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Content

Volume 58 | Number 1 | 2018

Review Paper

Diversity and functional role of gut microbiota of silkworm, *Bombyx mori* L.

Diversite et role fonctionnel du microbiote intestinal chez le ver a soie, *Bombyx mori* L.

Y. Thirupathaiah, E. Bhuvaneswari, P. V. Vijayanthi, Vineet Kumar and V. Sivaprasad

1

Research Papers

A novel approach for prevention of exfoliation problems associated with imported dupion silk yarn

Une approche nouvelle pour prevenir les problemes d' exfoliation associes aux fils de soie doupion importes

M. A. Joseph, K. Jaganathan, Sangappa Shillin, Basavaraja C. Herakal and Subhas V. Naik

12

Impact of age and size of host on the reproductive performance of an ecto-pupal parasitoid, *Trichomalopsis uziae* Sureshan & Narendra Kumar

Impact de l' age et de la taille de l'hote sur la performance reproductive d'un parasitoide pupal, *Trichomalopsis uziae* Sureshan & Narendra Kumar

J. B. Narendra Kumar and D. Manjunath

17

Assessment of host plant suitability for best silk production efficiency and post cocoon attributes of *Antheraea mylitta* in Uttarakhand

Evaluation de la pertinence de la plante hote pour une meilleure efficacite de la production de soie et les caracteres post-cocon chez *Antheraea mylitta* en Uttarakhand

Narendra Kumar Bhatia

28

Cost subvention to young stage silkworm rearing entrepreneurs and the corresponding surge in bivoltine raw silk production in southern India

Cout des subventions aux eleveurs de jeunes vers a soie et mortee correspondante de la production de soie grege bivoltine en Inde du sud

K. Sashindran Nair, H. S. Phaniraj, G. Srinivasa, P. K. Kalpana and R. K. Mishra

48

Bridging of gaps in adoption of drought management technologies in mulberry cultivation in drought prone areas of south India

Comblement des fosses dans l'adoption des technologies de gestion de la secheresse pour la culture du murier dans les aires soumises a la secheresse en Inde du sud

*A. Mahimasanthi, S. Rajaram, A. G. K. Daniel, M. Vidyunmala, K. Vedavyasa,
M. N. Morrison and V. Sivaprasad*

55

Technical Report

Enhancing income generating projects (IGPs) in a sericulture R & D management set-up: The DMMMSU-SRDI experience

Projets pour generer l'augmentation des revenus (IGPs) dans la mise en place d'une gestion R&D: l'experience DMMMSU-SRDI

Angelina T. Gonzales

64



Tropical tasar silkworm affected by bacteriosis



DIVERSITY AND FUNCTIONAL ROLE OF GUT MICROBIOTA OF SILKWORM, *BOMBYX MORI* L.

Y. Thirupathaiah*, E. Bhuvaneswari, P. V. Vijayanthi, Vineet Kumar and V. Sivaprasad

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ABSTRACT

Gut microbiota plays an important role in host nutrition and immunity against pathogenic organisms in most of the vertebrates and in some species of invertebrates by adopting different mechanisms. However, relatively less information is available about the diversity, ecology and function of gut microbiota of the mulberry silkworm, *Bombyx mori* L. The physiological activity of silkworm is often reflected by its genetic constitution, microbes present in the gut, nutritional (quality of mulberry leaves) and environmental factors. Recent studies have also demonstrated that silkworm gut microbes could synthesize and produce extracellular enzymes, vitamins, metabolites, antimicrobial substances and antioxidants, which help in digestion and absorption of nutrients inhibiting colonization of pathogenic micro-organisms and stimulating host immune response. With the advancement in meta-genomic approaches to identify novel microbial species, focus on *Bombyx mori* L., gut microbiome using such tools would help to develop innovative strategies for boosting silkworm growth, development, defense mechanism and thus improving silk production and quality. In addition to improving silk productivity and immune response, identification of indigenous probiotics and their transfer into silkworm gut would help in the syngenical development of climate resilient breeds with improved silk productivity.

Key words: *Bombyx mori* L., gut microbiota, metagenomics, probiotics, silkworm.

INTRODUCTION

Microorganisms evolved on the earth about 3.6 billion years ago, since then, microbes have been diversifying and adapting themselves to almost every habitat on the planet. They co-evolved with all kinds of living organisms and adapted to those life forms. The amazing diversity of the micro-organisms is displayed with remarkable metabolic capabilities, which are directed by their flexible genetic programme. The symbiotic association between microbes, plants and animals began even during the early phase of eukaryotic evolution and continued throughout the evolutionary journey of life on the earth, of course, there is a doubt on these little bugs whether they might have played any role while silkworm made a selective choice of mulberry as its host. The present understanding of silkworm gut microbiota and future research on both

silkworm and mulberry microbiome may provide exact role of gut microbes in silkworm, *Bombyx mori* L. (*B. mori*). If it might have evidenced, the same would be one of the prime examples for the commercially exploited microbe, plant and insect symbiotic system.

The silkworm, *B. mori* L. is an economically important domesticated insect for production of silk. The quantity and quality of silk produced depends on the silkworm race, climatic condition, and overall physiological function of silkworm as well as mulberry leaf quality including its nutrient status. Preliminary studies assumed that, microbiota found in the midgut of the silkworm larvae may influence the nutrient absorption/nutrient utilization or incidence of diseases. The silkworm midgut is the primary site for digestion and absorption of food and hosts diverse microbial populations, which could perform a vital role in

optimizing functional capabilities to produce silk. Some of the bacterial species present in the gut provide better digestibility and render tolerance to diseases caused by various micro-organisms. The contribution of gut micro-organisms to silkworm function is highly relevant from several perspectives such as growth, development, disease resistance and silk production. Gut communities associated with silkworm may vary based on environmental conditions or geographical location and generally one or a few bacterial taxa may be shared across most of the silkworm races.

Culture-based techniques allow growing only a proportion of gut bacterial species severely limiting knowledge of the microbial communities of a silkworm midgut. In addition, the majority of the silkworm gut microbes are unculturable, molecular analyses have gradually been revealing their diversity and symbiotic mechanisms. In order to elucidate the functions of these unculturable symbionts, such as nutrition, growth, development, physiology, behaviour, environmental adaptation and barrier against microbial pathogens, it requires a metagenomic approach (Krishnan *et al.*, 2014). Microbiome studies by the metagenomic approach are usually characterized by next-generation sequencing of 16S rRNA genes or whole genome sequencing of silkworm gut bacteria. Such comprehensive analyses will be expected to provide insights into the total diversity and metabolic activity of silkworm-associated microbial communities that have not been revealed by previous studies. Further, the gut bacteria of other insects *viz.*, honey bee, termites and *Drosophila* have also been shown to contribute towards nutrition, protection from parasites and pathogens, modulation of immune responses and communication. The extent of these roles is still unclear and awaits further studies in silkworm, *B. mori* L.

Gut structure of silkworm, *B. mori* and its microbes

The silkworm gut is inhabited by a wide range of micro-organisms which varies with constituting intestinal compartments and its internal environmental condition. The silkworm gut has three distinct regions: foregut,

midgut and hindgut. Ingested mulberry feed along with micro-organisms are transferred passively from the mouth to the region of the foregut (Chapman *et al.*, 2013). The foregut is covered with an exoskeleton made up of chitin and cuticular glycoproteins. As foregut exoskeleton shed at each moult, it cannot maintain any stable microflora within the region. However, it can continuously expose to diverse microbial species associated with mulberry leaf and surrounding environment through silkworm mouthparts (Figure 1).

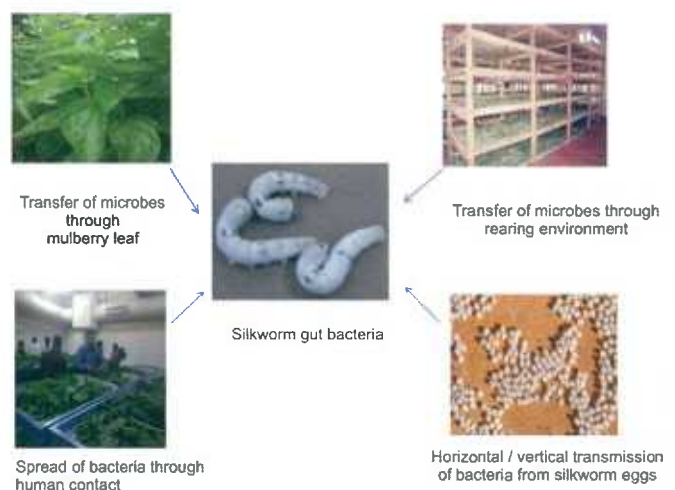


Figure 1: Possible source of silkworm gut microbial communities

The midgut is the main site for food digestion and absorption and is devoid of an exoskeleton but, covered with the peritrophic matrix made up of chitin, proteins and proteoglycons, which are continuously replaced during moulting, allowing microbes to be temporarily colonized (Engel and Moran, 2013). The peritrophic matrix divides the midgut into the endo- and ectoperitrophic spaces, and micro-organisms are usually found in the endotrophic space. Micro-organisms enter midgut along with food and are thought to play an important role in digestion and metabolism (Figure 2). Peritrophic matrix usually protects from colonization of micro-organisms to midgut epithelial cells and its invasion. However, peritrophic matrix is transiently punctuated by mechanical (food particles) or chemical stress and allows micro-organisms to colonize in

midgut epithelial cells (Spence and Kawata, 1993; Edwards and Jacobs-Lorena, 2000). Midgut of *B. mori* larvae is characterized by extreme alkalinity, with a pH as high as 11-12 (Harrison, 2001). The extreme condition also adversely affects the growth and colonization of most microbial communities and excludes most bacteria. Moreover, extreme alkalinity in midgut may not entirely prevent microbial colonization but, instead, supports the growth of alkaline-tolerant bacterial and fungal species particularly *Firmicutes*, *Clostridium*, *Planctomycetes* and *Microsporidians* (Bignell, 2010). Presence of low oxygen levels in the midgut of *B. mori* makes it a favorable environment for facultatively anaerobic micro-organisms (Johnson and Barbehenn, 2000).

Hindgut is also covered with an exoskeleton as similar to foregut, which is shed down in each molt along with its micro-organisms. The hindgut contains a combination of nitrogenous waste such as urea, uric acid and food waste, creating a nutritive and fermentative environment for any remaining gut bacteria. At the end of the fifth instar, silkworm eliminates its entire larval gut, along with its micro-organisms and other contents. There is no evidence of direct transfer of symbiotic micro-organisms between

hosts or on their transmission to upcoming generations through the eggs, however, microsporidians are transmitted from one generation to another through eggs of *B. mori*.

Diversity of gut microbiota of silkworm, *B. mori* L.

The micro-organisms in mulberry silkworm gut consist of protists, fungi and bacteria but due to adverse alkaline conditions prevailing in the gut region, only bacterial species can adapt dominantly. However, most of the *B. mori* L. gut microbiota studies focussed on bacterial 16S rRNA gene primers, possibly biasing views of the composition of gut communities. In *B. mori*, almost all gut micro-organisms are acquired through environment as considered to be gut symbionts and not transmitted through eggs as heritable symbionts, and these gut communities are dominated by widely distributed bacteria prevailing in the surrounding environment or mulberry leaf flora that appear to colonize silkworm opportunistically. The environmentally acquired bacteria, whether pathogenic or beneficial, may have specific adaptive interaction to the physicochemical conditions of gut compartments, such as pH, redox potential and availability of particular substrates (Ruby *et al.*, 2004; Wier *et al.*, 2010). Such physical and chemical conditions may play the selective adaptation of silkworm gut bacteria that are acquired independently from environment each generation, therefore, these gut communities are not expected to be random assemblages of microbial species from the food or local environment. However, *B. mori* gut bacterial communities vary among individuals and appear to consist largely of bacteria with an average bacterial concentration of 7.1×10^7 CFU ml⁻¹, ranging from 5.6×10^7 to 9.9×10^7 CFU ml⁻¹ (Tang *et al.*, 2012; Liang *et al.*, 2015). Based on metagenomic studies, silkworm gut usually contains 23 to 35 different bacterial species which range from aerobic bacteria to facultative anaerobes (Liang *et al.*, 2015).

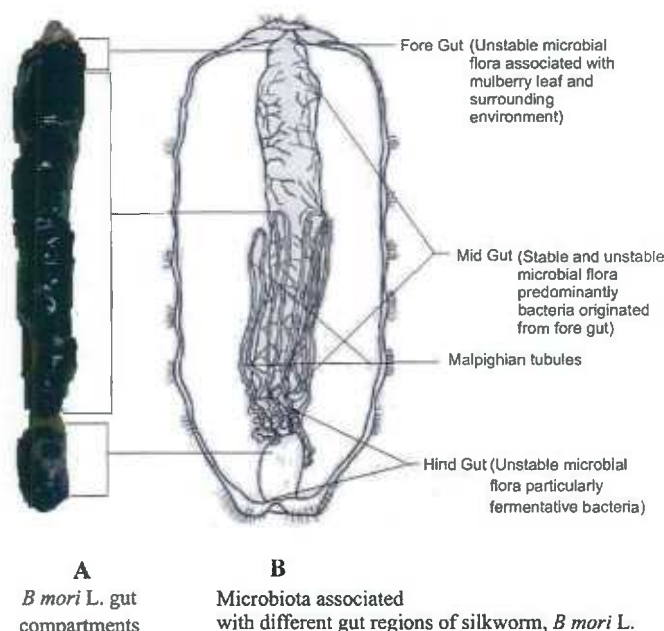


Figure 2: Main compartments of silkworm gut versus microbial interactions

Yuan *et al.* (2006) identified the main bacteria species in the intestinal tract of the *B. mori* as *Arthrobacter*, *Lactobacillus*, *Escherichia*, *Pseudomonas*, *Bacillus* and

Table 1: Diversity of gut bacteria in silkworm, *B. mori* L.

Bacterial group / Genus / Species	Technique / Method	Reference
<i>Arthrobacter</i> , <i>Lactobacillus</i> , <i>Escherichia</i> , <i>Pseudomonas</i> , <i>Bacillus</i> and <i>Staphylococcus</i> .	Culture dependent method followed by PCR.	Yuan <i>et al.</i> (2006)
<i>Microbacterium oxydans</i> and <i>Rhodococcus</i> sp.	Conventional culture dependent methods.	Tian <i>et al.</i> (2007)
<i>Bacillus subtilis</i> , <i>Pseudomonas fluorescens</i> and <i>Streptomyces noursei</i> .	16s rRNA probes	Subramanian <i>et al.</i> (2009)
<i>Bacillus circulans</i> , <i>Proteus vulgaris</i> , <i>Klebsiella pneumoniae</i> , <i>Escherichia coli</i> , <i>Citrobacter freundii</i> , <i>Serratia liquefaciens</i> , <i>Enterobacter</i> sp., <i>Pseudomonas fluorescens</i> , <i>P. aeruginosa</i> , <i>Aeromonas</i> sp. and <i>Erwinia</i> sp.	Culture dependent methods	Anand <i>et al.</i> (2010)
a) <i>Aeromonas</i> , <i>Citrobacter</i> , <i>Brevibacterium</i> , <i>Klebsiella</i> and <i>Corynebacterium</i> (fed with mulberry leaves).	Culture dependent method followed by 16s rRNA gene sequence.	Feng <i>et al.</i> (2011)
b) <i>Pseudomonas</i> and <i>Agrobacterium</i> (fed with <i>Tricuspid cudrania</i> leaves).		
c) <i>Brevundimonas</i> , <i>Stenotrophomonas</i> , <i>Enterobacter</i> and <i>Staphylococcus</i> (common in both types of diet).		
<i>Bacillus pumilus</i> , <i>B. atrophaeus</i> , <i>B. licheniformis</i> and <i>B. amyloliquefaciens</i> .	Culture dependent methods followed by biochemical characterization.	Subramanian <i>et al.</i> (2009), Ceuppens <i>et al.</i> (2013)
<i>Acinetobacter</i> and <i>Bacteroides</i> (Bioregenerative way of rearing).	16s rDNA sequence and DGGE	Liang <i>et al.</i> (2015)
<i>Bacillus</i> and <i>Arcobacter</i> (Traditional way of rearing).		
<i>Bacteroides</i> , <i>Chryseobacterium</i> , <i>Clostridium</i> , <i>Enterococcus</i> , <i>Porphyromonas</i> , <i>Paenibacillus</i> , and <i>Devosia</i> (common in both types).		
<i>Enterococcus</i> , <i>Delftia</i> , <i>Pelomonas</i> , <i>Ralstonia</i> and <i>Staphylococcus</i> .	16s rRNA gene sequence	Sun <i>et al.</i> (2016), Pandiarajan and Krishnan (2018)
<i>Enterococcus</i> , <i>Bacillus</i> and <i>Lactobacillus</i> .	Metagenomic analysis of 16s V3-V4 region.	Thirupathaiah <i>et al.</i> , 2018

Staphylococcus. But, *Enterococcus*, is a predominant bacterium in the silkworm gut (Xiang *et al.*, 2007). Further, *Microbacterium oxydans* and *Rhodococcus* sp. were also isolated from silkworm digestive tract (Tian *et al.*, 2007). Subramanian *et al.* (2009) reported *Bacillus* group (*Bacillus pumilus*, *Bacillus atrophaeus*, *Bacillus licheniformis*, and *Bacillus amyloliquefaciens*) in the mid gut of indigenous silkworm breeds and observed that, *Bacillus* is a functionally important beneficial microbial group. Further, they also developed 16s rDNA probes for the identification of a few bacterial species such as *Streptomyces*, *Pseudomonas fluorescens* and *Bacillus subtilis* to characterize gut microflora of *B. mori* breeds

(Subramanian *et al.*, 2009) (Table 1).

Microbial community studies based on 16S rRNA gene sequences of silkworm *B. mori* gut revealed that it is dominated by genus *Enterococcus*, *Delftia*, *Pelomonas*, *Ralstonia* and *Staphylococcus* (Sun *et al.*, 2016). Interestingly, Feng *et al.* (2011) reared silkworm larvae with different types of leaves and studied bacterial profile and reported five phylotypes including *Aeromonas*, *Citrobacter*, *Brevibacterium*, *Klebsiella* and *Corynebacterium* whereas, genus *Pseudomonas* and *Agrobacterium* were found in larvae fed with tricuspid cudrania leaves. Similarly, genera *Brevundimonas*,

Table 2: Functional role of gut microbiota of silkworm, *B. mori* L.

