2003) Collaborative forest management in Kyrgyzstan: Moving

- from top-down to bottom-up decision- making. *Natural Resources Group and Sustainable Agriculture and Rural Livelihoods Programme*, I.I.E.D. London, UK.
<http://pubs.iied.org/pdfs/6360IIED.pdf>
- Census (2011) *Census 2011*, Office of the Registrar General and Census Commissioner, India, Ministry of Home Affairs, Government of India. <http://censusindia.gov.in/>
- Cesard N. (2004) Harvesting and commercialisation of Koto (*Oecophylla smaragdina*) in the Malingping area, West Java, Indonesia. In: *Forest Products, Livelihoods and Conservation: Case Studies of Non-Timber Forest Product Systems*, Volume 1- Asia, Kusters K. and Belcher B. (Eds.), CIFOR, Bogor, Indonesia, pp. 61-78.
- Chakravorty R. (2004) Diversity of muga and eri sericulture and its prospects in Himalayan states. In: *Proceedings of the National Workshop on Potential and Strategies for Sustainable Development of Vanya silk in the Himalayan States*, Khatri R. K. (Ed.), Directorate of Sericulture, Government of Uttarakhand, Dehradun, India, pp. 9-16.
- Cheng A. and Mattor K. M. (2006) Why won't they come? Stakeholder perspectives on collaborative National Forest Planning by Participation Level. *Environ. Manage.*, **38**: 545-561.
- Cranston P. S. (2009) Insect biodiversity and conservation in Australasia. *Annu. Rev. Entomol.*, **12 (55)**: 55-75.
- CSB (2020) *Annual Report*, Central Silk Board, Ministry of Textiles, Government of India, Bengaluru, India, p. 81. <http://csb.gov.in/wp-content/uploads/2021/03/CSB-ANNUAL-REPORT-2019-20-compressed-97-196-eng.pdf>
- CSTRD (2012) *Report of the study on Lac subsector*, Chhattisgarh State Institute of Rural Development, Department of Panchayat and Rural Development, Govt. of Chhattisgarh, Raipur, India, 68p. <http://www.cgsird.gov.in/Lac%20ersion%20-2.pdf>
- de Beer J. H. and McDermott M. (1996) The economic value of non-timber forest products in Southeast Asia. *The Netherlands Committee for IUCN*, Amsterdam.
- De Foliar G. R. (1992) Insect as human food. *Crop Protection*, **11 (5)**: 395-399.
- De Foliar G. R. (1997) An overview of the role of edible insects in preserving biodiversity. *Ecol. Food Nutr.*, **36 (2/4)**: 109-132.
- Dove M. R. (1993) A revisionist view of tropical deforestation and development. *Environ. Conserv.*, **20**: 17-24.
- Dove M. R. (1995) The theory of social forestry intervention: the state of the art in Asia. *Agrofor. Syst.*, **30**: 315-340.
- Elson D. (2010) Investing in locally controlled forestry: reviewing the issues from a financial investment perspective. *Background paper, The Forests Dialogue*, London, UK, 24-25 May 2010. http://environment.yale.edu/tfd/uploads/TFD_ILCF_London_Backgrounder_Elson.pdf
- Falconer J. (1990) The major significance of "minor" forest products: The local use and value of forest products in the West African humid forest zone. *Community Forestry Note No.6*, Food and Agriculture Organization of the United Nations, Rome.
- FAO (2009) *Bees and their role in forest livelihoods. A guide to the services provided by bees and the sustainable harvesting, processing and marketing of their products*, Food and Agriculture Organization of the United Nations, Rome.
- FAO (2011) *State of the World's Forests 2011*, Food and Agriculture Organization of the United Nations, Rome. <http://www.fao.org/docrep/013/i2000e/i2000e00.htm>
- FAO (2012 a) *Making forest work for the poor: Assessment of the contribution of forestry to poverty alleviation in Asia and the Pacific*, FAO, Regional office and Pacific, Bangkok, 359 p. <http://www.fao.org/docrep/016/i2732e/i2732e.pdf>
- FAO (2012 b) *Edible forest insect*, Food and Agriculture Organization of the United Nations, Rome. <http://www.fao.org/forestry/edibleinsects/65427/en/>
- Fisher R., Prabhu R. and McDougall C. (2007) *Adaptive collaborative management of community forests in Asia: Experiences from Nepal, Indonesia and the Philippines*, CIFOR, Bogor, Indonesia, p. 228.
- Fisher R. J. (2011) Thailand's forest regulatory framework in relation to the rights and livelihoods of forest dependent people. In: *Critical review of selected forest-related regulatory initiatives: Applying a rights perspective*, H. Scheyvens (Ed.), Institute for Global Environmental Strategies (IGES), Hayama, Kanagawa, Japan.

- FSI (2009) *State of Forest Report 2009*, Ministry of Environment and Forests, Government of India, Dehra Dun, India. <https://fsi.nic.in/sfr2009/chapter2.pdf> (accessed on 21 July 2021).
- FSI (2019) *State of forest report 2019*, Forest Survey of India, Ministry of Environment and Forest, Government of India, Dehradun, India. <https://fsi.nic.in/isfr19/voll/executive-summary> (accessed on 21 July 2021).
- Godfray H. C., Lewis O. T. and Memmott J. (1999) Studying insect diversity in the tropics. *Philosophical Transactions of the Royal Society of London, Series B. Biol. Sci.*, **354**: 1811-1824.
- Godoy R., Brokaw N. and Wilkie D. (1995) The effect of income on the extraction of non-timber tropical forest products: Model, hypotheses, and preliminary findings from the Sumu Indians of Nicaragua. *Hum. Ecol.*, **23**: 29-52.
- Hazarika L. K., Saikia C. N., Katakya A., Bordoloi S. and Hazarika J. (1998) Evaluation of physico chemical characteristics of silk fibres of *Antheraea assama* reared on different host plants. *Bioresour. Technol.*, **64**: 67-70.
- Hecht S. B., Anderson A. B. and May P. (1988) The subsidy from nature: Shifting cultivation, successional palm forests, and rural development. *Hum. Organ.*, **47** (1): 25-35.
- Hobley M. (2008) Can forest reduce poverty? In: *People, Forest, and Human Well-being- Managing Forests for People in a Period of Rapid Change*, Asia-Pacific Forestry Week: Social Session, National Convention Center, Hanoi, Vietnam.
- Holden S. (1991) Edible caterpillars - A potential agroforestry resource? They are appreciated by local people, neglected by scientists. *Food Insects Newsletter*, **4** (2c): 3-4.
- Holldobler B. (1983) Territorial behaviour in the green tree ant (*Oecophylla smaragdina*). *Biotropica*, **15**: 241-250.
- Hunter M. L. J. R. (1999) *Maintaining biodiversity in forest ecosystem*, Cambridge University Press, Cambridge, p. 698.
- ICFRE (2012) *Forest Sector Report India 2010*, Indian Council of Forestry Research and Education, Dehradun, Ministry of Environment and Forest, Government of India, pp. 2-35.
- ISC (2021) *Global Silk Production*, International Sericultural Commission, Bengaluru, India. <https://inserco.org/en/statistics>.
- Global Hunger Index (2020) India <https://www.globalhungerindex.org/india.html>. (accessed on 05 July 2021).
- Jodha N. S. (1986) Common property resources and rural poor in dry regions of India. *Econ. Polit. Wkly.*, **21** (27): 1169-1181.
- Johnson V. D. (2010) The contribution of edible forest insects to human nutrition and to forest management. In: *Forest insects as Food: Humans Bite Back*, Chiang M., Durst P. B., Johnson D. V., Leslie R. N. and Shono K. (Eds.), Proceedings of workshop on Asia-Pacific resources and their potential for development, FAO, Regional office for Asia and the Pacific, Bangkok, Thailand, 19-21 February 2008. <http://www.fao.org/docrep/012/i1380e/i1380e00.pdf> (accessed on 16 November 2012).
- Jolly M. S. (1970) Recent trends in researches on Indian tasar silkworm. *Bull. Entomol.*, **10**: 32-38.
- Jolly M. S., Sen S. K. and Ahsan M. M. (1974) *Tasar culture*, Central Silk Board, Ministry of Textiles, Government of India, Bangalore, p. 14.
- Jolly M. S., Sen S. K., Sonwalkar T. N. and Prasad G. K. (1979) Non-mulberry Silks. In: *Manual on sericulture*, Agricultural Services Bulletin, Food and Agricultural Organization of United Nations, Rome, pp. 1-12.
- Kant R., Chakrabarty S. and Mishra P. N. (2004) Prospects of Oak (*Quercus spp.*) as an agroforestry plant in Uttarakhand. *Proceedings of the National Workshop on Potential and strategies for sustainable development of Vanya silk in the Himalayan States*, Khatri R. K. (Ed.), Directorate of Sericulture, Government of Uttarakhand, Dehradun, India, pp. 88-92.
- Khatri R. K., Singh N., Paliwal D. P., Lal B., Siddiqui A. A. and Sharma A. K. (2004) Correlation studies on environmental factors and rearing and grainage behaviour of *Antheraea assama* Westwood under Doon valley condition. *Proceedings of the National Workshop on Potential and strategies for sustainable development of Vanya silk in the Himalayan States*, Khatri R. K. (Ed.), Directorate of Sericulture, Government of Uttarakhand, Dehradun, India, pp. 88-92.

- Kooiman J. (2003) *Governing as Governance*, SAGE Publication Limited, London, pp. 77- 115.
- Kumar S. (2002) Does participation in common pool resource management help the poor? A social cost-benefit analysis of joint forest management in Jharkhand, India. *World Dev.*, **30**: 763-782.
- LaFrankie J. V. (1994) Population dynamics of some tropical trees that yield non-timber forest products. *Econ. Bot.*, **48** (3): 301-309.
- Losey J. and Vaughan M. (2006) The economic value of ecological services provided by insects. *BioScience*, **56** (4): 311-323.
- Macqueen D. (2008) Supporting small forest enterprises - A cross-sectoral review of best practice. *IIED Small and Medium Forestry Enterprise Series No. 23*, IIED, London, UK. <http://pubs.iied.org/pdfs/13548IIED.pdf> (accessed on 15 December 2012).
- Matta J. R. and Alavalapati J. R. R. (2006) Perceptions of collective action and its success in community based natural resource management: An empirical analysis. *For. Policy Econ.*, **9**: 274-284.
- Mehta A. K. and Shah A. (2003) Chronic poverty in India: Incidence, cause and policies. In: Special issue on "Chronic poverty and development policy", Hulme D. and Shepherd A. (Eds.), *World Dev.*, **31** (3): 491-511.
- Mehta J. N. and Heinen J. T. (2001) Does community-based conservation shape favorable attitudes among locals? An empirical study from Nepal. *Environ. Manage.*, **28**: 165-177.
- MNRT (1998) *Tanzania bee keeping policy*, Ministry of Natural Resources and Tourism, Dar-es-Salaam, Tanzania.
- MoA (2010) *18th Livestock Census 2007, All India Report based on Quick Tabulation Plan- Village Level Totals*, Department of Animal Husbandry Dairying and Fisheries, Ministry of Agriculture, Krishi Bhavan, New Delhi, India.
- MoEF (1988) *National Forest Policy (1988) Resolution No. 3-1/86-FP*, Ministry of Environment and Forests, Government of India, New Delhi, India.
- MoEF (2004) Guidelines for diversion of forestland for non-forest purposes under the Forest (Conservation) Act, 1980, *Revised Guidelines for Tusser Cultivation (Vanya Silk Cultivation)*, Ministry of Environment and Forests, Government of India, New Delhi. <http://www.jharkhandforest.com/files/Handbook-38.pdf> (accessed on 03 November 2012).
- MoEF (2006) Measuring milestones. *Proceedings of the National Workshop on Joint Forest Mangement (JFM)*, Ministry of Environment and Forests, Government of India, New Delhi, India.
- MoEF (2009) *India Forestry Sector Outlook Study*, Ministry of Environment and Forests, Government of India, New Delhi, FAO, Regional office for Asia and the Pacific, Bangkok. <http://www.fao.org/docrep/014/am251e/am251e00.pdf> (accessed on 09 November 2012).
- Moeliono M. (2006) Conservation policy and the commons. *Common Property Resource Digest*, **76**: 1-4.
- Momberg F., Puri R. and Jessup T. (2000) Exploitation of gaharu, and forest conservation efforts in the Keyan Mentarang National Park, east Kalimantan, Indonesia. In: *People, Plants, and Justice: The Politics of Nature Conservation*, C. Zerner (Ed.), Columbia University Press, New York, pp. 259-284.
- Muafor F. J., Levang P., Angwafo T. E. and Gall L. E. (2012) Making a living with forest insect: beetles as an income source in Southwest Cameroon. *Int. For. Rev.*, **14** (3): 314-325.
- Nayak B. P., Kohli P. and Sharma J. V. (2012) *Livelihood of local communities and forest degradation in India: Issues for REDD+*, Ministry of Environment and Forests, Government of India, Delhi, 3p. <http://envfor.nic.in/assets/redd-bk3.pdf> on 23.11.2012.
- Nayak P. K. (2002) Community-based forest management in India: The issue of tenurial significance. *Working Paper*, Foundation for Ecological Security, Anand, India.
- Neumann R. P. and Hirsch E. (2000) *Commercialisation of Non-Timber Forest Products: Review and Analysis of Research*, CIFOR, Indonesia, p. 176.
- NFP (2011) *National Fibre Policy 2010-11*, Ministry of Textiles Government of India, Delhi, India. http://texmin.nic.in/policy/Fibre_Policy_dir_mg_d_20100608.pdf (accessed on 07 November 2012).