Bacterial group / Genus / Species	Technique / Method	Reference
<i>Enterobacteriaceae</i>	Carbohydrate metabolism.	Anand <i>et al.</i> (2010)
<i>Protius vulgaris</i> , <i>Klebsiella pneumonia</i> and <i>Citrobacter freundii</i>	Cellulose digestion by producing cellulases	Anand <i>et al.</i> (2010)
<i>Bacillus</i> , <i>Brevibacterium</i> , <i>Corynebacterium</i> , <i>Staphylococcus</i> , <i>Klebsiella</i> , and <i>Stenotrophomonas</i>	Lipase production.	Feng <i>et al.</i> (2011)
<i>Bacillus pumilus</i> , <i>B. atrophaeus</i> , <i>B. licheniformis</i> and <i>B. amyloliquefaciens</i>	Amylase and protease production,	Subramanian <i>et al.</i> (2009)
<i>Proteus vulgaris</i> , <i>Klebsiella pneumonia</i> , <i>Escherichia coli</i> , <i>Aeromonas</i> sp. and <i>Citrobacter freundii</i>	Cellulolytic and xylanolytic.	Vitthalrao <i>et al.</i> (2012)
<i>Pseudomonas fluorescens</i> and <i>Erwinia species</i>	Pectinolytic.	Vitthalrao <i>et al.</i> (2012)
<i>Klebsiella pneumonia</i>	Amylolytic.	Vitthalrao <i>et al.</i> (2012)
<i>Enterococcus</i>	Reduction of gut pH and suppression of <i>Nosema bombycis</i> germination.	Takizawa and Iizuka (1968); Lu and Wang (2002)
<i>Escherichia coli</i>	Induces the production of antimicrobial peptides in the gut.	Wu <i>et al.</i> (2010)
<i>Acinetobacter</i> , <i>Bacteroides</i> , <i>Bacillus</i> and <i>Arcobacter</i>	Changes with type of leaf fed.	Liang <i>et al.</i> (2015)
<i>Enterococcus</i> , <i>Delftia</i> , <i>Pelomonas</i> , <i>Ralstonia</i> and <i>Staphylococcus</i>	Reduces the <i>BmCPV</i> infection.	Sun <i>et al.</i> (2016)
<i>Lactobacillus</i> and <i>Saccharomyces cerevisiae</i>	Probiotic application for <i>Bombyx mori</i> .	Singh <i>et al.</i> (2005), Esaivani <i>et al.</i> (2014)
<i>Enterococcus</i> and <i>Staphylococcus</i>	Increased bacterial count after exposure to high temperature.	Sun <i>et al.</i> (2017)
<i>Saccharomyces cerevisiae</i> and <i>Bifidobacterium bifidum</i>	Supplemented as probiotics improved the economic traits in <i>B.mori</i> hybrid	Rehab <i>et al.</i> (2017)

Stenotrophomonas, *Enterobacter* and *Staphylococcus* are common in silkworm larvae fed with two types of leaves. Similarly, Liang *et al.* (2015) conducted an experiment to compare the differences in bacterial communities of the silkworm larval gut between the BLSS rearing way (BRW) and the traditional rearing way (TRW) through culture-dependent approach, 16S rRNA gene analysis and denaturing gradient gel electrophoresis (DGGE). Based on their findings, *Acinetobacter* and *Bacteroides* were dominant populations in the BRW, whereas, *Bacillus* and *Arcobacter* dominated in the TRW. Additional species found in the above study were *Enterobacter* sp., *Pectobacterium carotovorum* sub sp. *Carotovorum*, *Aeromonas hydrophila* sub sp. *Dhakensis*, *Lysobacter* sp.,

uncultured *Moraxellaceae* bacterium, *Alcaligenes* sp., *Pseudomonas fluorescens*, *Microbacterium oxydans*, *Rhodococcus* sp. and *Pantoea* sp. Seven genera such as *Bacteroides*, *Chryseobacterium*, *Clostridium*, *Enterococcus*, *Porphyromonas*, *Paenibacillus* and *Devosia* were common in both the samples. One study stated that, the bacterial flora may also change in each instar, the fourth and fifth instar silkworm gut microbiota had a differentiation to the extent of 46.5 %, exhibiting prominent difference in population and diversity in different instars, *Aeromonas* was found in the fifth instar, not in the fourth instar of silkworm fed on mulberry leaves (Kalpana *et al.*, 1994). Each investigation has demonstrated different kind of bacterial sp., which

silkworm would acquire independently from feed or environment in each generation.

The above mentioned studies on the diversity of bacterial communities in the silkworm gut resorted to analyses by using both culture-dependent and culture-independent methods. However, culture-dependent methods often stated biased results, but culture-independent molecular approaches based on analysis of the 16S rDNA sequences have yielded a better and more comprehensive picture of bacterial communities and have resulted in a dramatic improvement in understanding of the microbes living within the gut of mulberry silkworm. Recently, great progress in characterizing the structure of the silkworm gut microbiome has paved the way for ongoing and future studies on the functional interactions between the microbiota and the host (Andrew *et al.*, 2015). A very recent metagenomic study concluded that, *Enterobacteriaceae* family along with proteobacteria and firmicutes reside in the gut of *B. mori* L. particularly, the *Enterococcus mundtii* (Pandiarajan *et al.*, 2018). Based on the previous studies of silkworm mid gut bacterial communities, it is understood that, the diversity of silkworm gut bacteria change, depending upon the growth conditions, climate, race, developmental stage, region, diet and techniques used. None of the studies have focused on endosymbiotic bacteria or the heritable symbionts in the silkworm gut. However, one of the very recent metagenomic studies (Thirupathaiah *et al.*, 2018) indicated that, the bacterial diversity in silkworm, *B. mori* gut was found to be less than the expected. The predominant mid gut bacterial genera in mulberry silkworm of popular Indian races had *Enterococcus*, *Bacillus* and *Lactobacillus* (Thirupathaiah *et al.*, 2018).

Functional roles of gut microbiota of silkworm, *B. mori* L.

Mulberry silkworm is a well known, commercially important lepidopteran that feeds only on the mulberry leaves. Despite the ecological and economical importance of *B. mori*, the role of their microbial gut symbionts for its health and nutrition is unknown. It is

understood that the silkworm genetic machinery alone is not sufficient to utilize and assimilate all the macromolecules present in the mulberry leaf and to synthesize key cofactors (Cobalamin) as well as additional metabolites to support its life process. Earlier, it was assumed that micro-organisms play a little role in nutrition and digestion of mulberry silkworm (Appel and Martin, 1990; Bignell and Eggleton, 1995). But, further investigations have evidenced that mid gut of *B. mori* contain bacteria which produce digestive enzymes that help in digestion of mulberry leaf constituents such as cellulose, xylan, pectin and starch (Dillon and Dillon, 2004).

i) Role of silkworm gut bacteria in the digestion of mulberry leaf and nutrient assimilation

Mulberry silkworm is often dominated by *Enterobacteriaceae*, which could play a key role in carbohydrate metabolism (Anand *et al.*, 2010). As silkworm genetic machinery does not find any gene for cellulase, it is assumed that cellulose of mulberry leaf component is digested by the gut symbiotic bacteria such as *Enterobacteriaceae*, *Protius vulgaris*, *Klebsiella pneumonia* and *Citrobacter freundii* (Ross *et al.*, 1991; Lynd *et al.*, 1999; Pytelkova *et al.*, 2009; Anand *et al.*, 2010; Watanabe and Tokuda, 2010). Nevertheless, it has been suggested that concentration of cellulose and the digestive action of cellulase are modulated in the two compartments of the digestive system (gut wall and digestive fluid), synergistically both by the host organism and the symbiotic microbes (Hongoh *et al.*, 2008; Liu *et al.*, 2008; Bhuvaneswari *et al.*, 2013). Based on comparative genomic studies of *B. mori* midgut isolates such as *Escherichia coli* and *Pseudomonas*, it is understood that they could play key role in cellulose synthesis and cellulose digestion (Amikam and Benziman, 1989; Romling, 2002). Feng *et al.* (2011) isolated and characterized several lipase-producing bacterial strains from silkworm gut and classified them into six genera, including *Bacillus*, *Brevibacterium*, *Corynebacterium*, *Staphylococcus*, *Klebsiella* and *Stenotrophomonas* (Table 2). One of the previous studies

also suggested that *Bacillus pumilus*, *B. atrophaeus*, *B. licheniformis*, and *B. amyloliquefaciens* in the gut of indigenous silkworm breeds were functionally important beneficial microbes, which can be developed as new probiotic formulations for enhancing the growth and development of silkworm (Subramanian *et al.*, 2009).

ii) Silkworm gut flora and its immunity

However, several studies showed that silkworm harbors gut bacteria, but a few demonstrated the role of gut bacteria in immune enhancement and disease prevention (Broderick *et al.*, 2004; Xiang *et al.*, 2006; Gao *et al.*, 2007; Anand *et al.*, 2010; Feng *et al.*, 2011). It was concluded that, *Enterococcus* that frequently occur in the *B. mori* L. gut reduces the gut pH which causes the suppression of *Nosema bombycis* germination (Takizawa and Iizuka, 1968; Lu and Wang, 2002). Recent study on the gut microbiota of healthy silkworm and the changes after the infection of BmCP virus (BmCPV) revealed that healthy silkworms are dominated by *Enterococcus*, *Delftia*, *Pelomonas*, *Ralstonia* and *Staphylococcus* whereas, when silkworm is infected by BmCPV, the bacterial diversity in the silkworm intestine is decreased and after the post infection with BmCPV, the abundance of *Enterococcus* and *Staphylococcus* (Gram-positive) increased (Sun *et al.*, 2016). Wu *et al.* (2010) demonstrated that oral administration of *E. coli* induced the production of antimicrobial peptides in the gut. These findings also indicated that activation of defense system in the gut functions to fight silkworm against orally ingested pathogenic bacteria. One of the very recent studies demonstrated that, after transient high temperature exposure to the silkworm, the diversity of intestinal flora of bacterial population was increased, these changes may be attributed to the overall immune response of the silkworm (Sun *et al.*, 2017).

iii) Application of microorganisms for improved silk production

Surprisingly, so far, no studies have been demonstrated on the exact role of silkworm gut bacteria in

silk improvement. In addition, to help mulberry leaf digestion and rendering disease resistance, silkworm mid gut bacteria may play an important role in synthesis of essential co-factors and metabolites. Some of the vitamins exclusively, Cobalamin forms of vitamin B₁₂ cannot be synthesized by silkworm which plays an important role in silkworm physiological function, as it is co-factor of propionate metabolism and important substrate for biosynthesis of juvenile hormone (Halarnkar and Blomquist, 1989). Mulberry leaves does not contain Cobalamin or its derivatives, but considerable amounts was observed in larvae and pupae. It is thought that actinomycetes in the gut lumen might be involved in the production of vitamin B₁₂ (Das and Medda, 1988). Further, they also reported that supplementation of mulberry leaves with B₁₂ vitamin could increase the synthesis of nucleic acids and proteins in the silk glands of the silkworm. Singh *et al.* (2005) demonstrated that supplementation of *Lactobacillus plantarum* during different instars of silkworm larva showed positive results as compared to controls with respect to larval body weight, cocoon weight, shell weight and pupation. Further analysis has to be undertaken on the mechanism of interaction of host native microbiota with the probiotic bacteria and its influence on silkworm physiology and innate immunity. Esaivani *et al.* (2014) were able to produce quality silk by fortification of mulberry leaf with probiotic microorganism, *Saccharomyces cerevisiae* in mulberry silkworm through profound increase in amylase and invertase activities in the digestive juice of the probiotic treated worms. Recently, Rehab *et al.* (2017) also demonstrated that, mulberry leaves supplemented with *S. cerevisiae* (yeast) and *Bifidobacterium bifidum* (bacteria) probiotics improve the larval, pupal, cocoon and shell weight, cocoon shell percentage and silk filament length in silkworm hybrids. Besides revealing insights into beneficial functions governed by the microbiota of this important insect, above findings indicate that *B. mori* L. can serve as a model for understanding more complex gut-associated microbial communities.

Future perspectives and biotechnological application of silkworm gut microbiota

Metagenomics approach would be a valuable tool to

elucidate both the culturable and unculturable microorganisms with an aim of understanding the diversity and functional role of microbial communities in the silkworm mid gut. Moreover, some of the novel gut bacterial species of silkworm can be exploited for biotechnological application, such as the production of novel enzymes, antibiotics and cell signaling molecules. The bacterial strains which play crucial roles in the growth, development and environmental adaptation of the silkworm can be considered to formulate probiotics for commercial production. Interestingly, the silkworm microbiota and their genomes, isolated from silkworm gut source can be recognized as major genetic resources for bio-prospecting industry. Some novel microbial cultures isolated from silkworm gut could be potentially applied as human or animal probiotics and bio-fertilizers (nitrogen fixing bacteria) for agricultural crop improvement. Silkworm gut is highly alkaline in nature, hence it is the potential source for screening of alkaline proteases, amylases and lipase producing microorganism for application in detergent industry. Some of the metabolic end products produced by silkworm gut bacteria might have desirable medicinal properties and can be used as therapeutic agents to combat human diseases. Consequently, the exploitation of silkworm gut microbiome using metagenomic approaches will enable us to find diverse biomolecules and to develop innovative strategies for identifying novel molecules for biotechnological applications.

Conclusion

Based on available literature, silkworm *B. mori* gut environment is often considered as unstable habitat for microbial colonization. Majority of the studies have reported different kinds of microbial species in silkworm gut environment. However, the growing field of *B. mori* and its gut microbiota association offers greater implications to understand its role in the growth, development and environmental adaptation of the host. The complexity, dynamics and types of interactions between the silkworm and their gut microbiota are far from being well understood. One possible mechanism by

which microbes can cause beneficial effects to silkworm is when microbes, particularly bacteria passing through the silkworm gut may be digested due to high alkaline condition or enzymes like lysozyme, then these lysed bacteria may serve as nutrients source, and at the same time, cell wall components may stimulate immune response. Further, understanding of the relationship dynamics between silkworm and their microbiota by both conventional methods as well metagenomic approach can improve in identifying beneficial microbes. Silkworm gut microbiome provides insights into the relationships between silkworms and gut bacterial communities for the development of beneficial microbial cultures (as probiotics) for commercial exploitation for improved silk production. Some of the indigenous probiotics cultures developed from both bivoltine and multivoltine silkworms and their transfer into silkworm gut would help in the syngenical development of climate resilient breeds with improved silk productivity and improved performance. The present review also provides a basis for future research aiming at a better understanding of the diversity and functional roles of mulberry silkworm gut microbiota for its silk production with respect to nutrition and pathogen defense.

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Revue

DIVERSITE ET ROLE FONCTIONNEL DU MICROBIOTE INTESTINAL CHEZ LE VER A SOIE, *BOMBYX MORI* L.

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ABSTRACT

Le microbiote intestinal joue un rôle important dans la nutrition et l'immunité contre les organismes pathogènes chez la plupart des vertébrés et quelques espèces d'invertébrés selon divers mécanismes. Cependant, relativement peu d'information sont disponibles quant à la diversité, l'écologie et la fonction du microbiote intestinal chez le ver à soie *Bombyx mori* L. L'activité physiologique du ver à soie est souvent le résultat de sa constitution génétique, des microbes présents dans l'intestin, des facteurs nutritionnels (qualité de la feuille de mûrier) et environnementaux. Des études récentes ont démontré que les microbes intestinaux peuvent synthétiser et produire des enzymes extracellulaires, des vitamines, des métabolites, des substances antimicrobiennes et des antioxydants qui aident à la digestion et à l'absorption des nutriments en inhibant la colonisation des microorganismes pathogènes et ainsi en stimulant la réponse immunitaire de l'hôte. Avec l'avancée des approches méta-génomiques pour identifier de nouvelles espèces microbiennes, une focalisation sur le microbiome intestinal de *Bombyx mori* L en utilisant de tels outils devrait aider à développer des stratégies innovantes pour pousser la croissance du ver à soie, son développement et ses mécanismes de défense et ainsi améliorer la production et la qualité de la soie. De plus, pour améliorer la productivité de soie et la réponse immunitaire, l'identification de probiotiques indigènes et leur transfert dans l'intestin pourrait aider au développement de lignées adaptées au climat et améliorer la productivité de soie.

Mots-clés: *Bombyx mori* L., microbiote intestinal, métagénomique, probiotiques, ver à soie.



A NOVEL APPROACH FOR PREVENTION OF EXFOLIATION PROBLEMS ASSOCIATED WITH IMPORTED DUPION SILK YARN

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ABSTRACT

The imported dupion silk yarns produced by different silk mills, were noticed to exhibit various degree of exfoliation defect when subjected to conventional degumming. To address this problem, degumming with recipes prevailing in the silk processing industry as well as pressurized degumming by varying the temperature and duration were carried out on an experimental basis. Silk yarn samples degummed under pressurized conditions were more lustrous in appearance and revealed improvement in fullness when compared with the yarn degummed by the conventional process. Further, evaluation of mechanical properties such as tenacity and elongation of the yarn samples degummed by using various recipes including pressurized degumming did not show any significant difference. The degummed yarn samples were further dyed in dark shades and converted into dupion fabrics and evaluated for the defect by the subjective analysis. The results, hence, reveal that the pressurized degumming under controlled conditions can avoid the exfoliation defects bound to happen with silk yarn samples under conventional degumming.

Key words: Dupion silk, exfoliation, HTHP degumming, luster.

INTRODUCTION

Exfoliation of silk is a defect, generally noticed as white dusty appearance, on the yarn/fabric surface after degumming and dyeing process and is more pronounced in certain dark colours. As per the Fairchild Textile Dictionary, (Isabel, 1988) Exfoliation is defined as “A defect in silk yarns or fabrics which may have originated during the reeling process, but it is never visible until degumming. It appears as little knots, tangles, slubs or split fibres which form little specks on the yarn or woven fabric, may be caused by too hot or too prolonged soaking of the cocoons before reeling” (Huang Guo Rui, 1999; Yong - Woo Lee, 1999). Exfoliation defect affects the luster and the general appearance of the silk fabric. This defect makes the new fabrics appear old and hence, reduces the value of the fabric in trading.

is affected since the fabric looks very dull. Though the defect has been reported widely, the industry has taken it in its stride and silently been suffering as the fabric with the exfoliation is considered as defective and is either rejected or its cost have been slashed in export market. Though the defect is generally reported by the manufacturers using the imported silk, it is also noticed on the fabrics woven with the indigenous silk. However, in the domestic market mainly catered by the handloom sector, it is not considered as a very serious defect. Under this backdrop, a systematic study was planned and carried out in an attempt to enhance the quality of silk yarns by addressing and rectifying the issue of exfoliation encountered while processing dupion silk, through appropriate techniques.

MATERIALS AND METHODS

As it reduces the luster of the fabric, the visual appeal

Various silk fabrics displaying exfoliation defects,

were carefully analyzed. Subsequent to this, the different stages of processing of silk yarn were closely monitored right from godown to finished warehouse. We could detect that the exfoliation was magnified and became noticeable only after the degumming & dyeing process. Hence, various degumming recipes practiced in the industry were identified and performed experiments with the silk yarn to confirm the role of degumming recipe and conditions on causing this defect. Further, a novel degumming process using High Temperature and High Pressure (HTHP) condition was also carried out under the degumming experiment. In this study, five lots (D1, D2, D3, D4 and D5) of imported dupion silk samples (hanks of 70- 80 grams) of 160-180 denier, from different mills were used. Yarn samples of the lots which have exhibited the defect earlier were chosen for the study.

The degumming experiments were carried out using the following recipes (Table 1).

Table 1: Recipes used for the degumming experiments

Recipe	Soap Grams / litre (gpl)	Soda ash Grams / litre (gpl)	Material to liquor ratio	Tempera- ture (°C)	Duration (min)
R1	5 (Marseilles Soap)	1.0	1:30	90-95	45-60
R2	5 (Standard soap)	2.0	1:30	90-95	45-60
R3	0.33 (Neutral detergent)	1.7	1:30	90-95	45-60
R4	Nil	Nil	1:10	121	10-15
R5	5 (Palm oil based soap)	1.0	1:30	90-95	45-60

RESULTS AND DISCUSSION

Evaluation of the five dupion lots, D1, D2, D3, D4 and D5 degummed using different recipes coded as R1, R2, R3, R4 and R5 revealed that the degumming recipe plays a major role in the formation of the defect. Out of the five dupion lots degummed, D4 performed very poor followed by D2, D1, D5 and D3. From the recipe point of view, R3 rendered a low performance followed by R5, R2, R1 and R4. It was quite interesting to note that R4 *i.e.*, pressurised degumming method performed well where the samples did not face any exfoliation problem. Even,

the most defective sample *i.e.*, D4 has also delivered grades of very good to excellent results with no exfoliation noticed. Table 2 presents the performance of various recipes with reference to the degree of exfoliation on a five point scale.

Table 2: Performance of various recipes with reference to the degree of exfoliation

Lot No.	Degumming recipe				
	R1	R2	R3	R4	R5
D1	2	2	1	5	3
D2	3	3	2	5	3
D3	4	4	4	5	4
D4	1	1	1	4-5	2
D5	3-4	3	3	5	3

(5 - Excellent, 4 - Very good, 3 - Good, 2 - Average, 1 - Poor)

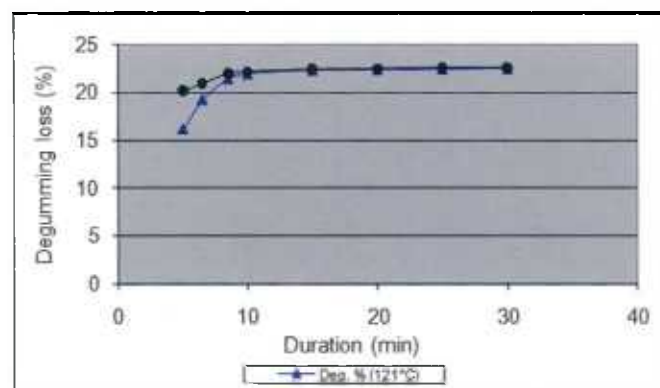


Figure 1: Effect of temperature and duration of treatment on degumming loss in pressurized degumming

Figure 2 shows the degumming loss of the most defective dupion yarn, D4 when degummed using different recipes. Degumming loss obtained with R2 and R3 were slightly higher which may presumably be due to the higher dosage of soda ash used in the degumming recipe. This also resulted in severe exfoliation of the treated yarn. The samples were subjected to tenacity and elongation test (BIS, 1999) before and after degumming experiments and the results in the form of bar chart are displayed in Figures 3 and 4. No significant difference was observed in the tenacity and elongation of the samples, among the recipes. Figures 5 and 6 depict the SEM photographs of the exfoliated yarn (D4) in conventional degumming (Gulrajani, 1988) whereas, Figure 7

represents that of the fabric made out of the exfoliated yarn. Figure 8 shows the SEM photograph of the fabric made out of the yarn degummed under pressurized conditions without any exfoliation defect. Figure 9 displays the seriplane photographs of the dupion yarn (D4) degummed using different recipes.