- NIC (2012) *Global Trends 2030: Alternative Worlds*, National intelligence Council, Washington, USA, p. 137.
http://www.dni.gov/files/documents/GlobalTrends_2030.pdf (accessed on 01 November 2012).
- Novotny V., Basset Y., Miller S. E., Weiblen G. D., Bremer B., Cizek L. and Drozd P. (2002) Low host specificity of herbivorous insects in a tropical forest. *Nature*, **416**: 841–844.
- Novotny V., Drozd P., Miller S. E., Janda M., Basset Y. and Weiblen G. D. (2006) Why are there so many species of herbivorous insects in tropical rain forests? *Science*, **313**: 1115–1118.
- Odum E. P. (1975) *Ecology: the Link between the Natural and the Social Sciences*, Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, p. 244.
- Ojha N. G. and Panday P. N. (2004) *Silk Production*, ABH Publishing Corporation, New Delhi, India, p. 2.
- Oudhia P. (1998) Medicinal insects and spiders. *Insect Environment*, **4** (2): 57-58.
- Padoch C. (1992) Marketing of non-timber forest products in western Amazonia: general observations and research priorities. *Advances in Economic Botany*, **9**: 43-50.
- Paimin F. B. and Paimin F. R. (2001) Budi dayasemutrangrangpenghasil Kroto (Élevagedelafourmirangrangproductrice de Kroto). *Penebar Swadaya*, Jakarta.
- Pimentel D., McNair M., Buck L., Pimentel M. and Kamil J. (1997) The value of forests to world food security. *Hum. Ecol.*, **25** (1): 91-120.
- Planning Commission (2011) *Rapid Poverty Reduction: Eleventh Five Year*, Planning Commission, Government of India, New Delhi. http://planningcommission.nic.in/plans/planrel/fiveyr/11th/11_v3/11v3_ch4.pdf (accessed on 03 December 2012).
- Planning Commission (2012) *Faster, sustainable, and more inclusive growth: an approach to the twelfth Five Year Plan*. Planning Commission, Government of India, New Delhi. http://planningcommission.nic.in/plans/planrel/12appdrft/approach_12plan.pdf (accessed on 23 December 2012).
- Prasad R. (2006) Strategy for sustainable forest management in India. *National Status Report for ITTO Mission to India*, Ministry of Environment and Forests, Government of India, New Delhi.
- Ramos-Elorduy J., Moreno J. M. P., Prado E. E., Perez M. A., Otero J. L. and Guevvara O. L. (1997) Nutritional value of edible insects from the State of Oaxaca, Mexico. *J. Food Compos. Anal.*, **10** (2): 142-157.
- Rao J. V. K., Singh R. N. and Shetty K. K. (2003) Catalogue of wild silkworms and their host plants in India. *Proceedings of the National Workshop on Vanya Silk Culture and Forestry*, Rana A. K., Bisht N. S., Khatri R. K., Khanna D., Siddiqui A. A. and Babula (Eds.), Forest Research Institute, Indian Council of Forestry Research and Education, New Forest, Dehradun, India, p. 6.
- Rao K. V. S. (2001) Tasar crop planning in Bastar plateau of Chhattisgarh. *Indian Silk*, **40** (5): 11-13.
- Ribot J. C. (2000) Rebellion, representation, and enfranchisement in the forest villages of Makacoulbantang, eastern Senegal. In: *People, Plants, and Justice: The Politics of Nature Conservation*, C. Zerner (Ed.), Columbia University Press, New York, pp.134-158.
- Rouquette J. (1995) Honey harvesting: Developing alternative sources of income in the DanauSentarum Wildlife Reserve, West Kalimantan, Indonesia. *Report to Wetlands International Indonesia Office*, Bogor, Indonesia.
- Ruiz Perez M., Belcher B., Fu M. and Yang X. (2004) Looking through the bamboo curtain: an analysis of the changing role of forest and farm income in rural livelihoods in China. *Int. For. Rev.*, **6** (3-4): 306-316.
- Sala O. E., Chapin F. S., Armesto J. J., Berlow E., Bloomfield J., Dirzo R., Huber- Sanwald E. and Huenneke L. F. (2000) Global Biodiversity scenarios for the year 2100. *Science*, **287**: 1770–1774.
- Salafsky N. and Wollenberg E. (2000) Linking livelihoods and conservation: a conceptual framework and scale for assessing the integration of human needs and biodiversity. *World Dev.*, **28**: 1421-1438.
- Samways M. J. (2007) Insect conservation: A synthetic management approach. *Annu. Rev. Entomol.*, **52**: 465–487.

- Sarin M., Singh N. M., Sunda R. N. and Bhogal R. K. (2003) Devolution as a threat to democratic decision-making in forestry? Findings from three states in India. In: *Local forest management: The impacts of devolution policies*, Edmunds D. and Wollenberg E. (Eds.), Earthscan Publications, London and Sterling, VA, pp. 55-126.
- Saw L. G., Lafrankie J. V., Kochummen K. M. and Yap S. K. (1991) Fruit trees in a Malaysian rain forest. *Econ. Bot.*, **45**: 120-136.
- Selin S. and Chavez D. (1995) Developing a collaborative model for environmental planning and management. *Environ. Manage.*, **19** (2): 189-195.
- Shah A. (2010) *Patterns of poverty in remote rural areas: A case study of a forest-based region in Southern Orissa in India*, Overseas Development Institute and the Chronic Poverty Research Centre, Overseas Development Institute, U. K., p. 30. <http://www.odi.org.uk/sites/odi.org.uk/files/odi-assets/publications-opinion-files/5504.pdf>(accessed on 17 November 2012).
- Shah A. and Guru B. (2004) Poverty in remote rural areas in India: A review of evidence and issues. *CPRC-IIPA Working Paper 21*, Chronic Poverty Research Centre, Indian Institute of Public Administration, New Delhi.
- Sharma S. (2019) Around 22% Indians live below poverty line; Chhattisgarh, Jharkhand fare worst. *Financial Express*, 21, September 2019.
[<https://www.financialexpress.com/economy/around-22-indians-live-below-poverty-line-chhattisgarh-jharkhand-fare-worst/1713365/>].
- Sharma K. K., Jaiswal A. K. and Kumar K. K. (2006) Role of lac culture in biodiversity conservation: issues at stake and conservation. *Curr. Sci.*, **91** (7): 894 - 898.
<http://www.iisc.ernet.in/currsci/oct102006/894.pdf>(accessed on 16 December 2012).
- Singh B. D. and Mishra P. N. (2003) Culture of Vanya Silk vis-a-vis forestry with relevance to North Western Himalayan ecosystem. In: *Proceedings of the National Workshop on Vanya Silk Culture and Forestry*, Rana A. K., Bisht N. S., Khatri R. K., Khanna D., Siddiqui A. A. and Babula (Eds.), Forest Research Institute, Indian Council of Forestry Research and Education, New Forest, Dehradun, India, pp. 76-80.
- Singh B. M. K. and Sinha A. K. (2000) Role of sericulture on sustenance of forest management. *Indian Silk*, **39** (6): 14-18.
- Singh K. C. and Singh N. I. (1998) Biology and ecology of temperate tasar silkmooths, *Antheraea proylei* J. and *Antheraea pernyi* Guerin-Meneville (Saturniidae): A review. *Indian J. Seric.*, **37** (2): 89-100.
- Sivaram V. (2012) *Status, prospects, and strategies for development of organic beekeeping in the South Asian Countries*, Bangalore University Bangalore, India, p. 31. http://www.apiservices.com/articles/us/23_02_12_concept_organic_south_asia.pdf (accessed on 03 October 2012).
- Sivaram V. and Anita M. (2000) Studies on the feasibility of commercial beekeeping in Western Ghat forests for sustainable forest management. *Asian Bee J.*, **2** (1): 25-31.
- Sivaram V., Anita M. and Reddy C. C. (1993) The preservation and management of wild honeybees for pollination. *Proceedings of the International Symposium on Pollination in Tropics*, Bangalore, India, 8-13 August 1993, pp. 251-253.
- Srivastav P. K. and Thangavelu K. (2005) *Sericulture and Seribiobiodiversity*. Associated Publishing Company, New Delhi, India, pp. 192-202.
- Stack J., Dorward A., Gondo T., Frost P., Taylor F. and Kurebgaseka N. (2003) *Mopane worm utilization and rural livelihoods in Southern Africa*, CIFOR livelihood conference, May 19-23, Bonn, Germany.
- Sunderlin W. D., Angelsen A., Belcher B., Burgers P., Nasi R., Santoso L. and Wunder S. (2005) Livelihoods, forests, and conservation in developing countries: An overview. *World Dev.*, **33** (9): 1383-1402.
- Sunderlin W. D., Angelsen A. and Wunder S. (2003) *Forests and poverty alleviation*, CIFOR, Indonesia. http://www.cifor.org/publications/pdf_files/research/livelihood/Forests-poverty.pdf (accessed on 19 November 2012).
- Suryanarayana N., Kumar R. and Gargi (2005) *Monograph on Indian tropical tasar silkworm food plants*, Central Tasar Research and Training Institute, Central Silk Board,

- Ministry of Textiles, Government of India, Ranchi, India, p. 20.
- Tesfaye Y., Roos A. and Bohlin F. (2012) Attitudes of local people towards collective action for forest management: The case of participatory forest management in Dodola area in the Bale Mountains, Southern Ethiopia. *Biodivers. Conserv.*, **21** (1): 245-265.
- Thampi K. B. (2012) Assessment of the contribution of forestry to poverty alleviation in India. In: *Making forestry work for the people: Assessment of the contribution of forestry to poverty alleviation in Asia and the Pacific*, Food and Agriculture Organization of the United Nations, Regional office and Pacific, Bangkok, pp. 99-139.
- The Hindu (2017) Silk production rises, but demand-supply gap remains. *The Hindu News paper*, 20 August 2017. <https://www.thehindu.com/news/national/karnataka/silk-production-rises-but-demand-supply-gap-remains/article19530300.ece>
- Thomas D., Pal N. and Rao K. (2001) Bee management and productivity of Indian honey bees. *Proceedings of the 37th International Apicultural Congress*, Durban, South Africa, 28 October -1 November 2001. <http://www.apimondia.com/congresses/2001/Papers/304.pdf> (accessed on 01 January 2013).
- Tripathi R. S. and Barik S. K. (2003) Shifting cultivation in north-east India. *Proceedings of Approaches for increasing agricultural productivity in hill and mountain ecosystem*, Bhatt B. P., Bujarbaruah K. M., Sharma Y. P. and Patiram (Eds.), ICAR Research complex for NEH Region, Meghalaya, India, pp. 317-322. <http://dspace.nehu.ac.in/jspui/bitstream/1/3455/1/SHIFTING%20CULTIVATION.pdf>(accessed on 15 January 2013).
- UNEP (2011) Sustaining forests: Investing in our common future. *UNEP Policy Series, Ecosystem management*, Issue 5, August 2011. http://www.unep.org/ecosystemmanagement/Portals/7/ Documents/unep_policy_series5thUNEPPolicySeries.pdf (accessed on 01 September 2012).
- Unni B. G., Goswami M., Kakoty Y., Bhattacharjee M. and Wann A. B. (2009) Indigenous knowledge of silkworm cultivation and its utilization in north eastern region of India. *Indian J. Tradit. Knowl.*, **8** (1): 70-74.
- Vantomme P., Gohler D. and N'deckere-Ziangba F. (2004) Contribution of forest insects to food security and forest conservation: The example of caterpillars in Central Africa. *ODI Wildlife Policy Briefing No. 3*, Overseas Development Institute, London, UK.
- Victor M., Lang C. and Bornemeier J. (1998) Community forestry at crossroads: reflections and future directions in the development of community forestry. *Proceedings of International Seminar, RECOFTC, Report No.16*, Bangkok, Thailand, 17-19 July 1997.
- Warner K. (2007) Big trees for little people: Managing forests for poverty reduction. In: *A cut for the poor*, Obendorf R., Durst P. B., Mahanty S., Burslem K. and Suzuki R. (Eds.), RAP Publication 2007/09, RECOFTC Report No. 19, FAO, Bangkok, pp. 10-18.
- Wiersum K. F. (1997) Indigenous exploitation and management of tropical forest resources: An evolutionary continuum in forest people interactions. *Agric. Ecosyst. Environ.*, **63**: 1-16.
- Wilkie D. and Godoy R. (1996) Trade, indigenous rain forest economics and biological diversity, model predictions and directions for research. In: *Current Issues in Non-timber Forest Products Research*, Ruiz Perez M. and Arnold M. (Eds.), CIFOR, Indonesia, pp. 83-102.
- Williams M. (2002) *Deforesting the earth: From prehistory to global crisis*, University of Chicago Press, Chicago, USA, p. 715.
- Yokoyama T. (1963) Sericulture. *Annu. Rev. Entomol.*, **8**: 287-306.



THE SOCIOECONOMIC WORTH OF SILK FARMING

K. Sashindran Nair

National Silkworm Seed Organization, Central Silk Board, Ministry of Textiles,
Govt. of India, Bengaluru 560068, India.
Email: nairjula@yahoo.com

ABSTRACT

Natural fibres and man-made fibres are now being compared head on giving substantial importance to sustainability during the production and usage. Often the sustainability index thus worked out is used to promote the fibre and apparels made out of them. The latest development of man-made fibres being promoted as more sustainable than the natural fibres by industry inside groups or associations is disturbing. Silk which is traditionally considered as an excellent natural fibre type has been recently labeled as the least sustainable fibre among all the natural and man-made fibres by Sustainable Apparel Coalition's The Higg Material Sustainability Index based on tailor-made Life Cycle Assessment studies. The article examines the fault lines in such assessments and points to the need for more comprehensive life cycle assessments giving ample importance to the socioeconomic worth of the fibre which may possibly lead to a totally different and pleasant result.

In the changed context of environmental awareness, fashion statements and clothing options are influenced more by extraneous non-visible factors rather than comfort and appearance. Clothes made of natural fibers in general and silk in particular catch the imagination of users across social strata and more so by the elites. In the global arena, silk is valued high and considered as the 'Queen of Textiles'.

People's Republic of China has been the leading country in the world, producing raw silk and India remained at a far distant second position. Interestingly, India has been consistently growing at an annual rate of close to 7 % during the last 10 years from 18370 MT in the year 2010 to 35820 MT in 2020. On the contrary, China has been de-growing from 115000 MT in the year 2010 to 53359 MT in 2020, on the way touching the peak of 170000 MT in the year 2015. The numbers make it clear that China and India will continue to hold the top two positions in raw silk production for the years to come.

In comparison with other natural textile fibers, silk occupies only a very small slice of the world trade. The share of silk in the global textile market is in fact less than 0.2 %. Though the volume of silk trade is low, the value of international trade in silk and silk products is significant. For the silk producing countries, silk assumes importance owing to its socioeconomic impact on large silk farming population. Any loss of confidence in silk products by the users in European and US markets would have serious implications on the livelihood of many rural people. This may not be purely because of the shrinking export market alone but the influence of the global campaign among the domestic users as well.

Of late, the world apparel and fashion industry, under the aegis of Sustainable Apparel Coalition (SAC) is consistently making efforts to impress up on the customers and make them believe that the textile products made from synthetic fibers are more sustainable than that from natural fibers. The Industry insiders of large corporates form

pressure groups with seemingly innocuous declarations but with covert agenda of selling their products on premium pricing on the label of products manufactured out of sustainable fiber, which are predominantly man-made. In the process, to highlight the falsely perceived benefits rooted in sustainability, Life Cycle Assessment (LCA) studies are resorted to which are not based on the prescribed international guidelines. Interestingly, these LCA studies are limited to cradle-to-gate instead of the more inclusive and meaningful cradle-to-cradle or even cradle-to-grave. Such assessments must be as per the guidelines of International Organization for Standardization (ISO) and the Product Environmental Footprint Category Rule (PEFCR) of EU. It is of great concern that the users are deliberately made to believe that sustainability is all about adverse impact created during a part of the life cycle of a textile product on nature and such a belief is cleverly used as a marketing tool to influence their purchase behavior.

As advocated by the United Nations Organization, there are 17 identified and declared Sustainable Development Goals (SDGs) to transform the world, building on the principle of 'leaving no one behind'. It is important to attach required importance to all the major SDGs when the sustainability of an industry or a product is assessed. The SDGs, such as no poverty (SDG1), zero hunger (SDG2), gender equality (SDG5), decent work and economic growth (SDG8), industry, innovation and infrastructure (SDG9), reduced inequality (SDG10), responsible consumption and production (SDG12) and partnership to achieve the goal (SDG17) are particularly important while assessing the impact of silk industry. However, this assertion does not in any way belittle the importance of determining and highlighting the environmental impact of textiles including that made from natural fibers and specifically silk fiber. But while comparing the environmental impact of the textiles, the evaluation cannot be based on the data from production alone to differentiate the fiber type, instead the use phase is as important or more important. The impact often gets largely oscillated in favour of silk fiber when the use phase also is included which would otherwise fare poorly. In

this context, it is relevant to examine the socioeconomic impact of silk farming.