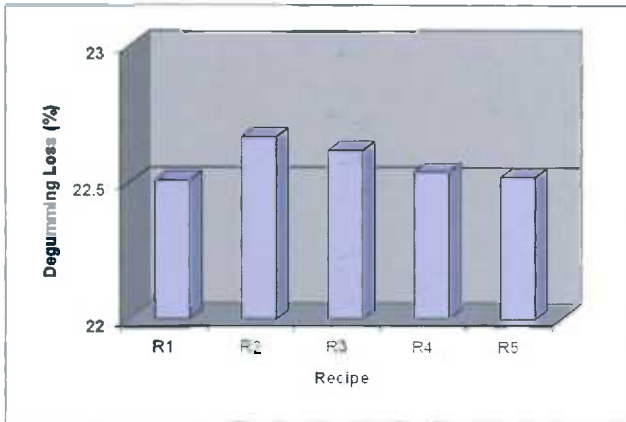
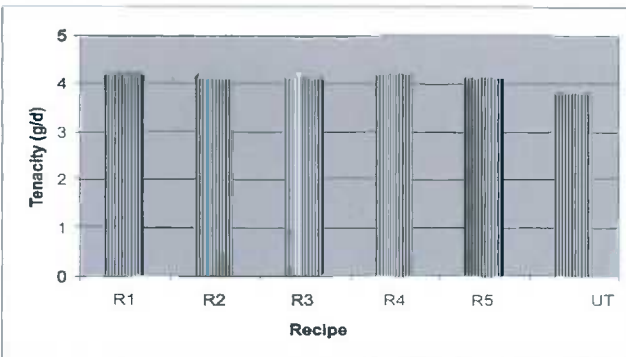
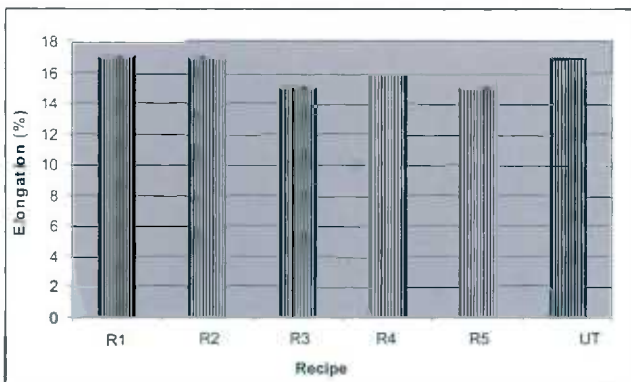


Figure 2: Effect of degumming recipes on degumming loss of dupion yarn (D4)



UT – un-treated

Figure 3: Effect of degumming recipes on tenacity of dupion yarn (D4)



UT – un-treated

Figure 4: Effect of degumming recipes on elongation (%) of dupion yarn (D4)

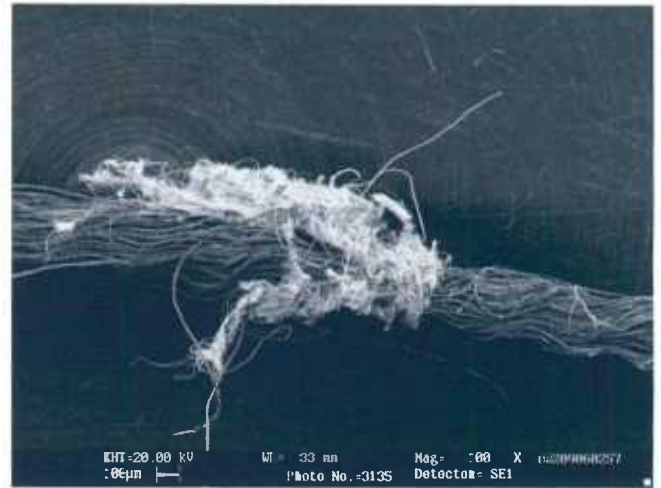


Figure 5: SEM photograph of exfoliated yarn unraveled from fabric (Magnification= 100 x 00209060257)



Figure 6: SEM photograph of exfoliated yarn unraveled from fabric (Magnification= 400 x 00209060257)

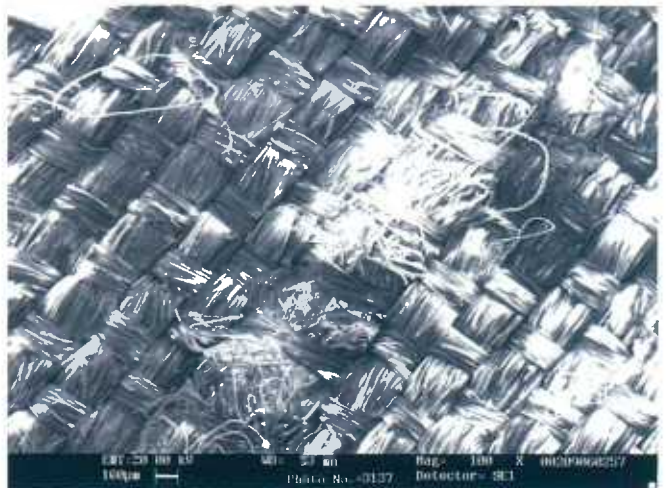


Figure 7: SEM photograph of dupion fabric with exfoliation defect (Magnification = 100 x 00209060257)

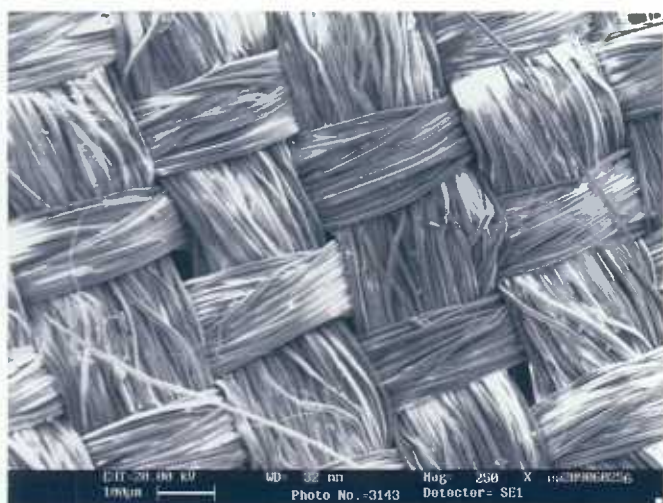


Figure 8: SEM photograph of dupion fabric without exfoliation defect (Magnification = 250 x 002090602576)

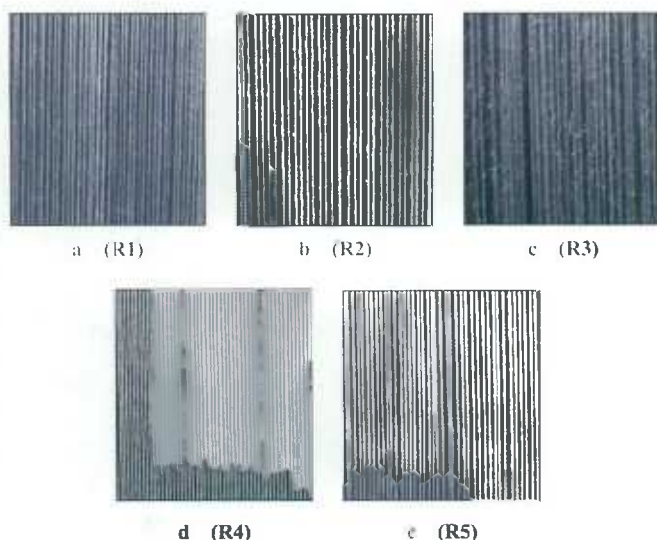


Figure 9: Seriplane photographs of dupion yarn samples (D4) degummed using different recipes viz., R1, R2, R3, R4 and R5

Our data are supportive to the present revelation that the degumming recipe and the conditions play a vital role in bringing about the exfoliation defect. Further, it is to state that the severity of the degumming conditions, such as usage of detergents, highly alkaline soap, boiling temperature and long duration might enhance the degree of exfoliation defect. Hence, it is advised to avoid using the detergent as degumming agent as it increases the risk of exfoliation of silk. Instead, it should better contain the neutral soaps. The recommended pH is between 9.5 and

10.5 at the beginning of the degumming process. The temperature during degumming should be monitored as not to exceed 90 to 95 °C and the duration of degumming process should be maintained as between 45 and 60 min.

The present results are at its best with the pressurized degumming process. This technique did not involve the use of chemicals viz., soap and soda, rather, only soft water at 121 °C for 10 to 15 minutes under pressure was used for degumming the silk. Under these conditions, even the samples of silk lots that performed the worst with the chemical degumming recipe, have yielded an excellent output. A pressurised vessel with liquor circulation may be used for carrying out the pressurised degumming process. Though the trials were carried out with dupion silk, the method is recommended for the filature silk also.

Conclusion

The pressurized degumming process proved to avoid the exfoliation problem. No significant difference was observed in tenacity and elongation of the samples, among degumming recipes. Silk yarn samples degummed under pressurized conditions were more lustrous in appearance and exhibited improvement in fullness when compared with the yarn degummed by the conventional process. Further, this process being economical and also environment friendly, is the best suited degumming process for the silk yarn.

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Article scientifique

UNE APPROCHE NOUVELLE POUR PREVENIR LES PROBLEMES D'EXFOLIATION ASSOCIES AUX FILS DE SOIE DOUPION IMPORTES

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ABSTRACT

Des expériences de décreusage ont été effectuées sur des fils de soie doupion importés produits par différentes filatures qui présentent des degrés variés d'exfoliation avec un décreusage conventionnel. Les recettes de décreusage qui prévalent dans l'industrie ont été utilisées. De plus, nous avons utilisé le décreusage sous pression à différentes températures et selon différentes durées. Les échantillons décreusés sous pression sont plus lustrés en apparence et montrent une amélioration globale comparés avec les fils décreusés selon les méthodes conventionnelles. De plus, l'évaluation des propriétés mécaniques telles que la ténacité et l'élongation des échantillons traités selon les différentes recettes ne montrent pas de différences significatives. Les échantillons de fils décreusés ont été teints et transformés en tissus doupions dont les défauts ont été évalués de manière subjective. Les résultats indiquent que le décreusage sous pression peut empêcher les défauts d'exfoliation avec des échantillons de fils susceptibles de donner des défauts avec les décreusages conventionnels.

Mots-clés: Soie doupion, exfoliation, décreusage haute température haute pression, lustre.



IMPACT OF AGE AND SIZE OF HOST ON THE REPRODUCTIVE PERFORMANCE OF AN ECTO-PUPAL PARASITOID, *TRICHOMALOPSIS UZIAE* SURESHAN & NARENDRA KUMAR

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ABSTRACT

In the current investigation, a gregarious ecto-pupal parasitoid, *Trichomalopsis uziae* Sureshan & Narendra Kumar (Hymenoptera: Pteromalidae) has been investigated for its reproductive efficiency as influenced by age and size of its host, *Exorista bombycis* (Louis) (Diptera: Tachinidae), considering the following parameters: per cent parasitism, developmental duration, progeny production, progeny sex ratio, and progeny female longevity when 1, 3, 5, 7, 9, and 11 day-old host pupae were provided for parasitism. Attempts have also been directed to document the progeny morphometric characteristics, apart from recording the reproductive efficiency of F1 progenies. The results indicated that per cent parasitism was appreciably higher in the younger host pupae (up to 3 day-old) with no perceptible change in the parasitoid developmental duration. With regard to progeny production and progeny sex ratio, substantially more numbers of male and female progeny individuals emerged from younger host pupae with their sex ratio too being greater. However, the progeny female longevity remained comparable among the treatments. When bigger and smaller host pupae were provided for parasitism, no significant variation in per cent parasitism, developmental duration, male progeny production, and longevity of female progeny was observed. However, the female and total progenies as also sex ratio were significantly higher when bigger host pupae were parasitized. Insofar as the impact of host size on morphometric parameters of progeny were concerned, body length, head width, and wingspan of males and females as well as abdomen length of females were significantly superior in the progenies developed in bigger pupae, while those developed in smaller pupae showed comparable body length, head width, and wingspan of males as well as abdomen width of females. The results, therefore, clearly demonstrate that both host age and size have significant impact on the reproductive performance of *T. uziae*.

Key words: Ecto-pupal parasitoid, host age, host size, parasitism, reproductive performance.

INTRODUCTION

Recently, *Trichomalopsis uziae* Sureshan & Narendra Kumar (Hymenoptera: Pteromalidae) has been reported to be a gregarious ecto-pupal parasitoid of the tachinid (uzi) fly, *Exorista bombycis* (Louis) (Diptera: Tachinidae) (Kumar *et al.*, 2015) that leads an endo-parasitic life in the larval stage of the silkworm, *Bombyx mori* L. As a result,

the sericulture farmers are constrained to forego 15-20 % in cocoon production in the Indian subcontinent's prosperous sericulture belt comprising the states of Karnataka, Andhra Pradesh and Tamil Nadu (Samson, 2000). The problem posed by *E. bombycis* has been continuing unabated since the accidental introduction of this fly pest (parasitoid) way back in 1980 and a host of management strategies have been employed, including the

bio-control, from time to time to contain the pest menace. As such, the bio-control included a gregarious ecto-pupal euplophid parasitoid, *Nesolynx thymus* (Girault), which is one among 21 parasitoids, including *T. uziae*, documented so far to parasitize *E. bombycis* (Narayanaswamy and Devaiah, 1998; Kumar *et al.*, 2015). Owing to the recent accession of *T. uziae* to the parasitoid complex of *E. bombycis*, it is yet to be studied for its biological and behavioral aspects to understand whether or not the parasitoid can be exploited alongside *N. thymus* for suppressing the populations of *E. bombycis*. Currently, such an attempt has become imminent owing to the fact that there is an exclusive dependence on *N. thymus* as a bio-control agent of *E. bombycis*. However, it is advisable to realize that dependence on a single bio-control agent for the management of any pest for that matter is not a good proposition (Bellows and Fisher, 1999). Further, in view of greater sensitivity of *B. mori* to chemical control, bio-control is expected to ideally suit and pay rich dividends in a long run while proving to be cost viable.

Parasitoids are known to exhibit a great deal of variation in their reproductive strategies depending on host and parasitoid related factors as well as environment associated factors (Aruna, 2007; Veena, 2008; Gangadhar, 2009; Bansude *et al.*, 2010; Ahmed *et al.*, 2013; Mohammad *et al.*, 2015; Skoygard and Nachman, 2015). The strategies adopted would be such that they ultimately confer maximum advantage in terms of overall perpetuation of generation while ensuring superior fitness/quality traits (bigger size) and higher sex ratio (number of females/male) among the progeny individuals (Veena and Manjunath, 2013). Many parasitoids prefer to attack only when hosts of certain age or size are available, although in most cases, their progeny can develop in all host (larval/pupal) ages and sizes (Nakamatsu and Tanaka, 2004; Li *et al.*, 2006; Aruna and Manjunath, 2006; Veena and Manjunath, 2007 a, b; Gangadhar and Manjunath, 2009, 2010; Naveed *et al.*, 2014; Broski and King, 2017; Li *et al.*, 2017). Successful parasitism requires a series of interconnected steps and complex interactions between parasitoids and their hosts, including habitat finding, host location, host acceptance, host suitability, and host regulation. However, host age has been frequently found to be a major factor affecting

host acceptance and host suitability (Veena and Manjunath, 2013; Naveed *et al.*, 2014; Broski and King, 2017). But host size is also equally important, especially in the case of gregarious ones, wherein the female parasitoid estimates the host size (host resources) before allocating the egg load (clutch size) in relation to that estimate with larger hosts receiving more eggs (Omwega and Overholt, 1997; Seko and Nakasuja, 2004; Aruna, 2007; Veena, 2008; Gangadhar, 2009; Aruna and Manjunath, 2010; Veena and Manjunath, 2013). Admittedly, the mechanism of estimating host size by parasitoid female before allocating the progeny is realized to be a strategy to avoid competition among the developing individuals, especially when she has to allocate a female-biased progeny.

In the current investigation, an attempt was made to record the impact of age and size of *E. bombycis* host pupae on the reproductive performance of *T. uziae*.

MATERIALS AND METHODS

Culture of the host: The maggots of *E. bombycis* emerging from the cocoons of *B. mori* were collected from the Government Cocoon Market, Kollegala (Mysuru District, Karnataka State). They were spread in a single layer in a plastic tray (size 2 x 3 ft.) for pupation at 23-28 °C and 60-80 % RH in the Pest Management Laboratory (PML) of the Central Sericultural Research and Training Institute (CSRTI), Mysuru. The pupation occurred in 12-24 h. The age of the puparia, hereinafter called pupae, was considered from the day the maggots pupated.

Culture of the parasitoid: The stock-cultures of *T. uziae* were raised on the pupae of *E. bombycis* at PML at the above-mentioned conditions of temperature and RH as per the method advocated by Kishore and Kumar (1989). The adults of the parasitoid were maintained on 50 % aqueous honey.

Impact of host age on the reproductive performance of *T. uziae*

Gravid females of the parasitoid were allowed to parasitize 1, 3, 5, 7, 9, and 11 day-old pupae of *E. bombycis*

(Figure 1) for three days at a host-parasitoid ratio of 5:1 in glass test tubes of 15 cm length and 1.5 cm diameter. Each treatment consisted of ten replications. After the duration of parasitism, the host pupae were observed for recording per cent parasitism as well as parasitoid developmental duration, progeny production, and sex ratio. In addition, the parasitoid progeny females were observed for their longevity.



Figure 1: *Trichomalopsis uziae* Sureshan & Narendra Kumar, ovipositing on its host pupa, *Exorista bombycis* (Louis)

Influence of host size on the reproductive efficiency of *T. uziae*

For experimentation, 3 day-old host pupae of *E. bombycis*, based on their fresh weight, were categorized into big (av. 0.12 ± 0.010 g) and small (av. 0.06 ± 0.005 g) pupae having significant difference in their weight between the two categories. They were placed separately in test tubes (15 cm length and 2 cm diameter) and exposed to mated females of the parasitoid for three days at a host-parasitoid ratio of 5:1 during which period, they were fed 50 % aqueous honey. Ten replications were maintained for each set of experiment. The parasitoid females were removed from the test tubes on the fourth day. After the emergence of the progeny adults, observations were recorded on per cent parasitism as well as parasitoid developmental duration, progeny production, and sex ratio. In addition, the progeny females were monitored for their longevity, morphometric parameters, and reproductive efficiency.

Effect of host size on the morphometric characteristics of *T. uziae*

Apart from recording the reproductive parameters of *T. uziae* as influenced by host size (big and small) in parent generation, the progeny individuals were measured for their morphometric parameters such as body length, head width, and wingspan of males and females as well as length and width of abdomen of females using an ocular micrometer under a light microscope at 40X.

Reproductive efficiency of F1 females of *T. uziae* as impacted by host size in parent generation

An experiment was conducted by exposing 3 day-old randomly chosen host pupae to 2 day-old mated females of the parasitoid progeny recovered from big and small host pupae that were exposed for parasitism by parent females at a host-parasitoid ratio, 5:1 for three days. After the emergence of F2 progeny adults, observations were documented on per cent parasitism as well as parasitoid developmental duration, progeny production, and sex ratio. In addition, the progeny females were monitored for their longevity.

All the treatments in the above investigations were based on 10 replications. The accrued data were analyzed by one-way ANOVA (version 21) followed by DMRT for understanding whether or not the results were significantly different from each other among the treatments as per the methods outlined by Snedecor and Cochran (1979).