Socioeconomic impact of Silk Industry

Production of raw silk from which silk clothes and garments are made, involves farming and industry. Silk farming being a large value chain, employs substantial number of people at each stop. This attractive livelihood opportunity offsets the possible impact of the enterprise to environment to a considerable extent. Livelihood generation is one of the major potentials of silk farming, popularly known as sericulture. Sericulture, over the years has emerged as one of the most important cash crops with minimum investment, low gestation period, high employment potential and highly remunerative return. It is suitable for every section of society regardless of the land holding and age or gender. It is well suited to the agrarian economy of the Tribal populace as well. Silk Farming involves simple technology, which is easy to understand and adopt. It has provided downstream employment and income generation in rural and semi-urban areas, high participation for low-income and socially under privileged groups.

In developing countries, sericulture assumes great significance. High incidence of rural poverty, unemployment and under-employment are prevalent in developing countries of the world. Poverty alleviation requires constant suitable policy interventions and appropriate technological upgradations that can increase productivity without causing any adverse impact on the productive capacity of natural resources. Popularizing rural based industries, such as sericulture has proved to be effective in creating job opportunities and continuous additional cash flow to the households in India and China, which can be replicated in other countries too.

Sericulture involves silkworm raising for the production of raw silk, which is the yarn obtained out of cocoons spun by the lepidopteran insects. The major activities of sericulture comprises of food-plant cultivation to feed the silkworms which spin silk cocoons and reeling the

cocoons for unwinding the silk filament for value added benefits such as processing and weaving.



The sericulture farmers face little hardship in selling of their cocoons at attractive price. The cocoon transaction is organized through Government regulated cocoon markets and hence, chance of exploitation is almost non-existent. As an alternative, direct transaction of cocoons with entrepreneurs who have established automatic reeling machines (ARMs) are also permitted. The demand for cocoons falls rarely and hence, no wild fluctuation occurs in cocoon price. This is one of the reasons for very low attrition rate in sericulture apart from the far better return on investment. Added to this, the technology in use now in sericulture are far more energy efficient. The farmers involved in sericulture are sensitized about the need for judicious consumption of water and energy apart from other inputs, such as chemical fertilizers and pesticides. Silkworm itself makes it sure that pesticide use on mulberry plantation is kept to the minimum and used at low concentration. Because silkworm is quite sensitive, indiscriminate use of pesticides would result in residues in the leaves beyond the safe period leading to larval mortality and crop loss.

Employment Potential

The employment potential in sericulture is huge. 21.50 million persons are engaged in various silk industry activities in the world. It is estimated that silk industry can generate employment at a rate of 14 persons per hectare

of mulberry plantation and throughout the year. No other industry is known to generate such a huge employment opportunity, especially in rural areas. This unique selling point (USP) helps sericulture to position itself as a tool for rural reconstruction.

The distribution of opportunities and returns to various verticals of sericulture practice may not seem equitable in the first glance because 56.8 % of the gross value of silk fabrics flows back to the cocoon growers or the farmers, 6.8 % to the silk reeler, 9.1 % to the twister, 10.7 % to the weaver and 16.6 % to the trader. But a closer look would reveal that flow of return commensurate with the investment and efforts. The opportunities in pre-cocoon sector further gets distributed among the enterprises, such as silkworm egg production, parent cocoon production, commercial young stage larva rearing (chawki rearing) and cocoon production for silk reeling. In the process, the large chunk of income flows back to the villages from the cities.

Capital base and return on investment

Establishment of silkworm seed (egg) production centers (SSPCs) and chawki rearing centers (CRCs) are relatively capital intensive to such an extent that an amount of US\$ 541,00 to US\$ 757,00 is required for establishing a production facility with 1 million silkworm egg production capacity, including the working capital. For the chawki rearing enterprise, someone with 2 acres of chawki mulberry plantation would be investing US\$ 338, 00 including the working capital. The annual return on these investment has been worked out as US\$340, 00 to US\$108,108 and US\$ 541, 00 with cost-benefit ratios of 1:1.32 and 1:1.64, respectively. In contrast, very limited investment is required (excluding cost of land and rearing space) for undertaking mulberry cultivation and silkworm rearing in one acre of irrigated land. The visible advantages here are that mulberry takes only six months to grow for commencement of silkworm rearing. Mulberry once planted will go on supporting silkworm rearing year after year for 15-20 years

depending on the inputs and management provided. Five crops can be taken in a year under tropical conditions. By adopting stipulated package of practices, a farmer can attain net income levels up to US\$1150 per acre per annum, which is considered as very good.

Gender equality

Women constitute over 60 % of those employed in downstream activities of sericulture in India. This is possible because sericulture activities starting from mulberry plantation management, leaf harvesting and silkworm rearing are more effectively handled by the women folk. Silk reeling industry including weaving is largely supported by women.

Takes care of the interest of weaker sections

Sericulture can be practiced by persons with very low land holding. An acre of mulberry garden and silkworm rearing can support a family of three without hiring labour and utilizing only the family labour. Features such as low gestation and high returns make sericulture an ideal programme for weaker sections of the society.



Sericulture is eco-friendly

As a perennial crop with good foliage and root-spread, mulberry contributes to soil conservation and provides green cover. Waste from silkworm rearing is recycled as inputs to garden. This helps in reduction of chemical inputs almost by 50 % and still not affecting the normal

leaf yield. Being a labour intensive and predominantly agro-based activity, involvement of smoke-emitting machinery is minimal. Developmental programmes initiated for mulberry plantation are mainly in upland areas where unused cultivable land is made productive. Mulberry can also be cultivated as intercrop with numerous plantations. Mulberry being a deep-rooted perennial plant, can be raised in vacant lands, hill slopes and watershed areas. Currently, only about 0.1 % of the arable land in the country is under mulberry cultivation.

Better cultivation practices

The improved plantation methods with wider spacing has improved the leaf yield substantially. The water usage is brought down to a considerable extent by adopting micro irrigation (drip irrigation) by which water usage in the mulberry garden is minimum compared to the older practice of flood irrigation. The cases of over irrigation and over fertilization are almost things of the past. Adoption of latest technologies and innovations are helping large number of farmers to optimize the input and output sides so that resources are utilized scientifically. The new plantation method where mulberry is trained to grow as short trees with wider spacing saves water to the extent of 70 % and at the same time, the quality and yield of foliage are not compromised.



It is important to mention here that sericulture is practiced as a dry land farming; 100 % in China and 30 % in India. Through these methods, use of chemical fertilizers and disinfectants is far less than the recommendation and

water usage is understandably nil except the rain water. Though the leaf yield in dry land mulberry is no way near to the yield in irrigated mulberry, the cost economics for the producers continue to remain attractive. In addition, the practice imposes little impact on the environment.

Sericulture satisfies equity concerns

In sericulture, the benefits of value-addition primarily accrue to rural households. As the end-product users are mostly from the higher economic groups, the money flows from high end groups to low end groups and mostly from cities to rural areas. Cases of landless families engaged in cocoon production using mulberry contracted from local farmers are common in many countries.

Summary

On one hand, silk is considered as the most elegant textile in the world with unparalleled grandeur, natural sheen and inherent affinity for dyes, high absorbance, light weight, soft touch and high durability. On the other hand, it stands for livelihood opportunity for millions owing to high employment oriented, low capital intensive and remunerative nature of its production. The very nature of this industry with its rural based on-farm and off-farm activities and enormous employment generation potential has attracted the attention of the planners and policy makers to recognize the industry among one of the most

appropriate avenues for socioeconomic development of many developing countries like India. This situation warrants a more careful approach while dealing with silk fabric. Labeling silk as a less sustainable fabric than the others may be a little premature. This is nothing but belittling the popular belief of considering silk and other natural fibers as environmentally sustainable products, the sustainable existence of which can be traced back to more than 5000 years. Sustainability studies should be more broad based but focused with data collected from different geographical regions and representation from all major silk producing countries. The studies should add not only the use phase of the fiber but also the value of the co-products while attaching considerable importance to the socioeconomic impact of the industry. In such a scenario, the silk fiber would find a much improved and acceptable sustainability score which will help this industry to coexist harmoniously with other natural and man-made textile fibers so that the customers can make more independent and informed purchase decisions.



Sericologia 61 (1&2): 69-73, 2021

This report is a re-publication of the author's article captioned "Silk and the importance of the SDGs" appeared in *Apparel insider-Sustainable Fashion, Financial Insight* (2021), 17: 24-26, with modification after obtaining necessary permission from the original publisher.

Received: 24th June 2021; Accepted: 13th July 2021

Impact of Covid- 19 on the Global Silk Industry and the Way Forward

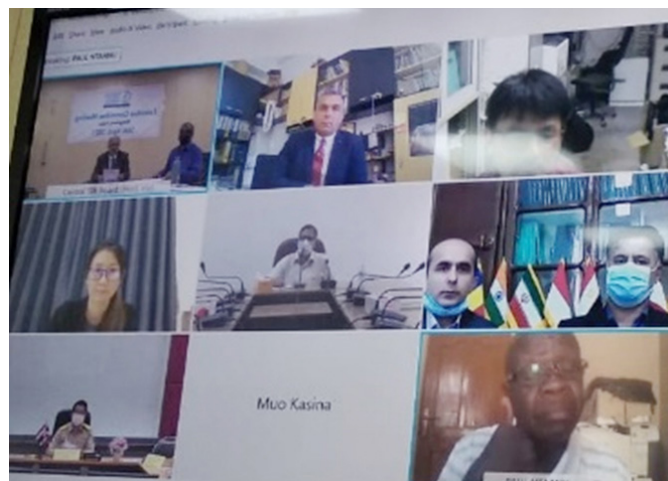
The Covid-19 has created considerable damage to silk industry thereby affecting the livelihood opportunities of more than 22 million people living all across the globe. In order to understand the impact of Covid-19 on the global silk industry, ISC has undertaken an impact assessment study among the silk producing, manufacturing and consuming countries during the period from January to September, 2020. Based on the analysis of the survey inputs and also by including the prevailing issues plaguing the industry, a comprehensive and holistic Plan of Action in 15 major areas have been identified. The entire exercise has been put forth in the form of a booklet and circulated among three hundred identified agencies and individuals associated with the silk industry all across the globe.



Executive Committee meeting of ISC

The Executive Committee (EC) meeting of International Sericultural Commission (ISC) for the year 2021

was held online on 26.04.2021. The EC witnessed the participation of 14 delegates from nine countries. The EC has approved the budget for the year 2021 and also the plan of activities. Apart from the procedural approvals, the EC has extensively discussed on the study undertaken by ISC on the “Fallout of Covid-19 on Sericulture and Silk Industry”, introduction of Higg Index on silk industry, collaboration with International Silk Union, China, creation of a global initiative namely “Natural Fibre Coalition”, organization of 26th ISC Congress at Romania and other issues concerning the development of sericulture and silk industry across the globe.



MoU signed between International Sericultural Commission (ISC) and International Silk Union (ISU)

ISC has signed a Memorandum of Understanding (MoU) with International Silk Union (ISU), China during the Chairman's meeting of ISU held on 10th June, 2021. The major objectives of the MoU are; promote exchange and cooperation between ISU and ISC in the field of silk Industry, exchange of information and resources, taking up collaborative research programmes, exchange visits, *etc.* The MoU was signed by the Secretary Generals of both the organizations. During the meeting, Mr. Rajit Ranjan Okhandiar, Secretary General, ISC has presented a paper entitled "Enhancing Cooperation, Promoting the Global Development of Sericulture and Silk Industry". The meeting, organised in online and offline mode, witnessed the participation of 315 delegates from 28 countries.



International Think Tank Forum on Silk Sustainable Development

The Sustainable Apparel Coalition (SAC), a global consortium of apparel manufacturers and suppliers, has developed an aggregated environmental impact score, namely "**Higg Index**" which unfairly portray silk as an environmentally unsustainable fibre. Since the Higg Index has been creating considerable consternation among the global silk fraternity, ISC has undertaken a detailed study on the Higg Index and found that the method adopted by the SAC is faulty and against the globally accepted standards prescribed by UNEP, ISO and European Commission. As part of this, ISC in coordination with International Silk Union (ISU) has jointly organised the **International Think Tank Forum on Silk Sustainable Development** on 10th June, 2021. The event was held as an offline meet for the Chinese participants and an online meet for other delegates. The Think Tank Forum witnessed the participation of 315 delegates from 28 countries.

Mr. Dileep Kumar R., Programme Coordinator, ISC has presented the Key Note address in the Think Tank Forum with the title: "**The Fallout of Higg**"

Index on Silk and the Way Forward". The Key Note indicated the major flaws of the Higg Index, and an important proposal as the way forward for developing global sustainability standards for silk by undertaking a comprehensive Life Cycle Assessment (LCA) study in the silk producing and consuming countries. The Key Note address was followed by presentation of papers on environmental foot print studies by scientists and technocrats from 18 countries. The idea put forth by ISC has found traction with most of the participants and based on which, a joint declaration namely; **"Proposal for the Comprehensive and Objective Assessment of Life Cycle of Silk Products"** was released as the outcome of the meeting. This document is printed on the succeeding pages of this volume of SERICOLOGIA.



Round Table Meeting on Leveraging FDI Flows for Sustainable Recovery

The ISC HQs represented Silk Sector in the international web Policy Roundtable meeting collaboratively organised by the Institute for studies in Industrial Development (ISID) and United Nation's UNCTAD on **"Leveraging FDI Flows for Sustainable Recovery"** on 29th June, 2021. The Key Note of the meeting was given away by Mr. Richard Bolwijn, Director, Investment Research Branch, UNCTAD, Geneva. The meeting witnessed the participation of more than 93 delegates from India and abroad.



Policy Roundtable on
Leveraging FDI Flows for Sustainable Recovery
World Investment Report 2021

Tuesday, 29th June 2021
from 3.00 PM to 4.30 PM (IST)

zoom
Joining Link: <https://us02zoom.us/j/8686708687>
pwd: 8686708687
Meeting ID: 868 3675 8682
Passcode: 8686708687

Moderator	Presentation	Keynote Address	Distinguished Panelists
 Prof Nagesh Kumar Director, ISID	 Mr Richard Bolwijn Director, Investment Research Branch, UNCTAD, Geneva	 Dr Krishnamurthy Subramanian Chief Economic Advisor, Govt. of India	 Prof Manoj Pant Director, Institute for Studies in Industrial Development Tirunelveli (ISID)  Mr Deepak Bagla MD and CEO, Invest India New Delhi

The panel will be followed by Q&A

iscid.org.in | 800 049 0000 | 21.06.2021

全面客观评价丝绸产品 生命周期倡议书

Proposal for the Comprehensive and Objective
Assessment of Life Cycle of Silk Products

June 10, 2021



近年来，我们关注到可持续服装联盟（SAC）推出了希格材料可持续性指数（Higg MSI），其中关于丝绸面料的环境影响信息存在片面性和不准确性，给国际丝绸行业的生产和消费带来误导，对全球乡村地区、生产企业等数百万利益相关者产生连锁反应。

为了更加全面客观地反映丝绸产品的碳中和性和可持续性，国际丝绸联盟（ISU）联合国际蚕业委员会（ISC）、意大利丝绸协会（UIS）、法国丝绸协会、巴西丝绸协会（ABRASEDA）等多家单位联合发起以下倡议：

In recent years, we have noticed that the Sustainable Apparel Coalition (SAC) has released the Higg Material Sustainability Index (Higg MSI). However, the one-sidedness and inaccuracy of the index on the environmental impact of silk have created considerable confusion and consternation among the global silk fraternity. This may create cascading effect on the livelihood opportunities to millions of stakeholders in the rural areas and producing mills all across the globe.