RESULTS AND DISCUSSION

Effect of host age on the reproductive performance of *T. uziae*

A great deal of variation in the per cent parasitism of 1, 3, 5, 7, 9, 11 day-old host pupae of *E. bombycis* by *T. uziae* was observed. It ranged from 88.00 ± 8.00 (3 day-old) to 44.00 ± 4.00 (11 day-old) and showed a decreasing trend as the age of host pupae advanced. The variation in per cent parasitism among the treatments was significant at 1 %

($P < 0.01$). With regard to parasitoid developmental duration, the mean results differed somewhat with the longest and the least durations of 15.80 ± 0.20 days with 11 day-old pupae and 13.40 ± 0.40 and 13.40 ± 0.24 days with 7 day and 9 day-old pupae, respectively. Comparison of mean values revealed significant variation at 1%. Looking at the average progeny production per female of *T. uziae*, male, female, and total progeny production exhibited a decreasing trend with the decline being more pronounced in host pupae that were older than 3 days with the progenies produced in 1 and 3 day-old pupae being *at par* with each other. Likewise, the progenies produced in 5, 7, and 9 day-old pupae were somewhat comparable with each other. Substantial reduction in progeny production was noticed when the parasitoid development occurred in 11 day-old host pupae. The mean results for this parameter fluctuated from 20.60 ± 2.68 (3 day-old) to 6.40 ± 0.93 (11 day-old), from 105.60 ± 22.15 (1 day-old) to 17.80 ± 3.26 (11 day-old), and from 126.00 ± 21.23 (3 day-old) to 24.20 ± 3.88 (11 day-old) individuals for male, female, and total progenies, respectively, with the values differing significantly at 1%. The parasitoid progeny sex ratio (no. of females/male) too differed significantly at 1% among the treatments with the greatest sex ratio being realized in progenies developed in 1 day-old pupae (5.75 ± 0.29) and the least in 11 day-old pupae (2.91 ± 0.43) with the parameter remaining almost alike in pupae up to the age of 5 days. Comparison of mean values showed

significant variation at 1%. Insofar as the longevity of the progeny females was concerned, a non-significant difference in the mean results for the parameter was noticed with the values ranging between 14.80 ± 1.98 (1 day-old) and 10.20 ± 3.14 days (5 day-old) (Table 1).

Based on per cent parasitism, it was evident that *T. uziae* showed distinct preference for ovipositing in younger host pupae in comparison to older ones. There was a sharp decline in per cent parasitism of host pupae that were older than 3 days of age, with an apparent indication of per cent parasitism decreasing with advancement in host age. Though the parasitoid developmental duration differed significantly among the treatments, it did not appear to be really substantial as to indicate that age of host pupae to be less important in influencing the rate of parasitoid development. Host age did show significant impact on the production of parasitoid male, female, and total progenies. The younger hosts (less than 5 day-old) were found significantly more suitable for progeny allocation as evidenced by production of 1.60 (58.06%), 2.14 (113.56%), and 2.02 (102.27%) times more male, female, and total progenies (average), respectively when 1 and 3 day-old pupae were exploited for oviposition compared to the older ones (5, 7, 9, and 11 day-old), which diminished in a linear fashion with host age and such an effect was relatively less evident with male progeny. The reduction in the production of male,

Table 1: Influence of host age on the reproductive performance of *Trichomalopsis uziae*

Host age (days)	Per cent parasitism ^a	Developmental duration (days)	Total progeny production (numbers)			Sex ratio (Female/male)	Adult female longevity (days)
			Male	Female	Total		
1	76.00 ± 7.48^{ab}	14.00 ± 0.00^b	18.00 ± 3.21^a	105.60 ± 22.15^a	123.60 ± 25.29^a	5.75 ± 0.29^a	14.80 ± 1.98
3	88.00 ± 8.00^a	14.20 ± 0.37^b	20.60 ± 2.68^a	105.40 ± 19.23^a	126.00 ± 21.23^a	5.08 ± 0.56^{ab}	11.80 ± 1.85
5	60.00 ± 14.14^{abc}	14.00 ± 0.32^b	14.00 ± 3.77^{ab}	70.80 ± 16.56^{ab}	84.80 ± 19.90^{ab}	5.37 ± 0.48^{ab}	10.20 ± 3.14
7	48.00 ± 12.00^{bc}	13.40 ± 0.40^b	13.60 ± 2.69^{ab}	53.00 ± 14.64^{bc}	66.60 ± 16.51^{bc}	3.88 ± 0.71^{bc}	13.40 ± 5.02
9	60.00 ± 6.32^{abc}	13.40 ± 0.24^b	15.60 ± 2.38^a	56.00 ± 7.06^{bc}	71.20 ± 9.04^{abc}	3.80 ± 0.51^{bc}	10.60 ± 2.48
11	44.00 ± 4.00^c	15.80 ± 0.20^a	6.40 ± 0.93^b	17.80 ± 3.26^c	24.20 ± 3.88^c	2.91 ± 0.43^c	11.20 ± 1.98
F-value	3.225 **	9.344 **	3.092 **	4.859 **	4.763 **	4.610 **	0.872 NS

Values given in the Table are the mean of 10 replications (Mean $\pm$ SE); Mean values followed by the same superscript in columns are statistically not significant; ^a - Out of 5 pupae provided for parasitization; ** - Significant at 1%; NS - Non-significant.

female, and total progenies was too drastic in 11 day-old pupae, which was 1.94 (93.75 %), 2.78 (177.52 %), and 2.53 (152.87 %) times fewer than the averages for that realized from the other younger pupae. The parasitoid progeny sex ratio too was significantly higher when the younger pupae were offered for oviposition against the older ones, except the 5 day-old pupae where the sex ratio stood comparable with that from the younger pupae, with the progeny sex ratio in the oldest ones (11 day-old) being the least. Further, irrespective of the age of host pupae, the longevity of the progeny females was found comparable among the treatments, though it was considerably higher for the ones emerging from the youngest pupae (1 day-old), thus indicating that host age doesn't have any impact on the longevity of the parasitoid progeny females.

The preference by the parasitoid female for progeny allocation/production in the younger host relative to older one would be due to one or more of the following reasons: 1) softness of the puparial case with relatively less deposition of chitin that facilitates easy and effective oviposition following display of events preceding oviposition, 2) palatability of host resources (tissues) for the developing parasitoid individuals, 3) availability of more quantities of host resources, and 4) production and volatilization of increased levels of kairomone(s) from host pupae to elicit enhanced ovipositional response in the parasitoid female. Elsewhere, a number of researchers observed the preference of younger hosts to older ones by idiobiontic as well as koinobiontic parasitoids (egg, larval, and pupal) considering rate of parasitism, developmental duration, progeny production, and sex ratio. Previously, preference for younger hosts for progeny production was demonstrated in *Psix striaticeps*

(Dodd) (Ravindranath Singh and Shashi Shekar Sinha, 1995), *Praon pequdorum* Vicedk (Sequeria and Mackauer, 1988), *N. thymus* (Aruna and Manjunath, 2010), and *Tetrastichus howardi* (Olliff) (Gangadhar, 2009). These observations were in sharp contrast to those reported in *Perilitus coccinellae* (Schrank) (John *et al.*, 1985) and *Trichopria* sp. (Veena, 2008).

Reproductive efficiency of *T. uziae* as influenced by host size

The per cent parasitism by *T. uziae* was almost identical in both big (94.00±4.27%) and small (88.00 ±5.33%) pupae of *E. bombycis* with the average number of pupae parasitized (out of 5 host pupae provided) being 4.70±0.21 and 4.40±0.27, respectively. The parasitoid developmental duration too remained comparable when the development occurred in big (13.30±0.15 days) and small (12.80±0.29 days) host pupae. With regard to total progeny production, the variation was non-significant for males when they developed in big host pupae (16.10±0.95) in comparison to those in small host pupae 17.90 ±1.86, while it was significantly greater ($P<0.01$) for females and total progenies with the mean values of 149.7 ±8.24 and 165.80±8.70 in big pupae against 85.00±8.38 and 149.70±8.24 in small pupae, respectively. Similarly, significantly higher ($P<0.01$) sex ratio was recorded for progenies that developed in big pupae (9.50±0.61) when compared with that in small pupae (4.80±0.22), with the progenies emerging from either sized pupae showing comparable longevity (Table 2).

It was observed that per cent parasitism by *T. uziae* did not differ significantly when the host pupae of two distinct

Table 2: Influence of host size on the reproductive performance of *Trichomalopsis uziae*

Host size	Per cent parasitism ^a	Developmental duration (days)	Total progeny production (numbers)			Sex ratio (Female/male)	Adult female longevity (days)
			Male	Female	Total		
Small	88.00±5.33	12.80±0.29	17.90±1.86	85.00±8.38	102.90±10.13	4.80±0.22	7.24±0.06
Big	94.00±4.27	13.30±0.15	16.10±0.95	149.70±8.24	165.80±8.70	9.50±0.61	7.66±0.06
F-value	0.771 NS	2.320 NS	0.740 NS	30.309 **	22.182 **	52.881 **	1.652 NS

Values given in the Table are the mean of 10 replications (Mean ± SE); ^a - Out of 5 pupae provided for parasitization; ** - Significant at 1 %; NS - Non-significant.

Table 3: Comparative morphometric characters of *Trichomalopsis uziae* emerged from small and big pupae of *E. bombycis*

Host size	Body length (mm)		Head width (mm)		Wingspan (mm)		Female abdomen size (mm)	
	Male	Female	Male	Female	Male	Female	Length	Width
Small	0.996±0.010	1.212±0.022	0.273±0.001	0.318±0.009	1.620±0.020	1.638±0.016	0.792±0.008	0.414±0.019
Big	1.038±0.024	1.296±0.013	0.282±0.009	0.348±0.008	1.656±0.013	1.686±0.014	0.828±0.008	0.432±0.012
F-value	2.673 NS	11.025 **	0.783 NS	6.081 *	2.250 NS	5.236 *	10.125 **	0.648 NS

Values given in the Table are the mean of 10 replications (Mean ± SE); ** - Significant at 1 %; * - Significant at 5 %; NS - Non-significant.

Table 4: Performance of F-1 generation of the parasitoids emerged from small & big pupae when provided with normal host pupae

Parasitoids emerged from	No. of pupae parasitized	Per cent parasitism*	Developmental duration (days)	Total progeny production (numbers)			Progeny production per pupa (numbers)			Sex ratio (Female/male)	Adult longevity (days)
				Male	Female	Total	Male	Female	Total		
Big	2.40±0.27	48.00±5.33	14.20±0.29	10.90±1.23	44.00±3.00	54.90±3.90	4.97±0.70	19.40±1.36	24.37±2.00	4.47±0.53	6.82±0.08
Small	2.10±0.23	42.00±4.67	13.60±0.31	9.90±2.04	43.00±6.79	52.90±8.59	4.30±0.61	20.50±2.18	24.80±2.50	5.66±1.03	6.66±0.08
F-value	0.717 NS	0.717 NS	2.025 NS	0.170 NS	0.018 NS	0.045 NS	0.515 NS	0.183 NS	0.018 NS	1.056 NS	1.424 NS

Values given in the Table are the mean of 10 replications (Mean ± SE); @ - Out of 5 pupae provided for parasitization; NS - Non-significant.

size (based on fresh weight), i.e., big and small, were offered for oviposition. In other words, the parasitoid female showed equal preference for oviposition in big and small host pupae. Even the parasitoid developmental duration too remained similar when the progeny was allocated to either sized pupae. It is, therefore, implicit that quantum of host resources does not have any significant bearing on the rate of parasitism as well as the parasitoid developmental duration. When the progeny was allocated, the parasitoid female was found to have shown no discrimination for allocating male progeny among the two distinct sized pupae, while it did exhibit a significant differentiation for allocating female progeny with bigger hosts receiving 1.76 times (76.12 %) more female progeny when compared with their smaller counterparts. Taking cognizance of total progeny allocation, it works out to be 1.61 times (61.12 %) in excess in the bigger pupae against the smaller ones. It can, therefore, be inferred that the parasitoid female uses its discrimination ability for allocating the progeny which was obviously in favor of resource-rich (bigger) hosts, especially while allocating the female progeny, consequent to host resource estimation, an activity well-known to be a developmental strategy exhibited by all parasitoids. Understandably, the allocation of substantially more female progeny to bigger pupae by *T.*

uziae reflected in significantly increased sex ratio (97.92%) in the populations developed in such pupae. The progeny females, however, failed to secure any advantage of relatively more quantity of resources in bigger hosts as the individuals emerging from either sized hosts possessed comparable longevity.

Production of significantly more progeny, more so of female with concomitant improvement in sex ratio, when bigger hosts were offered for oviposition has been demonstrated in *Hyssopus thymus* Girault (Purrrington and Uleman, 1972), *Ephedrus cerasicola* Stray (Hagvar and Hofsvang, 1986), *Cotesia flavipes* Ameron (Omwega and Overholt, 1997), *Pimpla parnorae* (Ueno, 1999), *Parnara guttata* Bremer et Grey (Seko and Nakasuja, 2004), *N. thymus* (Aruna, 2007), *Trichopria* sp. (Veena, 2008) and *T. howardi* (Gangadhar, 2009).

Impact of host size in parent generation on the morphometric traits of *T. uziae*

Body length, head width, and wingspan of male and female progenies as well as abdomen length and width of female progeny of the parasitoid were considered for recording the impact of host size on the morphometric parameters. Irrespective of size of host that was provided

for parasitism in parent generation, body length, head width, and wingspan of males did not differ significantly, while these traits in females were significantly superior when the parasitoid developed in big pupae. The mean results for these parameters for females from big pupae were 1.296 ± 0.013 , 0.348 ± 0.008 , and 1.686 ± 0.014 mm against those for females with measurements of 1.212 ± 0.022 , 0.318 ± 0.009 , and 1.638 ± 0.016 mm, respectively from small pupae. With regard to abdomen length and width of progeny females of *T. uziae*, significantly higher abdomen length ($P < 0.01$) was noticed for those developed in big pupae (0.828 ± 0.008 mm) against small pupae (0.792 ± 0.008 mm). Further, the abdomen size for these females remained highly comparable when they developed in either sized host pupae (Table 3).

From the above findings, it becomes evident that host size in parent generation had a significant impact on the morphometric parameters (body size) of the progenies, especially the females. The body size parameters that included body length, head width, and wingspan as well as abdomen length were significantly greater for females generated from bigger hosts. Obviously, this indicated the suitability of bigger hosts for progeny development, more so for females that exploit more quantity of host resources compared to males during growth and development as is known elsewhere in other parasitoids (Veena and Manjunath, 2007 a; Aruna and Manjunath, 2010; Broski and King, 2017). However, it is a matter to be understood that the parent female would be more meticulous in estimating the host resources and allocating the progeny according to that estimate so that the ensuing progeny individuals, especially females, would not be bereft of the required fitness traits such as temperature tolerance, efficient host searching and dispersal ability in the field, enhanced longevity, increased progeny production for perpetuation of generation and so on, i.e., positive correlation between female body size and fitness traits (Sequeira and Mackauer, 1988; Visser, 1994). But the hypothetical question arises as to why the females generated in smaller hosts were morphometrically inferior despite the mandatory estimation of host resources prior to allocation of progeny by female *vis-à-*

vis that estimate? As such, the fact of the matter needs to be understood, analyzed, and answered. This apart, by virtue of their being significantly superior in morphometric scores, by which the females were bigger in size, these females supposed to have lived longer than their counterparts emerging from smaller hosts; this, however, failed to become a reality (Table 2).

Parasitoid size, especially of female, has been realized to be impacted by host size. The general observation made by a number of workers was that there was a positive correlation between host size and parasitoid female size, i.e., those generated in bigger hosts were significantly superior morphometrically. Such an observation has been recorded in *Dinarmus basalis* (Rond.), *Trichogramma* sp. (Raznik and Umarova, 1990; Greenberg *et al.*, 1998), *Pteromalous cerealellae* (Oliver) (Wen *et al.*, 1995), *N. thynus* (Aruna, 2007), *Trichopria* sp. (Veena, 2008), and *T. howardi* (Gangadhar, 2009). By contrast, Bokonon-Ganta *et al.* (1995) noticed that host size did not have significant impact on the size of *Anagyrus mangicola* Noyes. It is also a well-established fact that there is a positive correlation between size of parasitoid female and its life span as demonstrated by Bai *et al.* (1992) in *Trichogramma pretiosum*, Visser (1994) in *Aphaereta minuta* Nees, and Veena (2008) in *Trichopria* sp. In sharp contrast to the observations by these authors, in the current study, both bigger and smaller females of *T. uziae* have shown comparable longevity (Tables 2 and 3).

Reproductive efficiency of F1 generation of *T. uziae* as impacted by host size in parent generation

Based on per cent parasitism, developmental duration, progeny production (male, female, and total), sex ratio, and adult longevity of progeny females (F2), it was observed that there were no significant variations among the treatments when 2 day-old adult females of *T. uziae* emerging from bigger and smaller pupae of *E. bombycis* were allowed to parasitize 3 day-old randomly chosen host pupae at a parasitoid-host ratio of 1:5 (Table 4).

Despite significantly superior morphometric traits

(bigger size) of F1 females of *T. uziae* emerging from bigger pupae, it was observed that these females failed to transform that advantage into improved reproductive efficiency while producing F2 progeny as evidenced by their comparable performance with those emerging from smaller pupae in terms of male, female, and total progeny production as well as sex ratio and female longevity.

Insofar as our awareness goes, there is scanty information as to the influence of host size in parent generation on the reproductive efficiency of parasitoid progenies (F1). Nonetheless, Seko and Nakasuja (2004) reported that females of *Parnara guttata* (Bremer and Grey, 1853) generated in bigger hosts were more fecund. Similarly, Veena (2008) dealing with *Trichopria* sp. found that the parasitoid produced significantly more progenies (F2) when they developed as F1 individuals in bigger host pupae. However, studies by Aruna (2007) and Gangadhar (2009), employing *N. thymus* and *T. howardi*, respectively, indicated no correlation between host size in parent generation and reproductive efficiency of progenies of these parasitoids. The findings in the current attempt with regard to *T. uziae* on this score fall in line with those by Aruna (2007) and Gangadhar (2009).

From the foregoing account, it can be inferred that host age and host size have significant impact on the reproductive performance of *T. uziae* with younger (up to 3 day-old) and bigger pupae of *E. bombycis* to be significantly desirable. Host size is observed to have significant positive correlation with parasitoid progeny female body size but has no impact on the reproductive efficiency of progenies. The findings of the current investigation, therefore, throw light on the selection of age and size of a host in the mass production of the parasitoid in question, if such an attempt is contemplated in the biocontrol program of *E. bombycis*.

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Article scientifique

IMPACT DE L'AGE ET DE LA TAILLE DE L'HOTE SUR LA PERFORMANCE REPRODUCTIVE D'UN PARASITOIDE PUPAL, *TRICHOMALOPSIS UZIAE* SURESHAN & NARENDRA KUMAR

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ABSTRACT

Dans cet article, un ectoparasitoïde pupal, *Trichomalopsis uziae* Sureshan & Narendra Kumar (Hyménoptère: Pteromalidae), a été étudié pour son efficacité reproductive en fonction de l'âge et de la taille son hôte *Exorista bombycis* (Louis) (Diptère: Tachinidae), en considérant le pourcentage de parasitisme, la durée du développement la production de descendants le sex-ratio de la progéniture et la longévité des femelles de la progéniture quand des pupes de 1, 3, 5, 7, 9 et 11 jours sont fournies au parasite. Des tentatives ont été menées pour définir les caractéristiques morphométriques des progénitures ainsi que l'efficacité reproductive des descendants F1. Les résultats montrent que le taux de parasitisme est plus élevé chez les pupes hôte les plus jeunes (jusqu'à 3 jours) sans changement dans la durée

du développement du parasitoïde. En ce qui concerne la production de descendants et leur sex-ratio plus de mâles et de femelles sont produits à partir des pupes hôte les plus jeunes avec un sex-ratio trop élevé. Cependant ; la longévité des femelles est la même quels que soient les traitements. Lorsqu'on utilise des hôtes plus gros et plus petits on ne constate pas de différences quant au taux de parasitisme, à la durée de développement, à la production de descendants mâles et à la longévité des descendants femelles. Toutefois, le total des descendants et des femelles ainsi que le sex-ratio sont significativement plus élevés lorsque des pupes plus grosses sont parasitées. La longueur du corps, la largeur de la tête et l'envergure des ailes des mâles et des femelles ainsi que la longueur de l'abdomen des femelles sont significativement supérieures chez les descendants obtenus à partir des plus grosses pupes. Les résultats démontrent clairement que la taille et l'âge de l'hôte ont un impact significatif sur les performances reproductives de *T. uziae*.