With a view to reflect the carbon neutrality and sustainability of silk products in a more comprehensive and objective manner, International Silk Union (ISU) joined hands with several organizations, such as International Sericultural Commission (ISC), Ufficio Italiano Seta (UIS), INTERSOIE France and Brazilian Silk Association (ABRASEDA), to table the following proposal:

一、质疑 Higg MSI 对丝绸面料的评分方法

I . To Question the Method of Developing Higg MSI Scoring on Silk

Higg MSI 将丝绸面料的环境影响值评为 1086，是合成面料的 30 多倍，其评分的不合理主要表现为：

1. Higg MSI 对丝绸的生命周期评价仅停留在从蚕桑到面料（即从“摇篮到大门”）的阶段。参照国际标准《ISO 14020:2000 Environmental labels and declarations — General principles》和《ISO 14040:2006 Environmental management — Life cycle assessment — Principles and framework》，对丝绸产品的生命周期评价宜为从“摇篮到坟墓”的研究类型，即涵盖丝绸成衣、丝绸服饰、丝绸家纺产品的生产、使用和废弃处理阶段。丝绸作为“纤维皇后”，其制成品使用周期更长、洗涤次数更少、天然可降解，从“摇篮到坟墓”的研究更具说服力、完整性和科学性。

2. Higg MSI 的评价指标仅包括“全球变暖潜值”“富营养化”、“水资源短缺”、“化石燃料枯竭”和“化学影响”五项指标，应依据“欧盟产品环境足迹种类规则（PEFCR）”，增加评价指标，全面地评估丝绸的资源环境影响。

3. 据相关资料表明，Higg MSI 对丝绸的评分数据来源于 Miguel F. Astudillo 等人在《清洁生产》杂志上发表的“Life cycle assessment of Indian silk”一文。论文数据收集早于 2013 年，缺乏时效性，且用个别国家和地区的数据来评价丝绸的环境影响，不具有代表性和全面性。据了解，该研究是出于完全不同的目的而开展的，并非用于希格指数。

4. Higg MSI 没有公开其计算方法，缺乏社会监督，丝绸生产者对其结果更是不得而知，无从溯源。久而久之，加剧了消费者对丝绸的负面看法，同时也让生产者信心受到重创。

Higg MSI arrived the environmental impact value of silk as 1086, which is more than 30 times worse than synthetic fabric. The irrationality of its scoring was mainly manifested on the following aspects:

1. Higg MSI's assessment of the life cycle of silk only stays at the stage from sericulture to fabric (that is, from "cradle to gate"). Refer to the international standards of ISO 14020:2000 Environmental labels and declarations-General principles and ISO 14040:2006 ISO 14040:2006 Environmental management — Life cycle assessment — Principles and framework, the life cycle assessment of silk products should

be a research type from "cradle to grave", which covers the production, use and disposal of silk ready to wear, silk apparels and silk home textiles. Silk is the "queen of fibers", and its manufactured goods had a long service life and were eventually biodegradable. Therefore, the research from "cradle to grave" is more convincing, complete and scientific.

2. The evaluation indicators of Higg MSI only included "global warming potential", "nutrient pollution in water / eutrophication", "water scarcity", "fossil fuel depletion" and "chemistry". It should be added to comprehensively evaluate the environmental performance according to the Product Environmental Footprint Category Rules Guidance (PEFCR).

3. As manifested by relevant data, Higg MSI's scoring data of silk originated from a paper called Life Cycle Assessment of Indian Silk published by Miguel F. Astudillo *et al.* on the Journal of Cleaner Production. The data in this paper were collected early than 2013, lack of timeliness, and using the data from individual countries or regions to evaluate the environmental impact of silk is not representative and comprehensive. It is understood that the research was carried out for a completely different purpose, not for the Higg Index.

4. Higg MSI didn't and still does not make public its calculation method and is free from social supervision. The silk producers made nothing of the results and cannot trace their origins. By and by, the consumers' negative perception on silk are being intensified and the producers' confidence also severely blown.

二、开展全面客观的丝绸产品生命周期评价

II. To Make a Comprehensive and Objective Assessment of Life Cycle of Silk Products

2015 年，近 200 个国家在“巴黎气候变化大会”上联合通过了《巴黎协定》。多个国家陆续出台了低碳发展战略，中国于 2020 年提出了“2030 碳达峰、2060 碳中和”的目标；英国运用限制和激励两种手段促进温室气体减排，确定低碳电力是低碳发展的核心；法国颁布《控制温室效应国家计划》，明确了减排措施选取和制定原则。

响应全球低碳发展战略，推动丝绸产业健康发展是丝绸学术界、企业界与消费者的共同责任与担当。国际丝绸产业需要一个公开的全面客观的丝绸产品生命周期评价体系，指导丝绸行业的生产和消费。

1. 依据相关国际标准，确定符合现阶段丝绸生产和消费的评价系统边界，开展从种桑养蚕、生产设计、循环使用到废弃处理的全生命周期环境评价，评价结果应符合 ISO14040/14044 要求，并公开解释与使用。

2. 评价样本要具有全面性、代表性和准确性，既要包括中国、印度和乌兹别克斯坦等丝绸主要生产国，也应涵盖欧洲、美国的丝绸生产商和消费者，涉及丝绸生产的缫丝、捻线、织造、印染等关键环节，真实反映国际丝绸产业的生产技术和生产条件，以及消费者的消费行为和消费习惯。

3. 合理划分产业链，对各阶段进行全面深入的清单分析，逐步完善丝绸产品生命周期评价，让更加公开透明、经得起实践考验的评价体系在丝绸行业中广泛应用，提升丝绸行业的环境责任意识。

4. 积极寻求政策支持，充分发挥行业组织和企业的联动性，确保高质量的、有时效性的产业数据运用在评价体系中，客观的反映丝绸产品的环境表现。推进市场导向的绿色技术创新，规范全球丝绸行业的 LCA 研究，制定丝绸产品种类规则（PCR）、行业标准和可持续指数，引导丝绸企业绿色生产。

5. 积极宣传丝绸的可持续性，培育消费者的绿色价值观与绿色消费习惯，充分发挥媒体平台的宣传功能，让消费者全面认识碳中和、可持续和生态环保，打造绿色丝绸产业发展的需求引擎。

In 2015, nearly 200 countries jointly adopted the Paris Agreement at the United Nations Climate

Change Conference in Paris. Many countries have enacted low-carbon development strategies in succession. In 2020, China set out the goal of “achieve peak CO₂ emissions before 2030 and carbon neutrality before 2060”. Britain boosted the reduction of greenhouse gas using two approaches, restriction and incentive, and identified low-carbon electricity as the core of low-carbon development. By formulating the National Programme for the Mitigation of Climate Change, France clearly defined the selecting and formulating principles of emission reduction measures.

It is a joint duty and commitment of the countries, silk academia, business circles and consumers to respond to the global low-carbon development strategies and facilitate the healthy development of silk industry. The international silk industry requires an open, comprehensive and objective assessment system for the life cycle of silk products, to steer the production and consumption of silk industry.

1. It is necessary and impelling to determine the boundaries of the assessment system which confirms to the current production and consumption of silk according to relevant international standards, as well as evaluate its environmental performance in the whole life cycle from sericulture, production, design, use, re-use, up cycling and disposal of silk products. The evaluated sustainability scores are validated by ISO and provided for public use and interpretation.

2. The evaluation sample should be comprehensive, representative and accurate. It should include major silk producing countries such as China, India and Uzbekistan, as well as silk manufacturers and consumers in Europe and the United States, involving the key links of silk production such as silk reeling, twisting, weaving, printing and dyeing, truly reflect the production technology and production conditions of the international silk industry, and the consumer behavior and consumption habits.