Mots-clés: Parasitoïde pupal, âge de l'hôte, taille de l'hôte, parasitisme, performance reproductive.



Research Paper

ASSESSMENT OF HOST PLANT SUITABILITY FOR BEST SILK PRODUCTION EFFICIENCY AND POST COCOON ATTRIBUTES OF *ANTHERAEA MYLITTA* IN UTTARAKHAND

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ABSTRACT

Antheraea mylitta Drury is a silk producing forest insect commercially exploited in nine tasar producing states of India, but still remains untapped of its potential in Uttarakhand. In this study, effect of forestry host plants, rearing season and their interactions were studied on silk producing efficiency and post cocoon attributes of Daba ecorace (BV) of *A. mylitta* at Forest Research Institute, Dehra Dun (Uttarakhand). Four experimental outdoor rearings were conducted on seven forest tree species in six replications during July-August and September-November 2012 & 2013 and data were collected on fourteen variables of silk producing traits and five variables of post cocoon attributes of *A. mylitta*. A two-way completely randomized block factorial ANOVA was done by STATISTICA 10 at significance level of $P=0.05$. Post HOC test was carried out by using Tukey's HSD test and a common evaluation index (E.I.) was also drawn to ascertain the superiority of forestry host plants for all the studied variables. Results indicated that *Terminalia alata*, *T. tomentosa*, *Lagerstroemia speciosa* and *T. arjuna* are the best suitable forestry host plants in their order of merit for most of the examined variables. Interestingly, overall silk production efficiency and post cocoon attributes of *A. mylitta* was found better on *L. speciosa* than *T. arjuna*. In Uttarakhand, *L. speciosa* possessed certain advantages as luxurious growth, non-preference by browsing animals, larger leaf area than *T. arjuna* and ease of propagation and maintenance. It performed as good as a primary forestry host plant of *A. mylitta* in Uttarakhand whereas, in other parts of the country, *L. speciosa* is considered as a secondary food plant of *A. mylitta*.

Key words: Livelihood delivery of the forest, tropical tasar culture, wild silk moth.

INTRODUCTION

There are 6.23 Lakh families of the status of below poverty line, inhabiting in ninety-four hill blocks of thirteen districts in Uttarakhand state, whose migration to the plains has now been accelerated (Census, 2011; NIC, 2012; DES, 2013). In this situation, improved livelihood delivery of the forests to their dependents may assist in reducing the poverty (Kalirajan and Singh, 2006) and may thereby curb their migration. Therefore, to improve the livelihood functions of the tropical forests in the state, a new livelihood intervention in the form of introduction of forest based rearing of tropical tasar silkworm, *Antheraea*

mylitta (Lepidoptera: Saturniidae) can be undertaken as a new Forest Insect Enterprise for the Forest Dependent People (FDP) of the Uttarakhand state.

Studies have shown that when forest dependent people are associated with forest related entrepreneurial activity, such income generating avenues improve the socio-economic status of the associated families and concomitantly fosters its impact on forest conservation efforts through evolved multiagency linked Collaborative Forest Management system (Bhatia and Yousuf, 2013 a, b). Secondly, creation of rural employment, alleviation of poverty and elevation of socio-economic status of forest

dependent people are the unique features of Indian tropical tasar culture (Suryanarayana and Srivastava, 2005; Manohar *et al.*, 2009). Third, when it comes to associate "Forestry" with "Sericulture"; Tropical Tasar Culture stands alone there as a *Vanya Silk* component, because plantation of *Morus alba* for *Bombyx mori* to produce mulberry silk on forest land is not a forestry activity as per prevailing ruling of the Government (MoEF, 2004).

A. mylitta is a forest insect, but its biological success, silk producing traits and post cocoon attributes are greatly influenced by the heterogeneity of the forestry host plants, climatic variability of the habitat and interactions among these factors (Hunter *et al.*, 2000). This is the basic reason, why studies on the effects of host plants on the biology of insects are important to understand the host suitability under different environmental condition (Xue *et al.*, 2009). *A. mylitta* in its natural habitat, hatches and multiplies in favourable season synchronising with growth cycle of the available forestry host plants and develop an appropriate voltinism as per the habitat ecology (Thangavelu, 2000). Larvae of *A. mylitta* feed on many forest tree species, but show great degree of selectivity as a function of their behavioural responses to the physical structure and chemical stimuli of the food plants that differ in nutrient profile and concentration of phagostimulants (Reddy *et al.*, 2010). Therefore, the evaluation of forest tree species as food material in respect of the traits that contribute to better silk production efficiency and post cocoon attributes of *A. mylitta* is critical in the way of introducing tropical tasar culture in Uttarakhand, which has not yet been attempted.

MATERIALS AND METHODS

Study area, climate and test forestry host plants

This study was conducted at the New Forest, Forest Research Institute (FRI), Dehra Dun, Uttarakhand having moderate climate due to its location at foot of the Himalayas where altitude is the main factor for variation in temperature and vegetation (WMD, 2011). Seven forest

tree species viz., *Terminalia alata*, *T. tomentosa*, *T. arjuna*, *T. bellirica*, *T. chebula*, *L. speciosa* and *L. tomentosa* that are widely distributed in tropical forests of the Uttarakhand state (Thangavelu, 2004) were chosen for the study. Identification of the tested forest tree species was carried out at Systematic Botany Division, FRI, Dehra Dun and voucher specimens were deposited. Data on weather variables during the study period are presented in Table 1.

Table 1: Weather variables of the study site (New Forest, FRI, Dehradun) during 2012-14

Month	Temperature (°C)		Relative humidity (%)		Rainfall mm	Bright sunshine		Wind velocity km/h
	Max.	Min.	Max.	Min.		Days	h/day	
January	19.50	3.95	98.50	49.50	19.00	2.5	5.85	2.25
February	22.85	6.10	96.50	38.50	36.80	3	6.7	2.6
March	29.40	10.60	89.00	31.50	13.75	1.5	8.4	2.95
April	34.25	14.80	68.50	26.00	17.65	1.5	8.35	3.55
May	36.50	18.00	57.50	25.50	12.65	1.5	8.4	3.8
June	37.35	21.05	64.00	34.50	66.15	7	6.9	3.95
July	30.80	23.05	93.00	75.00	660.25	18	3.2	2.7
August	29.55	22.75	96.00	79.50	964.60	22	2.55	2.4
September	29.40	20.75	94.00	73.50	579.00	14.5	5.65	2.5
October	29.55	13.65	93.00	49.50	5.60	1	8.15	2.1
November	25.90	8.65	98.00	48.00	19.05	1.5	5.8	1.6
December	21.85	4.35	98.50	46.00	26.05	1.5	5.7	1.7

Test insect and its forest based outdoor rearing

Bivoltine (BV) Daba ecotype of *A. mylitta* that is endowed with high exploitation potential and better ecological adaptability was chosen for the study and 75 DFLs (Disease Free Layings) were procured from the Basic Seed Multiplication and Training Centre (BSMTC), Central Silk Board, Ambikapur, District, Surguja, Chhattisgarh, on 8th July 2012 after carrying out microscopic examination as described by Sharan *et al.*, 1992. Four outdoor experimental rearings of *A. mylitta* were conducted as per the improved rearing technology of Mathur *et al.* (1998) during July-August and September-

November in 2012 and 2013. The generated cocoons (Figure 1) were utilised to assess the suitability of forestry host plants for best silk production efficiency and post cocoon attributes of the tropical tasar silkworm, *A. mylitta* in Uttarakhand.

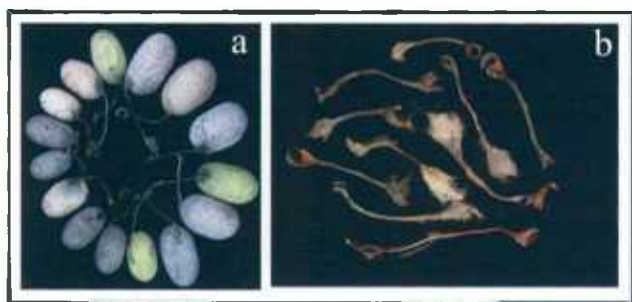


Figure 1: (a) Variation in harvested cocoons of *A. mylitta* fed on different host plants (b) Peduncles of cocoons

Variables measured

In order to examine the silk production efficiency and post cocoon attributes of *A. mylitta*, the following nineteen variables were measured and analysed:

1. Peduncle length of ♂ cocoons
2. Peduncle length of ♀ cocoons
3. Length of ♂ cocoons
4. Length of ♀ cocoons
5. Breadth of ♂ cocoons
6. Breadth of ♀ cocoons
7. Length & Breadth ratio of ♂ cocoons
8. Length & Breadth ratio of ♀ cocoons
9. Weight of ♂ cocoons
10. Weight of ♀ cocoons
11. Shell weight of ♂ cocoons
12. Shell weight of ♀ cocoons
13. Shell percentage of ♂ cocoons
14. Shell percentage of ♀ cocoons
15. Silk filament length
16. Non-breakable silk filament length
17. Raw silk recovery percentage
18. Denier of silk filament
19. Required number of cocoons to produce one kg of raw silk

The post cocoon assessment (mono-cocoon) was carried out at Demonstration Cum Technical Service Centre (DCTSC), Central Silk Board, Govt. of India at Premnagar, Dehra Dun, where samples @ 20 cocoons in each were analysed and data were collected as per the experimental protocol of the study. Deflossing, stifling and cooking of the cocoons were executed as per the procedure laid down by CSTRI (2010). Mono cocoon wet reeling was done by Epprouvette to assess the silk filament length and non-breakable silk filament length for which, formula of Rui (1998), was applied. Raw silk recovery and denier of the silk filament were calculated by the formula of Sonwalkar (1988) and Rui (1998), respectively. However, required number of *A. mylitta* cocoons to produce one kg of raw silk was calculated by the following formula:

$$\text{Cocoons required for 1 kg of raw silk} = \frac{1000}{\text{Weight of single cocoon fiber}}$$

Statistical methods

All the tested seven forest tree species were taken as treatments and there were six replications of each treatment. Normality of the data was checked prior to statistical analysis and percentage data were transformed to their respective arcsine values. Data of first and second rearing seasons were combined and then treatment-wise descriptive statistics was calculated by using Microsoft Excel for all the variables and mean tables were prepared accordingly (Table 3). A two-way completely randomized block factorial design was used to test the significance of differences between means of variables. Factorial ANOVA was carried out by using advance statistical software, STATISTICA 10 (Table 2). Rearing seasons, host plants and their interactions were treated as the main (fixed) effects and all the nineteen variables served as dependent variables for block effect. The level of significance was fixed at $p=0.05$. Post HOC test was carried out by using Tukey's HSD test to compare the homogeneous pairs of means (Table 4). A common evaluation index (E.I.) method, as laid down by Mano *et al.* (1998) was also used to confirm the superiority of forestry host plants for the studied variables of *A. mylitta* (Table 5).

RESULTS AND DISCUSSION

Host plants and rearing seasons influence the economic traits of cocoons and silk production efficiency of the silkworms (Ueda *et al.*, 1971; Hough and Pimental, 1978; Pillai *et al.*, 1987; Venugopal and Krishnaswami, 1987; Lindroth and Hemming, 1990). Rearing performance of *A. mylitta* is influenced by the season, host plants and their interactions and accordingly, the cocoons of *A. mylitta* show considerable variations in their colour, size, shape, pupal weight, shell weight and the silk output and such variations mainly occur due to the variations of races, climatic conditions, food plants, altitude *etc.* (Jolly *et al.*, 1974, 1979; Nayak and Guru, 1998 b).

Peduncle length

According to Panda (1972), peduncle character of the tasar silkworm cocoon is an important feature for accurate identification of its variety (Bogai or Nadia). In the present study, higher peduncle length was observed for ♂ cocoons of second rearing season as compared to those of the first rearing season on all the forestry host plants. Further, irrespective of the rearing seasons and host plants, higher peduncle length was observed in ♀ cocoons as compared to the ♂ cocoons. Nayak and Guru (1998 a) and Srivastava *et al.* (2002) had also reported higher peduncle length in ♀ cocoons as compared to ♂ cocoons in Daba ecorace of *A. mylitta* under the agro-climatic conditions of Ranchi, Jharkhand.

Results indicated that ♂ cocoons generated on *T. alata*, *T. tomentosa* and *T. arjuna* had shown higher peduncle length of 47.25, 44.45 and 40.65 mm, respectively, as compared to shorter peduncle length of the cocoons generated on *L. tomentosa* (36.80 mm), *T. bellirica* (37.00 mm) and *L. speciosa* (37.69 mm) by *A. mylitta* fed larvae. Similarly, in ♀ cocoons, overall highest peduncle length was recorded from the cocoons generated on *T. alata* (51.23 mm), followed by *T. tomentosa* (46.59 mm) and *T. arjuna* (42.82 mm); whereas, cocoons generated on *T. Chebula* have shown minimum peduncle length (35.14 mm), followed by *T. bellirica* (36.56 mm).

Silk producing insects present a great deal of variation in the colour and morphological characters of the cocoons fed on different host plants (Lefroy, 1909; Crotch, 1956; Pandey, 1995). Variations in the peduncle length of ♂ and ♀ cocoons were found significant between rearing seasons, host plants and their interactions ($P>0.05$), which indicate that rearing season influence the length of peduncle in both the sexes. In the second season, peduncle length was found comparatively higher on all the forestry host plants except for *T. alata*. Host plants have also shown significant effect on peduncle length in both the sexes, as cocoons generated on *T. alata*, *T. tomentosa* and *T. arjuna* have shown higher peduncle length as compared to *L. speciosa*, *T. bellirica*, *T. chebula* and *L. tomentosa*. Such fluctuations in peduncle length might have been attributed to the variations in larval weight gain owing to differences in availability of the foliar nutrients in the leaves of tested forestry food plant species.

Length and breadth of cocoons

Results indicated that length and breadth of ♂ and ♀ cocoons differ significantly between rearing seasons, among host plants and their interactions ($P>0.05$) (Table 2). Results also indicated that the mean length of ♂ cocoons, generated on *T. alata* (49.84 mm) and *T. tomentosa* (47.84 mm) differed significantly with that of the ♂ cocoons generated on *T. arjuna* (44.65), *L. speciosa* (44.27 mm) and *T. bellirica* (43.86 mm) fed larvae; whereas, length of ♀ cocoons generated on *T. alata* (53.83 mm) differed significantly with that of the cocoons generated on *T. tomentosa* (51.05 mm) (Table 3). Further, length of ♀ cocoons generated on *T. arjuna* (46.92 mm), *T. bellirica* (45.74 mm) and *L. speciosa* (45.60 mm) did not differ significantly and formed a homogenous group (Table 3). However, *L. tomentosa* delivered the shortest of the cocoons (40.05 mm).

During the second rearing season, *A. mylitta* produced bigger cocoons on all the forestry host plants. Further, *T. alata*, *T. tomentosa* and *T. arjuna* fed larvae produced bigger cocoons in both the rearing seasons as compared to *L. tomentosa* and *T. chebula*. Similar trends were also

Table 2: Analysis of variance for effects of rearing seasons, host plants and their interactions on silk production traits and post cocoon attributes of *A. mylitta* in Uttarakhand

Trait	Factor	DF	SS	MS	F value	P - value
Peduncle length of ♂ cocoons	Rearing seasons	1	1994.73	1994.73	74.12	0.00
	Host plants	6	11654.80	1942.47	72.19	0.00
	Rearing season* host plant	6	6967.76	1161.29	43.15	0.00
	Error	826	22229.32	26.91		
	Total	839	42846.61			
Peduncle length of ♀ cocoons	Rearing seasons	1	1702.30	1702.3	55.36	0.00
	Host plants	6	25027.64	4171.27	135.66	0.00
	Rearing season* host plant	6	6914.09	1152.35	37.48	0.00
	Error	826	25398.60	30.75		
	Total	839	59042.63			
Length of ♂ cocoons	Rearing seasons	1	8594.46	8594.46	418.56	0.00
	Host plants	6	18875.52	3145.92	153.21	0.00
	Rearing season* host plant	6	952.91	158.82	7.74	0.00
	Error	826	16960.65	20.53		
	Total	839	45383.54			
Length of ♀ cocoons	Rearing seasons	1	11197.39	11197.39	914.15	0.00
	Host plants	6	16732.08	2788.68	227.67	0.00
	Rearing season* host plant	6	897.70	149.62	12.22	0.00
	Error	826	10117.66	12.25		
	Total	839	38944.83			
Breadth of ♂ cocoons	Rearing seasons	1	2379.57	2379.57	445.72	0.00
	Host plants	6	16462	2743.67	513.92	0.00
	Rearing season* host plant	6	666.67	111.11	20.81	0.00
	Error	826	4409.74	5.34		
	Total	839	23917.98			
Breadth of ♀ cocoons	Rearing seasons	1	5253.50	5253.5	1437.18	0.00
	Host plants	6	13883.39	2313.9	633.01	0.00
	Rearing season* host plant	6	558.94	93.16	25.48	0.00
	Error	826	3019.37	3.66		
	Total	839	22715.20			
L&B ratio of ♂ cocoons	Rearing seasons	1	0.032	0.032	0.738	0.39@
	Host plants	6	13.714	2.286	51.952	0.00
	Rearing season* host plant	6	0.823	0.137	3.117	0.00
	Error	826	36.34	0.044		
	Total	839	50.909			
L&B ratio of ♀ cocoons	Rearing seasons	1	0.84	0.84	29.29	0.00
	Host plants	6	12.03	2.01	69.89	0.00
	Rearing season* host plant	6	1.12	0.19	6.44	0.00
	Error	826	23.70	0.03		
	Total	839	37.69			
Weight of ♂ cocoons	Rearing seasons	1	619.16	619.16	733.62	0.00
	Host plants	6	2741.20	456.87	541.33	0.00
	Rearing season* host plant	6	110.56	18.43	21.83	0.00
	Error	826	697.13	0.84		
	Total	839	4168.05			

cont'd. ...

Host plants of *A. mylitta* in Uttarakhand

Weight of ♀ cocoons	Rearing seasons	1	970.02	970.02	968.94	0.00
	Host plants	6	3109.61	518.27	517.69	0.00
	Rearing season* host plant	6	129.84	21.64	21.62	0.00
	Error	826	826.92	1.00		
	Total	839	5036.39			
Shell weight of ♂ cocoons	Rearing seasons	1	22.84	22.84	1430.16	0.00
	Host plants	6	78.58	13.1	820.05	0.00
	Rearing season* host plant	6	5.95	0.99	62.11	0.00
	Error	826	13.19	0.02		
	Total	839	120.56			
Shell weight of ♀ cocoons	Rearing seasons	1	57.25	57.25	1537.22	0.00
	Host plants	6	157.30	26.22	703.95	0.00
	Rearing season* host plant	6	10.31	1.72	46.12	0.00
	Error	826	30.76	0.04		
	Total	839	255.61			
Shell percentage of ♂ cocoons	Rearing seasons	1	460.95	460.95	244.13	0.00
	Host plants	6	1230.64	205.11	108.63	0.00
	Rearing season* host plant	6	125.01	20.84	11.04	0.00
	Error	826	1559.59	1.89		
	Total	839	3376.19			
Shell percentage of ♀ cocoons	Rearing seasons	1	932.73	932.73	493.56	0.00
	Host plants	6	2449.27	408.21	216.01	0.00
	Rearing season* host plant	6	107.50	17.92	9.48	0.00
	Error	826	1560.99	1.89		
	Total	839	5050.49			
Silk filament length	Rearing seasons	1	9815053.50	9815053.50	3816.00	0.00
	Host plants	6	27689219.40	4614869.90	1794.20	0.00
	Rearing season* host plant	6	1691860.50	281976.70	109.60	0.00
	Error	826	2124510.00	2572.00		
	Total	839	41320643.40			
Non-breakable silk filament length	Rearing seasons	1	26518.50	26518.50	211.50	0.00
	Host plants	6	223574.0	37262.30	297.20	0.00
	Rearing season* host plant	6	4219.70	703.30	5.60	0.00
	Error	826	103554.10	125.40		
	Total	839	357866.30			
Raw silk recovery percentage	Rearing seasons	1	6274.55	6274.55	323.32	0.00
	Host plants	6	11640.98	1940.16	99.97	0.00
	Rearing season* host plant	6	3221.81	536.97	27.67	0.00
	Error	826	16029.92	19.41		
	Total	839	37167.26			
Denier of silk filament	Rearing seasons	1	16.84	16.84	12.48	0.00
	Host plants	6	200.11	33.35	24.72	0.00
	Rearing season* host plant	6	24.33	4.06	3.01	0.00
	Error	826	1114.44	1.35		
	Total	839	1355.71			
Required number of cocoons to produce one kg of raw silk	Rearing seasons	1	253349297.30	253349297.00	2050.30	0.00
	Host plants	6	656487173.30	109414529.00	885.50	0.00
	Rearing season* host plant	6	36331009.00	6055168.20	49.00	0.00
	Error	826	102066187.00	123566.80		
	Total	839	1048233667.00			

@: Non-significant

Table 3: Effect of rearing seasons, host plants and their interaction on silk production traits and post cocoon attributes of *A. mylitta* in Uttarakhand

Variables	Rearing season*	<i>T. alata</i>	<i>T. tomentosa</i>	<i>T. arjuna</i>	<i>L. speciosa</i>	<i>T. bellirica</i>	<i>L. tomentosa</i>	<i>T. chebula</i>
Peduncle length of ♂ cocoons	I	51.92 ^l (±0.71)	44.27 ^l (±0.78)	36.49 ^l (±0.69)	35.27 ^l (±0.61)	35.81 ^l (±0.59)	33.06 ^l (±0.57)	35.27 ^l (±0.57)
	II	42.57 ^h (±0.71)	44.63 ^l (±0.78)	44.82 ^l (±0.75)	40.12 ^{hi} (±0.70)	38.18 ^h (±0.59)	40.55 ^{hi} (±0.68)	42.79 ^h (±0.58)
	III	47.25 ^g (±0.66)	44.45 ^l (±0.55)	40.65 ^l (±0.64)	37.69 ^h (±0.51)	37.00 ^g (±0.43)	36.80 ^g (±0.56)	39.03 ^{bc} (±0.53)
Peduncle length of ♀ cocoons	I	55.00 ^u (±0.85)	47.51 ^l (±0.81)	39.05 ^u (±0.67)	37.97 ^u (±0.59)	35.55 ^u (±0.66)	32.05 ^u (±0.54)	34.28 ^u (±0.55)
	II	47.47 ^l (±0.85)	45.67 ^l (±0.81)	46.59 ^l (±0.71)	46.26 ^l (±0.84)	37.57 ^u (±0.65)	41.76 ^l (±0.73)	36.01 ^u (±0.64)
	III	51.23 ^g (±0.69)	46.59 ^l (±0.58)	42.82 ^l (±0.6)	42.11 ^u (±0.64)	36.56 ^u (±0.47)	36.91 ^u (±0.63)	35.14 ^u (±0.43)
Length of ♂ cocoons	I	48.80 ^u (±0.76)	44.35 ^l (±0.50)	41.93 ^g (±0.46)	41.04 ^u (±0.71)	39.10 ^l (±0.52)	31.45 ^l (±0.52)	34.77 ^l (±0.51)
	II	50.88 ^l (±0.76)	51.33 ^l (±0.51)	47.38 ^l (±0.46)	47.50 ^l (±0.78)	48.62 ^u (±0.52)	39.31 ^u (±0.52)	41.21 ^u (±0.51)
	III	49.84 ^l (±0.54)	47.84 ^l (±0.48)	44.65 ^l (±0.41)	44.27 ^l (±0.60)	43.86 ^l (±0.57)	35.38 ^l (±0.51)	37.99 ^l (±0.47)
Length of ♀ cocoons	I	51.60 ^u (±0.44)	48.38 ^l (±0.54)	44.06 ^l (±0.51)	41.76 ^u (±0.43)	40.35 ^l (±0.42)	35.67 ^l (±0.38)	37.66 ^l (±0.41)
	II	56.07 ^l (±0.44)	53.73 ^l (±0.54)	49.78 ^u (±0.51)	49.44 ^u (±0.43)	51.14 ^u (±0.44)	44.44 ^l (±0.38)	45.99 ^l (±0.42)
	III	53.83 ^l (±0.37)	51.05 ^l (±0.45)	46.92 ^l (±0.44)	45.60 ^l (±0.46)	45.74 ^l (±0.58)	40.05 ^l (±0.48)	41.83 ^l (±0.48)
Breadth of ♂ cocoons	I	33.13 ^l (±0.35)	28.98 ^l (±0.31)	26.10 ^l (±0.30)	24.28 ^l (±0.33)	21.11 ^l (±0.35)	17.28 ^l (±0.20)	19.51 ^l (±0.20)
	II	32.38 ^l (±0.35)	32.61 ^l (±0.32)	29.03 ^l (±0.30)	28.70 ^l (±0.33)	25.02 ^u (±0.35)	22.15 ^l (±0.20)	24.04 ^l (±0.20)
	III	32.75 ^l (±0.25)	30.79 ^l (±0.28)	27.57 ^l (±0.25)	26.49 ^l (±0.31)	23.07 ^l (±0.30)	19.72 ^l (±0.26)	21.77 ^l (±0.25)
Breadth of ♀ cocoons	I	32.35 ^l (±0.29)	30.05 ^l (±0.19)	27.03 ^l (±0.24)	24.32 ^l (±0.24)	21.31 ^l (±0.23)	18.38 ^l (±0.23)	20.47 ^l (±0.28)
	II	34.32 ^l (±0.29)	33.8 ^l (±0.2)	31.18 ^u (±0.24)	30.62 ^l (±0.25)	26.95 ^l (±0.24)	24.7 ^l (±0.24)	27.27 ^l (±0.29)
	III	33.34 ^l (±0.22)	31.93 ^l (±0.22)	29.1 ^u (±0.25)	27.47 ^l (±0.34)	24.13 ^l (±0.31)	21.57 ^l (±0.34)	23.87 ^l (±0.37)
L&B ratio of ♂ cocoons	I	01.48 ^l (±0.02)	01.54 ^u (±0.03)	01.61 ^u (±0.02)	01.71 ^u (±0.04)	01.87 ^u (±0.03)	01.83 ^u (±0.03)	01.79 ^u (±0.03)
	II	01.58 ^u (±0.02)	01.59 ^u (±0.02)	01.64 ^u (±0.02)	01.66 ^u (±0.03)	01.96 ^u (±0.03)	01.781 ^u (±0.02)	01.72 ^u (±0.02)
	III	01.53 ^u (±0.02)	01.56 ^u (±0.02)	01.63 ^u (±0.01)	01.69 ^u (±0.02)	01.92 ^u (±0.02)	01.80 ^u (±0.02)	01.75 ^u (±0.02)
L&B ratio of ♀ cocoons	I	01.60 ^l (±0.01)	01.61 ^u (±0.02)	01.64 ^u (±0.02)	01.73 ^u (±0.03)	01.9 ^u (±0.03)	01.96 ^u (±0.03)	01.85 ^u (±0.03)
	II	01.64 ^l (±0.01)	01.59 ^l (±0.02)	01.6 ^u (±0.02)	01.62 ^u (±0.02)	01.9 ^u (±0.02)	01.81 ^u (±0.02)	01.69 ^u (±0.02)
	III	01.62 ^u (±0.01)	01.60 ^l (±0.01)	01.62 ^u (±0.01)	01.67 ^u (±0.02)	01.9 ^u (±0.02)	01.88 ^u (±0.02)	01.77 ^u (±0.02)
Weight of ♂ cocoons	I	11.742 ^l (±0.178)	09.403 ^l (±0.107)	08.519 ^l (±0.120)	08.090 ^l (±0.085)	7.366 ^u (±0.105)	6.609 ^l (±0.105)	6.980 ^u (±0.105)
	II	13.253 ^l (±0.178)	12.440 ^l (±0.111)	10.429 ^l (±0.121)	10.240 ^l (±0.086)	9.168 ^l (±0.106)	7.460 ^u (±0.105)	7.739 ^u (±0.105)
	III	12.497 ^l (±0.143)	10.921 ^l (±0.159)	09.474 ^l (±0.122)	09.165 ^l (±0.115)	8.267 ^l (±0.111)	7.035 ^l (±0.084)	7.359 ^l (±0.081)
Weight of ♀ cocoons	I	13.072 ^l (±0.135)	11.167 ^u (±0.144)	10.469 ^l (±0.132)	9.73 ^u (±0.138)	8.97 ^u (±0.142)	7.821 ^u (±0.098)	8.22 ^u (±0.105)
	II	15.062 ^u (±0.133)	14.466 ^l (±0.147)	12.815 ^l (±0.133)	12.594 ^l (±0.138)	11.384 ^u (±0.143)	8.784 ^u (±0.098)	9.391 ^u (±0.107)
	III	14.067 ^u (±0.131)	12.816 ^l (±0.183)	11.642 ^l (±0.142)	11.162 ^l (±0.163)	10.178 ^l (±0.149)	8.303 ^l (±0.082)	8.805 ^l (±0.092)
Shell weight of ♂ cocoons	I	1.342 ^l (±0.020)	0.952 ^l (±0.018)	0.792 ^l (±0.007)	0.804 ^l (±0.012)	0.631 ^u (±0.010)	0.530 ^u (±0.008)	0.652 ^u (±0.012)
	II	1.733 ^l (±0.033)	1.567 ^l (±0.021)	1.137 ^l (±0.016)	1.206 ^l (±0.014)	0.988 ^l (±0.017)	0.648 ^l (±0.011)	0.732 ^l (±0.012)
	III	1.538 ^l (±0.026)	1.259 ^l (±0.031)	0.965 ^u (±0.018)	1.005 ^u (±0.020)	0.809 ^l (±0.019)	0.589 ^l (±0.008)	0.692 ^l (±0.009)
Shell weight of ♀ cocoons	I	1.822 ^l (±0.031)	1.428 ^l (±0.026)	1.204 ^l (±0.023)	1.168 ^l (±0.021)	0.954 ^l (±0.017)	0.750 ^u (±0.014)	0.816 ^u (±0.014)
	II	2.419 ^l (±0.036)	2.278 ^u (±0.036)	1.798 ^l (±0.032)	1.895 ^l (±0.028)	1.372 ^l (±0.021)	0.923 ^u (±0.014)	1.113 ^u (±0.019)
	III	2.120 ^l (±0.036)	1.853 ^l (±0.045)	1.501 ^l (±0.034)	1.532 ^l (±0.038)	1.163 ^l (±0.023)	0.836 ^l (±0.013)	0.964 ^l (±0.018)
Shell percentage of ♂ cocoons	I	11.532 ^l (±0.197)	10.169 ^u (±0.188)	09.396 ^u (±0.150)	10.010 ^u (±0.181)	08.638 ^l (±0.160)	8.114 ^l (±0.154)	9.418 ^u (±0.175)
	II	13.129 ^l (±0.216)	12.626 ^u (±0.171)	10.985 ^u (±0.198)	11.846 ^u (±0.187)	10.793 ^u (±0.161)	8.736 ^u (±0.161)	9.531 ^u (±0.171)
	III	12.33 ^l (±0.163)	11.397 ^l (±0.170)	10.19 ^l (±0.144)	10.928 ^l (±0.155)	09.715 ^u (±0.150)	8.425 ^l (±0.114)	9.474 ^l (±0.122)
Shell percentage of ♀ cocoons	I	13.951 ^l (±0.208)	12.837 ^l (±0.207)	11.532 ^l (±0.181)	12.076 ^l (±0.174)	10.66 ^l (±0.135)	09.627 ^l (±0.169)	09.945 ^u (±0.128)
	II	16.063 ^u (±0.203)	15.765 ^u (±0.206)	14.041 ^l (±0.210)	15.066 ^l (±0.199)	12.062 ^l (±0.120)	10.542 ^l (±0.163)	11.850 ^l (±0.143)
	III	15.007 ^l (±0.174)	14.301 ^l (±0.198)	12.786 ^l (±0.180)	13.571 ^l (±0.190)	11.365 ^l (±0.110)	10.085 ^l (±0.124)	10.898 ^l (±0.129)
Silk filament length	I	609.21 ^l (±10.29)	433.73 ^l (±05.42)	337.80 ^u (±05.83)	351.68 ^l (±05.29)	232.27 ^l (±3.07)	166.40 ^l (±2.46)	200.0 ^l (±2.91)
	II	898.97 ^l (±06.67)	793.01 ^l (±10.56)	555.07 ^l (±08.65)	617.88 ^l (±09.31)	410.28 ^l (±5.54)	257.77 ^l (±3.45)	311.45 ^l (±4.33)
	III	754.09 ^u (±14.62)	613.37 ^l (±17.50)	446.44 ^l (±11.23)	484.78 ^l (±13.32)	321.28 ^l (±8.75)	212.08 ^l (±4.69)	255.73 ^l (±5.73)
Non-breakable silk filament length	I	117.30 ^l (±1.54)	098.66 ^l (±1.11)	085.59 ^u (±1.26)	097.71 ^l (±0.91)	080.45 ^u (±1.4)	63.28 ^l (±0.94)	85.49 ^u (±1.33)
	II	132.40 ^u (±2.49)	113.56 ^l (±1.52)	100.62 ^u (±1.17)	106.39 ^l (±1.67)	90.16 ^l (±1.64)	76.52 ^l (±1.22)	87.50 ^l (±1.34)
	III	124.85 ^l (±1.61)	106.11 ^u (±1.16)	093.11 ^l (±1.1)	102.05 ^l (±1.03)	85.31 ^l (±1.16)	69.90 ^l (±0.98)	86.49 ^l (±0.94)
Raw silk recovery percentage	I	58.70 ^u (±0.70)	54.87 ^u (±0.51)	53.38 ^l (±0.43)	55.56 ^u (±0.61)	47.75 ^l (±0.39)	43.12 ^l (±0.61)	43.94 ^l (±0.60)
	II	59.68 ^u (±0.26)	58.12 ^u (±0.45)	56.55 ^u (±0.65)	57.46 ^u (±0.72)	54.62 ^u (±0.42)	54.46 ^u (±0.76)	54.70 ^u (±0.60)
	III	59.19 ^u (±0.38)	56.50 ^l (±0.37)	54.96 ^l (±0.42)	56.51 ^u (±0.48)	51.19 ^l (±0.42)	48.79 ^l (±0.71)	49.32 ^l (±0.65)
Denier of silk filament	I	10.88 ^u (±0.12)	10.73 ^u (±0.19)	11.22 ^u (±0.15)	10.79 ^u (±0.12)	11.82 ^l (±0.14)	11.82 ^l (±0.17)	11.43 ^l (±0.17)
	II	10.09 ^l (±0.13)	10.46 ^u (±0.16)	10.71 ^u (±0.16)	10.76 ^u (±0.17)	11.22 ^u (±0.15)	11.87 ^u (±0.10)	11.61 ^u (±0.15)
	III	10.48 ^l (±0.09)	10.59 ^u (±0.12)	10.97 ^u (±0.11)	10.78 ^u (±0.10)	11.52 ^l (±0.10)	11.85 ^l (±0.10)	11.52 ^l (±0.11)
Required no. of cocoons to produce one kg of raw silk	I	1385.38 ^u (±23.99)	1975.49 ^l (±32.4)	2435.53 ^l (±49.74)	2410.12 ^l (±34.49)	3334.95 ^l (±57.5)	4684.4 ^l (±90.83)	4026.94 ^l (±75.91)
	II	1005.65 ^l (±15.17)	1107.82 ^l (±18.68)	1560.18 ^l (±29.46)	1387.19 ^l (±26.3)	1992.38 ^l (±34.19)	2977.71 ^l (±37.85)	2533.2 ^l (±38.51)
	III	1195.52 ^l (±22.42)	1541.65 ^l (±43.91)	1997.85 ^l (±49.38)	1898.66 ^l (±51.62)	2663.67 ^l (±69.97)	3831.05 ^l (±92.3)	3280.1 ^l (±80.52)

* Values represent combined mean ± standard error of 30 observations of five samples each from six replications for the year 2012 and 2013. I: First crop rearing (combined for 2012 & 2013); II: Second crop rearing (combined for 2012 & 2013); III: Combined for first & second crop rearing 2012 & 2013. Significant difference within every variable are indicated by different superscript; whereas, same superscript within every variable represents homogeneous groups (Tukey's HSD test at alpha = 0.05).

Table 4: Tukey HSD test for effect of rearing seasons on various silk production traits and post cocoon attributes of *A. mylitta* in Uttarakhand

Parameter	Homogenous groups statistical descriptions	Rearing season	Mean*
Peduncle length of ♂ cocoons	alpha = 0.05000; Error MS = 26.912, df = 826.00	I	38.871
		II	41.953
Peduncle length of ♀ cocoons	alpha = 0.05000; Error MS = 30.749, df = 826.00	I	40.2
		II	43.048
Length of ♂ cocoons	alpha = 0.05000; Error MS = 20.533, df = 826.00	I	40.206
		II	46.603
Length of ♀ cocoons	alpha = 0.05000; Error MS = 12.249, df = 826.00	I	42.783
		II	50.085
Breadth of ♂ cocoons	alpha = 0.05000; Error MS = 5.3387, df = 826.00	I	24.339
		II	27.705
Breadth of ♀ cocoons	alpha = 0.05000; Error MS = 3.6554, df = 826.00	I	24.844
		II	29.846
LB ratio of ♂ cocoons	alpha = 0.05000; Error MS = .04399, df = 826.00	I	1.691
		II	1.703
LB ratio of ♀ cocoons	alpha = 0.05000; Error MS = .02868, df = 826.00	I	1.693
		II	1.756
Weight of ♂ cocoons	alpha = 0.05000; Error MS = .84398, df = 826.00	I	8.387
		II	10.104
Weight of ♀ cocoons	alpha = 0.05000; Error MS = 1.0011, df = 826.00	I	9.922
		II	12.071
Shell weight of ♂ cocoons	alpha = 0.05000; Error MS = .01597, df = 826.00	I	0.815
		II	1.145
Shell weight of ♀ cocoons	alpha = 0.05000; Error MS = .03724, df = 826.00	I	1.163
		II	1.685
Shell percentage of ♂ cocoons	alpha = 0.05000; Error MS = 1.8881, df = 826.00	I	9.611
		II	11.092
Shell percentage of ♀ cocoons	alpha = 0.05000; Error MS = 1.8898, df = 826.00	I	11.52
		II	13.627
Silk filament length	alpha = 0.05000; Error MS = 2572.0, df = 826.00	I	333.014
		II	549.205
Non-breakable silk filament length	alpha = 0.05000; Error MS = 125.37, df = 826.00	I	89.784
		II	101.021
Raw silk recovery percentage	alpha = 0.05000; Error MS = 19.407, df = 826.00	I	51.048
		II	56.514
Denier of silk filament	alpha = 0.05000; Error MS = 1.3492, df = 826.00	I	10.96
		II	11.244
Required number of cocoons to produce one kg of raw silk	alpha = 0.05000; Error MS = 123566.8, df = 826.00	I	1794.885
		II	2893.259

*Combined mean of the variable on all the forestry host plants during first and second rearing season.

observed by Srivastava *et al.* (2002) and Nayak and Guru (1998 a). Jindra and Sehnal (1989) advocated that due to insufficient nutritive quality of host plant, production of silk protein decreased that led to formation of smaller cocoons in *Galleria mellonella*. Therefore, it can be inferred that a similar phenomenon may have prevailed in the case of *L. tomentosa* and *T. chebula* fed larvae of *A. mylitta* resulting in the formation of smaller sized cocoons as compared to *T. alata*, *T. tomentosa* and *T. arjuna* fed larvae.

The overall mean breadth of ♂ cocoons differed significantly on all the forestry host plants that ranged from 32.75 mm on *T. alata* to 19.72 mm on *L. tomentosa*. Further, overall breadth of ♀ cocoons also differed significantly on all the forestry host plants, except for cocoons generated on *T. chebula* (23.87 mm) and *T.*

bellirica (24.13 mm), which did not differ significantly. The highest breadth of ♀ cocoons was recorded by *T. alata* (33.34 mm) fed larvae, followed by *T. tomentosa* (31.93 mm), *T. arjuna* (29.10 mm) and *L. speciosa* (27.47 mm) fed larvae. It has also been observed that in both the rearing seasons, length and breadth of ♀ cocoons was found higher than that of the ♂ cocoons on all the forestry host plants.

Further, in both the rearing seasons, length and breadth of female cocoons was found higher than that of male cocoons on all the forestry host plants. Panda (1972) had also made similar observations in the case of *A. paphia*.