3. It is a compelling duty to divide the industrial chain in a rational way, make a comprehensive, deep and transparent as well as really traceable inventory analysis on each stage and gradually improve the life cycle assessment of silk products, so that a more open and transparent evaluation system that withstands the test of practice can be widely used applied the silk industry, and raise the awareness of environmental responsibility of the silk industry.

4. To actively seek policy support, fully exert the linkage between trade organizations and enterprises, allow high-quality and time-sensitive industrial data to be applied to the assessment system and objectively reflect the environmental performance of silk products. Promote market-oriented green technological innovation, standardize LCA research in the global silk industry, formulate Silk Product Category Rules (PCR), industry standards and sustainability indexes, guiding silk enterprises to green production.

5. Last but not least silk needs all of us to take the initiative to cultivate consumers' green values and green spending habits, and give full value to the publicity function of the media platform, so that consumers can fully understand carbon neutrality, sustainability and ecological environment protection, and create a demand engine for the development of green silk industry.

统筹能源资源，倡导绿色低碳，我们有责任共建丝绸绿色家园。国际丝绸行业组织、企业和品牌需要凝聚力量，共谋发展，积极推动全面客观的丝绸产品生命周期评价，让丝绸产业健康持续发展。

Plan energy resources as a whole and advocate greenness and low carbon. We are liable to co-build a green home for silk. Industry organizations, enterprises and brands of International silk should pool efforts, seek common development, propel the comprehensive and objective assessment of the life cycle of silk products, and guarantee the healthy and sustainable development of the silk industry.

INTERNATIONAL SERICULTURAL COMMISSION

An intergovernmental organization instituted in 1960 and registered with United Nations

APPLICATION FOR ASSOCIATE MEMBERSHIP

Name (Personal Associate Membership for Individuals)			
Person In-Charge (Collective Associate Membership for Institutions/Libraries etc)			
Address			
Country			
Tel		Fax	
E-mail			
Privileges Personal Associate Member : Receives Sericologia Collective Associate Member : Receives Sericologia Receives Scientific and Technical information as and when sought Subsidized Registration fee for participation in ISC Congress			

I wish to become a Personal Associate/Collective Associate Member of ISC

New Application

☐

Renewal

☐

Rates : Personal Associate Members
Collective Associate Members

: US\$ 175 per year
: US\$ 470 per year

Applicant's signature : _____ **Date** : _____

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

Beneficiary : International Sericultural Commission

Account No. **3188283389**

Bank & Branch: Central Bank of India, CSB Branch, Bangalore, India

Bank Code: IFSC – CBIN0283975, SWIFT - CBININBBMRB

For overseas transfer

(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 or the references of your Bank Transfer must be mailed to the office of the International Sericultural Commission whose address is given below.

Ground Floor, Central Silk Board Complex, B.T.M. Layout, Madiwala, Bengaluru – 560 068. INDIA Tel: +91 80 26680162,
26282186 | Fax: +91 80 26681663 Email: iscbangalore@inserco.in

www.inserco.org

INFORMATION TO CONTRIBUTORS

SERICOLOGIA is a peer reviewed quarterly scientific journal dedicated to the science of sericulture, published by the International Sericultural Commission. Papers submitted to SERICOLOGIA should carry original contributions of scientific research (basic or applied) or reviews on any aspect of sericulture.

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.

Manuscripts and illustrations must be prepared in British English on a standard A4 size paper setting. It should be typed in 12 point Times New Roman or Arial font in double spacing and single column with well set margins on top, bottom, left and right. Page numbers should be given at the bottom centre of every page.

The typescript should contain the following features:

- **Title** of the paper should be in a 14 point font. It should be bold typed, centered and fully capitalized.
- **Authors'** full name, address, mobile/fixed line numbers, and email/alternate email address should be in 10 point font and centered underneath the title. The first address should be of the centre at which the study was conducted. In the case of multiple ownership, the authors may indicate the correspondence address.
- **Abstract** must be the gist of the paper which should explain the background, aims, methods, results & conclusion in a single paragraph not exceeding 200 words.
- **Key words** should follow the abstract, subject to a maximum of five, arranged in alphabetic order.
- **Main text** should have serially arranged sections such as Introduction, Materials and Methods, Results and Discussion for an effective and systematic presentation of the contents. Acknowledgements may be included if relevant. Only standard abbreviations should be used. Whenever specialized abbreviations are used, it should firstly be given in full with the abbreviation indicated in parenthesis. Scientific names should be given for all species used in the investigation.
- **Tables** should be simple, centered, separately numbered & self explained, and titles must be above the tables. Sources of data if any, should be mentioned below the table. All tables and figures should be referred to in the text.
- **Illustrations:** All necessary illustrations should accompany the manuscript but should not be inserted in the text. Photographs, graphs and diagrams should be numbered consecutively in Arabic numerals in the order in which they are referred to in the

text. Digital/electronic version of the graphs and photographs should be submitted as separate files. Graphs should be in excel format. Photographs should be of high resolution in jpeg format. Legends to figures should be typed on a separate sheet and not at the back of the original.

- **References:** In the text, the referencing pattern should be as Dupont (1964)/ (Dupont, 1964)/ Dupont and Durand (1964) or (Dupont and Durand, 1964). When a citation includes more than two authors, *e.g.*, Dupont, Durand and Martin, the paper should be cited in the text as Dupont *et al.* (1964) or (Dupont *et al.*, 1964). If papers by the same author(s) in the same year are cited they should be distinguished by the letters a, b, *etc.* following year of publication.
- At the end of the text, the list of references prepared following Harvard Style of Referencing should be alphabetically arranged. References not cited in the text should not be included. References should be cited in the following pattern:

Dollo M., Samal P. K., Sundriyal R. C. and Kumar K. (2009) Environmentally sustainable traditional natural resource management and conservation in Ziro Valley, Arunachal Himalaya, India. *J. Am. Sci.*, **5**:41–52.

Ceci S. J., Williams W. M. and Barnett S. M. (2009) Women's underrepresentation in science: Sociocultural and biological considerations. *Psychol. Bull.*, **135**: 218–261.

Russell E. W. (1961) Soil conditions and plant growth. (9th edition), John Wiley and Sons, New York.

Power J. F. (1990) Fertility management and nutrient cycling. In: *Dry land agriculture, strategies for sustainability. Advances in soil science*, Singh R. P., Parr J. F. and Stewart B. A. (Eds.), Springer Verlag, New York.

Fagoonnee I., Schmuterer R. and Ascher K. R. S. (1987) Use of neem in vegetable crop protection in Mauritius. *Proceedings of the 3rd International Neem Conference*, Nairobi, Kenya, 10-15 July, 1986, pp. 419-429.

Online Resources: Always indicate the date that the source was accessed, as online resources are frequently updated or removed.

Printing

Print-ready proof is sent electronically. Corrections to proof should be restricted to printer's errors only. The author should take a printout of the proof, mark the corrections legibly in red ink and send by speed post within 3 days of receipt. Alternatively, scanned images of the corrected proof can also be sent via email. If corrections are minimum, it may be indicated page-wise, column-wise and line-wise and intimated to the Chief Editor via email. If there are no corrections, the same may also be intimated to the Chief Editor.

Reprints

Sericologia sends the reprints electronically in the form of PDF to the principal or corresponding author.

The articles should be submitted in duplicate along with the soft copy to the Chief Editor, Sericologia, International Sericultural Commission, I Floor, Central Silk Board Complex, BTM Layout, Madiwala, Bengaluru - 560068, INDIA.

Tel: +91 80 26282191, Fax: +91 80 26681663, E-mail: sericologia@gmail.com, www.inserco.org



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