Length and breadth ratio of cocoons

Length and breadth ratio (LB ratio) of a cocoon

Table 5: Combined Evaluation Index (E.I.) for silk production traits and post cocoon attributes of *A. mylitta*, reared on different forestry host plants in Uttarakhand

Dependent variable	Rearing season	<i>T. alata</i>	<i>T. tomentosa</i>	<i>T. arjuna</i>	<i>L. speciosa</i>	<i>T. bellirica</i>	<i>L. tomentosa</i>	<i>T. chebula</i>
(A) Silk production traits of <i>A. mylitta</i> requiring higher E. I. values (>50)								
Peduncle length of ♂ cocoons	I	66.27	56.74	47.04	45.51	46.19	42.76	45.51
	II	51.08	54.66	54.98	46.82	43.45	47.56	51.46
	III	59.57	55.66	50.34	46.20	45.22	44.95	48.07
Peduncle length of ♀ cocoons	I	66.08	57.94	48.74	47.57	44.95	41.15	43.57
	II	56.12	53.63	54.91	54.44	42.42	48.22	40.25
	III	61.46	55.92	51.42	50.58	43.97	44.38	42.27
Length of ♂ cocoons	I	62.32	55.95	52.48	51.19	48.42	37.45	42.2
	II	56.83	57.56	51.24	51.43	53.22	38.34	41.38
	III	58.75	56.03	51.7	51.17	50.62	39.09	42.64
Length of ♀ cocoons	I	63.97	58.87	52.03	48.38	46.14	38.73	41.89
	II	61.64	57.09	49.42	48.75	52.06	39.01	42.04
	III	60.86	56.78	50.72	48.78	48.99	40.64	43.24
Breadth of ♂ cocoons	I	65.59	58.22	53.12	49.89	44.27	37.48	41.43
	II	60.55	61.07	53.00	52.25	43.94	37.46	41.73
	III	62.61	58.93	52.89	50.88	44.46	38.19	42.04
Breadth of ♀ cocoons	I	64.52	60.06	54.22	48.99	43.16	37.5	41.55
	II	61.57	60.25	53.45	52.00	42.53	36.86	43.35
	III	61.51	58.81	53.38	50.24	43.82	38.91	43.33
Weight of ♂ cocoons	I	67.97	55.44	50.71	48.41	44.53	40.48	42.46
	II	64.10	60.46	51.45	50.61	45.81	38.16	39.41
	III	64.59	57.52	51.02	49.64	45.61	40.08	41.54
Weight of ♀ cocoons	I	66.06	56.35	52.79	49.03	45.16	39.29	41.33
	II	62.36	59.9	53.08	52.16	47.16	36.42	38.93
	III	62.53	57.43	52.64	50.68	46.66	39.01	41.06
Shell weight of ♂ cocoons	I	69.53	55.08	49.15	49.62	43.18	39.47	43.97
	II	64.71	60.54	49.82	51.55	46.10	37.59	39.71
	III	64.72	57.38	49.6	50.68	45.51	39.69	42.42
Shell weight of ♀ cocoons	I	67.13	56.89	51.07	50.13	44.56	39.25	40.97
	II	62.85	60.38	51.98	53.68	44.50	36.64	39.97
	III	62.61	57.76	51.39	51.95	45.26	39.35	41.67
Shell percentage of ♂ cocoons	I	61.41	53.32	48.73	52.37	44.22	41.11	48.85
	II	60.03	57.55	49.47	53.71	48.53	38.40	42.31
	III	59.87	55.21	49.2	52.87	46.83	40.40	45.63
Shell percentage of ♀ cocoons	I	62.31	56.67	50.07	52.82	45.69	40.42	42.03
	II	60.01	58.79	51.70	55.91	43.57	37.33	42.70
	III	59.92	57.04	50.87	54.07	45.08	39.86	43.17
Average E.I.		61.73	57.04	51.30	50.33	46.09	40.43	44.26
(B) Post cocoon attributes of <i>A. mylitta</i> requiring higher E. I. values (>50)								
Silk filament length	I	68.51	56.75	50.32	51.25	43.25	38.83	41.09
	II	65.20	60.60	50.26	52.99	43.96	37.33	39.67
	III	64.10	57.76	50.24	51.97	44.60	39.68	41.65
Non-breakable silk filament length	I	65.00	54.84	47.72	54.32	44.91	35.56	47.66
	II	64.73	55.88	49.81	52.52	44.90	38.50	43.66
	III	64.26	55.18	48.89	53.22	45.11	37.65	45.68
Raw silk recovery percentage	I	60.76	55.38	53.28	56.35	45.37	38.85	40.01
	II	56.58	53.34	50.08	51.97	46.07	45.74	46.23
	III	58.13	54.09	51.77	54.10	46.11	42.50	43.30
Average E.I.		62.16	55.68	50.30	53.10	45.27	39.94	43.54
(C) Post cocoon attributes of <i>A. mylitta</i> requiring lower E. I. values (<50)								
Denier of silk filament	I	47.10	45.89	49.83	46.38	54.65	54.65	51.51
	II	43.22	46.10	48.05	48.44	52.03	57.10	55.07
	III	45.11	45.98	48.97	47.47	53.29	55.89	53.29
Required number of cocoons to produce one kg of raw silk	I	37.13	42.16	46.09	45.88	53.77	65.29	59.68
	II	39.11	40.52	46.76	44.37	52.73	66.32	60.19
	III	39.72	42.82	46.90	46.02	52.86	63.30	58.37
Average E.I.		42.42	44.40	47.94	46.75	53.08	59.60	55.83

I: crop rearing (combined E.I. for 2012 & 2013); II: II crop rearing (combined E.I. for 2012 & 2013); III: Combined E.I. for I & II crop rearing 2012 & 2013.

indicates its shape. If LB ratio is one, it entails that cocoon is perfectly spherical. Further, Somashekar (2003) reported that oval shaped cocoons facilitate reeling process; therefore, higher values of LB ratio (more than one) in the cocoons of *A. mylitta* are always preferable, that indicates that cocoons are of oval shaped.

LB ratio of ♂ cocoons did not differ significantly between rearing seasons ($P>0.05$); whereas, it differed significantly among host plants and their interactions ($P<0.05$) (Table 2). Results also indicated that LB ratio of ♀ cocoons was lower during second rearing season on all the forestry host plants, except for *T. alata*, as compared to the first rearing season. Higher LB ratio of the cocoons generated on *T. bellirica* (♂=1.92; ♀=1.90), *L. tomentosa* (♂=1.80; ♀=1.88) and *T. chebula* (♂=1.75; ♀=1.77) indicate their superiority over that of *T. alata* (♂=1.53; ♀=1.62), *T. tomentosa* (♂=1.56; ♀=1.60) and *T. arjuna* (♂=1.63; ♀=1.62).

It was also found that rearing seasons did not affect LB ratio of ♂ cocoons ($P<0.05$); whereas, it differed significantly among host plants and their interactions ($P>0.05$). However, in ♀ cocoons, LB ratio differed significantly between rearing seasons, among host plants and their interactions ($P>0.05$). It is also noticed that during the first rearing season; mean LB ratio of ♀ cocoons was higher on all the forestry host plants, displaying their superiority in terms of reeling.

Weight of cocoons

Cocoon weight is an important commercial character that determines its selling prices. Cocoon weight indicates the approximate quantity of raw silk that can be reeled from it. Host plant quality and rearing seasons influence the cocoon weight of *A. mylitta*, and a higher value of this trait is always desirable (Rath, 2000). Results indicated that mean weight of ♂ and ♀ cocoons differed significantly between rearing seasons, among host plants and their interactions ($P<0.05$). Cocoons produced during second rearing season weighed more on every host plant species.

Sengupta *et al.* (2002) had also recorded significantly higher cocoon weight in Daba ecorace of *A. mylitta* in second rearing season of September-November 2012 & 2013 under the agro-climatic condition of Ranchi. Findings also indicated that weight of ♀ cocoons was comparatively higher than that of ♂ cocoons in both the rearing seasons on all the forestry host plants. Since, ♀ larvae consume 16% more food, digest 28% faster (Rath, 2010) and gain 12% higher larval weight (Rath *et al.*, 2006), the average weight of ♀ cocoons is found always higher than the ♂ cocoons. There are reports that higher cocoon weight has direct positive correlation with pupal weight and silk yield (Gowda *et al.*, 1988; Govindan *et al.*, 1990).

Results also indicated that in both the rearing seasons, *T. alata* fed larvae produced cocoons with maximum weight, followed by *T. tomentosa*, *T. arjuna* and *L. speciosa* fed larvae; however, the minimum cocoon weight was shown by *L. tomentosa* and *T. chebula* fed larvae. These results corroborate the findings of Kumar *et al.* (2002-03), Rath (2000) and Kumar and Naik (2011), who also reported that *T. tomentosa* fed larvae of *A. mylitta* produce higher cocoon weight than *T. arjuna*, *L. speciosa*, *T. chebula*, *A. latifolia* and *Z. jujuba* fed larvae. However, the present findings differ with that of Deka and Kumari (2013), who reported maximum cocoon weight of *A. mylitta* by feeding on *T. arjuna* followed by *T. tomentosa*, *T. bellirica*, *L. speciosa* and *T. chebula*. Further, Reddy *et al.* (2012) had also found non-significant difference ($P>0.05$) between single cocoon weight of *A. mylitta* reared on *T. tomentosa* and *L. parviflora* food plants under the climatic conditions of Ranchi, Jharkhand.

It is reported that higher leaf nutrition of tasar food plant enhances the growth of *A. mylitta* larvae that has direct positive correlation with cocoon and shell weight along with silk filament length (Dash *et al.*, 1992; Yadav and Mahobia, 2010). It can be inferred that higher nutritive values of the leaves of *T. alata*, *T. tomentosa*, *T. arjuna* and *L. speciosa* (Sinha and Jolly, 1971; NISCAIR, 1976; Jolly *et al.*, 1979; Puri, 1994) and better rate of their intake, digestion and assimilation (Krishnaswami *et al.*, 1970;

Ray *et al.*, 1998; Rahman *et al.*, 2004, Saikia *et al.*, 2004) might have improvised the cocoon weight of *A. mylitta* on these tested forestry host plants. Krishnaswami *et al.* (1971) and Prasad *et al.* (2004) have also correlated the better rearing performance of *A. mylitta* larvae with higher water and nitrogen content of the leaves. Similar findings for the significant effect of rearing season and food plants on cocoon weight of eri (Srivastava *et al.*, 1994; Biswas and Das, 2001; Hazarika *et al.*, 2003; Rajesh Kumar and Elangovan, 2010) and muga silkworm (Barah *et al.*, 1988) have also been reported.

Shell weight

More important than the weight of the whole cocoon, is the weight of silk shell that provides silk for reeling. Therefore, heavier the shell weight, greater would be the silk yield from it. Cocoon shell weight and its thickness uniformity are the important commercial cocoon characters for raw silk reeling that influence economic margin of raw silk production. Present findings reveal that mean shell weight of ♂ and ♀ cocoons differ significantly between rearing seasons, among host plants and their interactions ($P < 0.05$). Siddiqui *et al.* (2006) have also reported that type of the food plants and environment of silkworm rearing influence cocoon shell weight and shell percentage of *A. mylitta*. Further, results indicated that cocoons produced in second rearing season were of higher shell weight in both the sexes on all the forestry host plants that might be due to prevalence of favourable temperature and humidity regime for better growth and development of *A. mylitta* larvae.

Experimental results have also indicated that *T. alata* contributed for cocoons with higher shell weight, followed *T. tomentosa*, *L. speciosa* and *T. arjuna*. The minimum cocoon shell weight was recorded in the cocoons of *L. tomentosa*, followed by *T. chebula* and *T. bellirica* fed larvae. Kumar *et al.* (2003) had carried out bioassay of *A. mylitta* on different accessions of *Terminalia* and *Lagerstroemia* spp. in Ranchi, Jharkhand and found maximum shell weight on *T. arjuna*, followed by *T. tomentosa*, *L. speciosa* and *T. chebula*, respectively

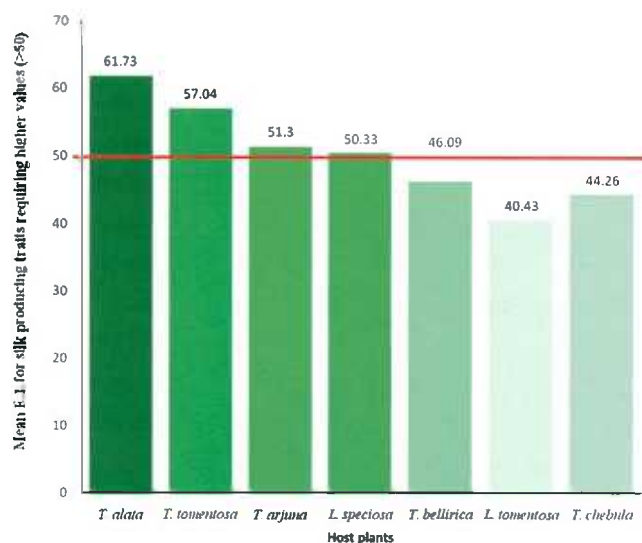


Figure 2: Combined E.I. for silk producing traits of *A. mylitta* requiring higher values (>50)

and their results differed from the present findings; as the quality of tasar food plant in terms of nutrition may influence cocoon weight and silk percentage that influences crop economics (Muthukrishnan and Pandian, 1987; Reddy *et al.*, 2010).

Furthermore, it is also reported that the proteins are the ubiquitous nitrogenous compounds in the tasar food plants that involves in structure and function of the cell (Sinha *et al.*, 2007). Machii and Katagiri (1991) reported that mulberry varieties containing higher contents of protein in their leaves have shown higher cocoon shell production efficiency. Crude protein content is reported to be higher in *T. alata*, *T. tomentosa*, *L. speciosa* and *T. arjuna* (Sinha and Jolly, 1971; Agarwal *et al.*, 1980) that might have contributed to the heavier shell weight of the cocoons. Moreover, Bose *et al.* (1995) have also reported that succulent leaves with less fibre and higher mineral contents stimulate the metabolic activities in silkworm that results in quantitative improvement of cocoon and silk. They found that *T. tomentosa* and *T. arjuna* were superior to *Shorea robusta* in this respect, because they contain higher percentage of total minerals (8.08 % and 6.82 %, respectively) and lower amount of crude fibre (16.09% and 12.82 %, respectively).

Results of the present study also indicated that mean shell weight of ♂ and ♀ cocoons on *T. arjuna* and *L. speciosa* did not differ significantly and formed a homogeneous group. This pattern of cocoon shell weight of *A. mylitta* on *L. speciosa* may be a boon for forest dependent people in Uttarakhand, because climatic conditions of Uttarakhand are more conducive for better growth and development of *L. speciosa*.

Secondly, *L. speciosa* flourish very well in Uttarakhand and produces more quantity of quality foliage due to many time larger size of lamina than *T. arjuna*. Hence, *L. speciosa* leaves provide more available food for silkworm feeding that reduces burden of transfer during late age rearing that reduces labour cost. Third, *L. speciosa* is not preferred for grazing by browsing animals. Fourth, in other parts of India, *L. speciosa* is considered as a secondary host plant for *A. mylitta*, but the results of present study clearly indicated that *L. speciosa* is as good as *T. arjuna* and can serve as one more primary host plant for successful commercial rearing of *A. mylitta* by the forest dependent people of Uttarakhand. Fifth, the results on multiple trait evaluation index analysis has also proved that *L. speciosa* is better host plant than *T. arjuna*, because it scored higher cumulative values of E.I. than *T. arjuna* (Table 5).

Shell percentage

The quality of cocoons as a raw material depends on the silk content. Silk percentage provides a fair indication to the quantity of raw silk that can be reeled from a fresh cocoon. Higher shell percentage is an indication of more quantity of raw silk. Shell percentage also influences reeling profitability, as the reelers would always prefer the cocoons with high shell percentage. Srivastava *et al.* (1994) suggested that silk percentage is the second most reliable economic character after effective rate of rearing (ERR) for assessing the effect of forestry host plants and rearing season of *A. mylitta*.

Results indicated that mean shell percentage of ♂ and

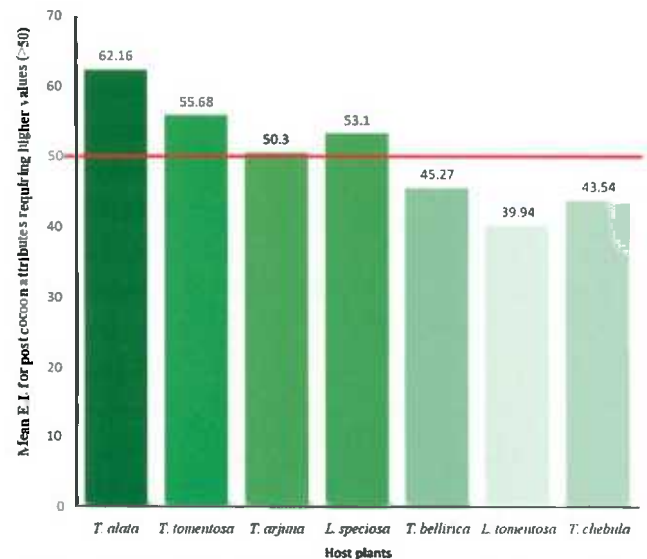


Figure 3: Combined E.I. for post cocoon attributes of *A. mylitta* requiring higher values (>50)

♀ cocoons differ significantly between rearing seasons, among host plants and their interactions ($P < 0.05$). Dash *et al.* (1994) reported that host plants, seasons and their interaction influence the cocoon shell weight of wild silkworm *A. paphia*. It is also evident that cocoons produced in second rearing season displayed higher shell percentage on all the forestry host plants. Deka *et al.* (2011) and Sengupta *et al.* (2002) had also recorded significantly higher shell percentage of Daba ecorace of *A. mylitta* in second rearing season under the climatic conditions of Ranchi, Jharkhand. They opined that the superiority of second crop to the first crop might be due to prevalence of optimum temperature and humidity regime for the better performance of *A. mylitta*.

Results showed that cocoons recording the highest shell percentage were found to be generated on *T. alata*, followed by those raised on *T. tomentosa*, *L. speciosa* and *T. arjuna* whereas, the minimum shell percentage was recorded by *L. tomentosa* and *T. chebula* fed larvae. Deka and Kumari (2013) had also assessed the effect of six forestry host plants viz., *T. tomentosa*, *T. arjuna*, *T. bellirica*, *T. chebula*, *L. speciosa* and *L. parviflora* on cocoon characteristics of *A. mylitta* under the agro-climatic conditions of Ranchi, Jharkhand. In their study, performance of *L. speciosa* on cocoon productivity and

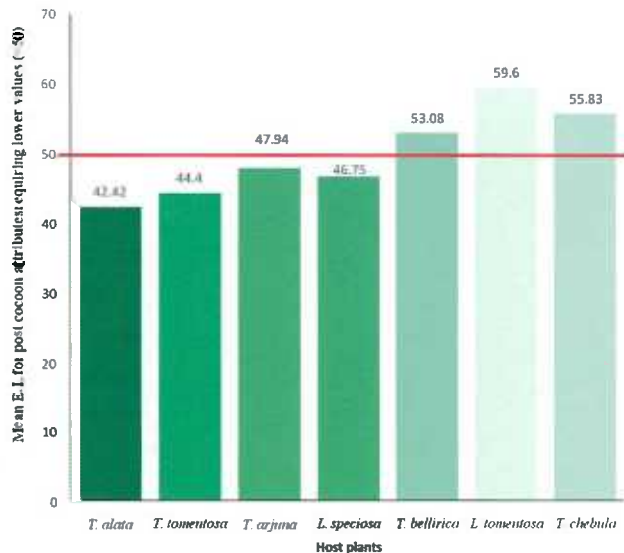


Figure 4: Combined E.I. for post cocoon attributes of *A. mylitta* requiring lower values (<50)

silk percentage of *A. mylitta* was found comparatively higher than that on *T. tomentosa* and *T. arjuna* that supports present findings. They further reported that the leaves of *T. arjuna*, *T. tomentosa* and *L. speciosa* possess more leaf moisture, chlorophyll, proteins and carbohydrate contents that support better larval growth of *A. mylitta*. Kumar *et al.* (2009) had also reported that *L. speciosa* is one of the most suitable host plants for *A. mylitta* in view of shell percentage, especially for the first rearing season.

The present results are also supported by the findings of Kumar *et al.* (2003), who had recorded maximum shell percentage of 12.59 % on *T. arjuna*, followed by 12.12 %, 10.97 % and 9.58 % on *T. tomentosa*, *L. speciosa* and *T. chebula*, respectively whereas, Jolly (1966) and Jolly *et al.* (1974) had obtained tough and thick-shelled cocoons of *A. mylitta* when reared on *S. robusta* that were rather tougher than those of *T. tomentosa* and *T. arjuna*. Cocoons of the lowest shell weight category resulted when larvae were raised on *L. tomentosa* in both the rearing seasons.

Silk filament length

Silk filament length (SFL) is as important as the

cocoon shell percentage. Silk filament length determines the work load, rate of production, evenness of the silk thread and output quality (Somashekar, 2003). In this study, silk filament length of *A. mylitta* differed significantly between rearing seasons, among host plants and their interactions ($P < 0.05$). During second rearing season, the mean silk filament length was found higher as compared to first rearing season. Sengupta *et al.* (2002) has also recorded significantly higher filament length of Daba ecorace of *A. mylitta* in second rearing season than first rearing season under Ranchi condition.

Results also indicated that the highest mean silk filament length was observed in the cocoons of *T. alata* fed larvae, followed by those of *T. tomentosa*, *L. speciosa* and *T. arjuna* fed larvae; whereas, the lowest mean silk filament length was observed in the replications of *L. tomentosa*, followed by *T. chebula* fed larvae. Kumar *et al.* (2003) had also carried out bioassay with different accessions of *Terminalia* and *Lagerstroemia* species under Ranchi conditions and found maximum filament length of 814 m on *T. arjuna*, followed by 724 m, 556 m and 487.5m on *T. tomentosa*, *L. speciosa* and *T. chebula*, respectively.

Non-breakable silk filament length

Non-breakable filament length (NBFL) depends on reelability of the cocoons, and if the reelability is better, NBFL would be on the higher side. NBFL determines the number of casting required per minute under given reeling speed. Thus, higher NBFL gives better productivity and quality of the raw silk. NBFL determines filament continuity, because inferior quality cocoons results in more number of breaks (Somashekar, 2003).

In the current study, it was found that NBFL of *A. mylitta* cocoons differed significantly between rearing seasons, among host plants and their interactions ($P < 0.05$). Further, during second rearing season, mean NBFL was found higher as compared to the first rearing season. Sengupta *et al.* (2002) had also recorded significantly higher NBFL of Daba ecorace of *A. mylitta* in second rearing season under Ranchi conditions. It is reported that

Daba ecorace of *A. mylitta* has maximum reelability among all its eco-races (Kumar and Roy, 2011). We have observed the highest mean NBFL for cocoons generated by *T. alata* fed larvae, followed by *T. tomentosa*, *L. speciosa* and *T. arjuna* fed larvae. Kumar *et al.* (2003) had also found maximum NBFL on *T. tomentosa*, followed by *T. arjuna*, *L. speciosa* and *T. chebula*.

Raw silk recovery percentage

Raw silk recovery percentage is the most important point of consideration from a reeler's point of view, because it determines the profitability of the reeling business and production of raw silk.

In this study, the raw silk recovery percentage of experimental cocoons differed significantly between rearing seasons, among host plants and their interactions ($P < 0.05$), the higher mean raw silk recovery percentage being recorded during second rearing season. Sengupta *et al.* (2002) had also recorded significantly higher average silk recovery of Daba ecorace of *A. mylitta* in second rearing season. The present results indicated the highest mean raw silk recovery percentage from the cocoons of *T. alata* fed larvae, followed by *L. speciosa*, *T. tomentosa* and *T. arjuna* fed larvae. However, Dash *et al.* (1992) had found superior raw silk recovery percentage of *A. mylitta* on *T. tomentosa* in both the rearing seasons. Their gradation of food plants with regard to raw silk recovery in decreasing order was; *T. tomentosa*, *T. arjuna*, *Z. jujuba*, *S. robusta*, *L. parviflora*, and *A. latifolia*. Rath *et al.* (1997) had also reported a similar finding.

Denier of silk filament

Cocoon filament denier indicates the thickness of the silk filament and its lower value is always desirable for the textile sector (Jolly *et al.*, 1979).

Results of the present study showed that mean filament denier of *A. mylitta* differed significantly between rearing seasons, among host plants and their interactions ($P < 0.05$). In second rearing season, the mean

filament denier was found lower as compared to the first rearing season. Sengupta *et al.* (2002) had also recorded significantly lower denier from the cocoons of Daba ecorace of *A. mylitta* during second rearing season. In contrary to our findings, Barah *et al.* (1988) reported that silk denier of *A. assama* did not show any variation irrespective of the rearing seasons. Results indicated that the lowest mean filament denier was shown by the cocoons of *T. tomentosa* fed larvae, followed by *L. speciosa*, *T. alata* and *T. arjuna* fed larvae. Our results are supported by the findings of Kumar *et al.* (2003), who also found the lowest filament denier in the cocoons of *T. tomentosa* fed larvae, followed by the cocoons of *T. arjuna*, *L. speciosa* and *T. chebula* fed larvae.

Number of cocoons required to produce one kg of raw silk

Required number of cocoons to produce 1 kg of raw silk provides commercial trading information to the reelers and the lower value of this trait is always worthy. Results indicated that mean number of cocoons to produce 1 kg of raw silk by *A. mylitta* differ significantly between rearing seasons, among host plants and their interactions ($P < 0.05$). Study also indicated that during second rearing season, it required less number of cocoons to produce 1 kg of raw silk as compared to the first rearing season. Sengupta *et al.* (2002) had also recorded significantly higher raw silk yield/1000 cocoons of Daba ecorace of *A. mylitta* in second rearing season.

Further, the lowest requirement of cocoons to produce 1 kg of raw silk was recorded by the cocoons of *T. alata* fed larvae, followed by *T. tomentosa*, *L. speciosa* and *T. arjuna* fed larvae. Results of the path coefficient analysis carried out by Siddiqui *et al.* (1989) revealed that larval weight of *A. mylitta* has direct and positive effect on the required number of cocoons to produce 1 kg of raw silk. Results have also shown that *T. alata* fed larvae exhibited higher larval weight, followed by *T. tomentosa*, *L. speciosa* and *T. arjuna* fed larvae and correspondingly higher production of absolute silk weight.

Combined multiple traits evaluation index analysis for best silk production efficiency and post cocoon attributes of *A. mylitta*

Combined multiple traits evaluation index (E.I.) analysis for twelve silk producing traits and three post cocoon attributes of *A. mylitta* requiring higher indices (E.I. > 50) and for two post cocoon attributes that require lower indices (E.I. < 50) are presented in Table 5. Results of the combined Evaluation Index analysis for silk producing traits requiring higher (E.I. > 50) indices indicated that four forestry host plants viz., *T. alata* (61.73), *T. tomentosa* (57.04), *T. arjuna* (51.30) and *L. speciosa* (50.33) are the best suited (Figure 2) in the order of merit for their utilization in generation of forest based “Eco tasar silk” in Uttarakhand after introducing Tasar Seri Business in the state.

Further, E.I. analysis clearly indicated that four forestry host plants viz., *T. alata* (61.16 & 42.42), *T. tomentosa* (55.68 & 44.40), *L. speciosa* (53.10 & 46.75) and *T. arjuna* (50.30 & 47.94) proved their superiority in the order of merit in respect of better reeling and post cocoon attributes (Figures 3 and 4) by scoring higher E.I. indices than other tested forestry host plants.

Prospects of tropical tasar silkworm rearing in Uttarakhand

Forestry host plants of *A. mylitta* viz., *T. alata*, *T. tomentosa* and *T. arjuna* are reported to be unevenly distributed up to an altitudinal range of 2000 feet (610 meter) in tropical moist deciduous and tropical dry deciduous forest areas of the Uttarakhand (Thangavelu, 2004). It is also reported that different eco-races of *A. mylitta* thrive well up to an altitude range of 610 m (Rao and Yadav, 2004) in different tasar producing states. SRTM (Shuttle Radar Topography Mission) mapping of Uttarakhand carried out during the study indicated that 3,217.9 km² of forest area distributed up to an altitudinal range of <610 meter in Dehra Dun, Haridwar, Nainital and U.S. Nagar districts of Uttarakhand can be appropriated for introduction of the forest based rearing

of *A. mylitta*. In addition, 12,790.06 km² area in the Uttarakhand state that is 23.91 % of its total geographical area is waste land (MoRD, 2013); and out of this vast area, 989.77 km² is distributed up to the altitudinal range of <610 meter having tropical moist deciduous and tropical dry deciduous forest conditions (Anonymous, 2011), this area can also be utilised for introduction of the tropical tasar culture in the state.

Conclusion

Results of this study concludes that *T. alata*, *T. tomentosa*, *L. speciosa* and *T. arjuna* are the best suitable forestry host plants in their order of merit to have best silk production efficiency and post cocoon attributes of Daba ecorace (Bivoltine) of *A. mylitta* under the climatic conditions of Dehra Dun, Uttarakhand. Accordingly, State Forest Department in association with Directorate of Sericulture, Uttarakhand and Central Silk Board, Bengaluru may initiate systematic plantation of these forestry host plants through their various forestation and plantation schemes and may initiate forest based commercial rearing of tropical tasar silkworm, *A. mylitta* to create a new forest insect industry in the state to improve livelihood delivery of the tropical forests to their dependents.

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Article scientifique

EVALUATION DE LA PERTINENCE DE LA PLANTE HÔTE POUR UNE MEILLEURE EFFICACITÉ DE LA PRODUCTION DE SOIE ET LES CARACTÈRES POST-COCON CHEZ *ANTHRAEA MYLITTA* EN UTTARAKHAND

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ABSTRACT

Antheraea mylitta Drury est un insecte forestier producteur de soie exploitée commercialement dans neuf états producteurs de tasar en Inde, mais reste inexploité en Uttarakhand. Dans cette étude, nous avons étudié l'effet des plantes hôtes des saisons et leurs interactions sur l'efficacité de la production de soie et les caractéristiques post-cocon chez la race Daba (BV) de *A. mylitta* au Forest Research Institute, Dehra Dun (Uttarakhand). Quatre élevages extérieurs ont été effectués sur sept espèces d'arbres en six réplifications pendant juillet-août et septembre-novembre en 2012 et 2013 ; les données ont été collectées sur quatorze variables pour la production de soie et cinq variables sur les caractères post-cocon chez *A. mylitta*. Une ANOVA à deux facteurs a été réalisée par STATISTICA 10 au seuil de signification de $P=0,05$. Un test post HOC a été réalisé en utilisant le test HSD de Tukey et un indice commun d'évaluation (E.I.) a été tiré pour affirmer la supériorité des plantes nourricières forestières pour toutes les variables étudiées. Les résultats indiquent que *Terminalia alata*, *T. tomentosa*, *Lagerstroemia speciosa* et *T. arjuna* sont les meilleures plantes hôtes dans leur ordre de performance pour toutes les variables étudiées. L'efficacité de la production globale de soie et les caractères post-cocon de *A. mylitta* sont meilleurs sur *L. speciosa* par rapport à *T. arjuna*. En Uttarakhand, *L. speciosa* possède certains avantages comme une croissance luxuriante, une non préférence par les animaux et une aire foliaire plus importante que celle de *T. arjuna* et facile à multiplier et à maintenir. C'est une bonne plante hôte primaire pour *A. mylitta*, en Uttarakhand alors dans d'autres régions *L. speciosa* est considérée comme une plante nourricière secondaire de *A. mylitta*.

Mots-clés: Moyens d'existence fournis par la forêt, élevage du tasar tropical, papillon séricigène sauvage.



COST SUBVENTION TO YOUNG STAGE SILKWORM REARING ENTREPRENEURS AND THE CORRESPONDING SURGE IN BIVOLTINE RAW SILK PRODUCTION IN SOUTHERN INDIA

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ABSTRACT

National Silkworm Seed Organization (NSSO) has been offering a subvention of 15 % on the cost of bivoltine hybrid disease free layings (DFLS) when bought by the enrolled Chawki Rearing Centres (CRCs) subject to certain stipulated conditions. The paper deals with the history of the scheme spanned through three Five Year Plans, such as 10th, 11th and 12th and the steady growth in the enrollment of the Registered Chawki Rearers who run the CRCs, in the number of bivoltine DFLs bought by them to distribute to their clients and in the amount given away by NSSO towards cost subvention. This study is specially focused on the 12th Five Year Plan period (2012-13 to 2016-17) and the year followed. The scheme became quite popular among the CRC entrepreneurs as evidenced by the impressive growth during the past five years when the consumption of bivoltine DFLs in southern India grew by 37.91 % through this scheme and in the process, the amount given away as discount grew by 45.98 %. This growth was further correlated with the growth in bivoltine raw silk production in southern India which grew at 27.76 %. The role played by the Silkworm Seed Production Centres (SSPCs) in distribution of high quality silkworm seed and the subsequent monitoring and follow-up at the CRC and farmers' level which contributed to such remarkable growth is highlighted.

Key words: Bivoltine hybrids, chawki rearing centres, cost subvention, disease free layings, raw silk production.

INTRODUCTION

National Silkworm Seed Organization (NSSO) is a coveted entity in India identified for producing and selling superior quality hybrid silkworm eggs, predominantly of bivoltine x bivoltine combination. In the year 2003-04, the organization realized that despite being the quality leader, its distribution of hybrid silkworm eggs was a dismal 8 % of the country's requirement. Therefore, it planned to expand the distribution base in commensuration with the production and to further aim at a complementing growth trajectory. One of the feasible systems thought of was to enroll the entrepreneurs running young stage silkworm rearing as a commercial venture in selected areas as franchises of NSSO to procure the hybrid eggs from seed production centres designated

to each franchise, and allow them to distribute to the farmers on legitimate profit. The entrepreneurs' venture of raising young stage silkworm until second moult in a commercial scale for the purpose of reselling is referred to as 'chawki rearing'. Scientific methods for rearing young stage silkworm in large scale was already in place (Krishnaswamy, 1990). There are quite a few successful entrepreneurs involved in commercial silkworm chawki rearing who demonstrated its sustainability over long term (Jagadeesh, 2013). NSSO opened its door to franchises and they were offered certain benefits in the form of discount in the cost of DFLs procured, incentives on the annual consumption and also supply of essential equipment/appliances limited to a fixed amount. By proposing to strengthen the marketing network by private participation, the organization was poised to improve the

seed production and distribution in a much organized manner with the following two underlying principles.

- ✓ Through the franchise system, NSSO would promote scientific incubation of silkworm eggs and chawki rearing to enhance productivity.
- ✓ The farmers would be able to differentiate among the quality of the crops which would enable NSSO to build a brand image for its silkworm seed.

METHODOLOGY

Evolution of the scheme

The primary objective of this then novel concept was to supply high quality chawki reared silkworms to establish a link between the Silkworm Seed Production Centres (SSPCs) and the farmers, for creating awareness among the farmers on the benefit of procuring chawki reared worms instead of silkworm eggs and thereby ensuring quality. The CRC entrepreneurs who enrolled as franchise during the 10th and 11th Five Year Plans were assisted with essential chawki rearing appliances worth a maximum of Rs. 1.25 lakhs. An annual target consumption of 1.5 lakh DFLs was set for each franchise CRC and a performance incentive of 2 % of the total cost of DFLs per annum was offered in the form of DFLs to those who reached the target. While the discount for buying bivoltine hybrid DFLs was 15 %, it was 10 % for cross breed DFLs with an intention to encourage consumption of bivoltine DFLs. By proposing to strengthen the marketing network like this by private participation, the organization was poised to improve the seed production and distribution in a much organized manner going forward. An exhaustive tripartite agreement among the Director, NSSO on behalf of Central Silk Board, the Head of SSPC and the prospective beneficiary in non-judicial stamp paper worth Rs. 100 in the presence of two witnesses was an important prerequisite for a beneficiary to get accepted in the scheme. The beneficiaries were to make a refundable deposit of Rs. 25000 through demand draft which would not carry any interest. As per the provisions of the agreement, NSSO could retrieve the rearing

equipment/appliances provided under the scheme if the organization was convinced that the performance of the beneficiary was not satisfactory at least during the first three years of enrollment.

Skewing discount towards bivoltine, a strategic move

It was towards the end of 11th Five Year Plan that the organization undertook a performance auditing of the beneficiaries covered until then and decided that the scheme had its bit of chaff among the beneficiaries. This prompted the organization to come out with a much leaner plan avoiding cumbersome procedures which was described as a no-frill scheme with more focus on entrepreneurial and industrial growth rather than mere beneficiary bloating. The 12th Five Year Plan scheduled from the financial year 2012-13 to 2016-17 saw the reworked plan being implemented with the following important guidelines:

- Any silkworm Chawki Rearer holding a valid Registration Certificate under the Central Silk Board (Amendment) Act, 2006 is eligible to enroll himself/herself for availing of the discount by applying through an SSPC in the prescribed format.
- The head of SSPC examines the facts and forwards the application to the NSSO with a recommendation followed by approval after proper scrutiny.
- The concerned SSPC collects the indent for DFLs well in advance.
- An enrolled Chawki Rearer is eligible for a discount of 15 % on the cost of the bivoltine DFLs in any given batch.
- The enrolled Chawki Rearers are eligible for the discount only on buying a minimum of 2500 DFLs on any given day.
- The discount is allowed only on cash purchase on the bill raised against the name of the Registered Chawki Rearer.
- There will not be any restriction whatsoever in terms

of territory *i.e.*, any SSPC may allow discount to the CRCs enrolled under this scheme regardless of the areas they belong to, provided the conditions laid down in this scheme are strictly adhered to.

- Each enrolled CRC is bound to buy a minimum of 50000 DFLs a year from the SSPC(s) of NSSO under this scheme. On failure to meet the annual target, the continuance of such CRC is reviewed and appropriate decision is taken.
- Any mis-utilization of the discount extended is viewed seriously and the CRCs involved are disqualified from availing of future benefit (s).
- The Heads of SSPCs and the extension machinery of NSSO make serious efforts to popularize the scheme and invite the entrepreneurs to get them enrolled.

Opportunities for seamless transition from old to new scheme

NSSO invited the CRC entrepreneurs to enroll in the new scheme strictly as per the new guidelines regardless of their status as existing beneficiary or new. The security deposits lying with the organization was returned to the beneficiaries after adjusting any dues. The equipment lying with the non-performers were retrieved after performance auditing. These actions were important for starting the modified scheme on a clean slate. On completion of the first year of the new scheme, an important policy decision was taken to do away with the discount on the cost of cross breed DFLs, making the position of the organization amply clear that, going forward such assistance from the Government's side would be available only for bivoltine, clearly aligning with the stand of Govt. of India.

RESULTS AND DISCUSSION

The CRC Discount Scheme has been the flagship programme of NSSO and seemingly popular among the Registered Bivoltine Chawki Rearers of Southern India. This scheme has the backing of a scientifically proven

methodology for young stage silkworm rearing (Sivaprasad *et al.*, 2015), training support (Vijayakumari *et al.*, 2010) and testimonials as a tool for socioeconomic uplift (Phaniraj *et al.*, 2018). Based on the previous experience and weighing the industry's need, minor tweaking was made in the attributes of the already existing discount scheme making it simple and no-frill. This change caught the fancy of quite a few serious entrepreneurs. Bringing down the annual target from 150000 DFLs to 50000 DFLs with an object of attracting more small scale CRC entrepreneurs to the scheme and to make it fairly inclusive was an important move. The Organization's, strategic decision to limit the discount on the cost of DFLs to bivoltine and withdraw the discount of 10 % earlier offered to cross breed DFLs sent the right signal to the beneficiaries that the thrust of the organization has shifted towards bivoltine raw silk production. This was for the organization to position itself firmly in line with the Govt. of India's thrust to encourage bivoltine sericulture. It was also a vindication of the general stand that cross breed silk production in India need not be incentivized any more especially when the Vision 2030 document of Central Silk Board makes it amply clear that the bivoltine raw silk production will be the primary focus point. Added to this, promoting maximum exploitation of the productive bivoltine silkworm hybrid combinations also continued as NSSO's long drawn policy.

Comparative performance among the Seed Production Centres and the states

The list of enrolled CRCs as on March 31, 2018 was 144. Out of this, 31 CRCs were enrolled during the year 2017-18. In total, 22 CRCs did not buy DFLs due to various reasons. Ten of them are newly enrolled ones who have enough time in hand to buy the DFLs as per the set target. But the remaining 12 would move out of the scheme as they were not able to honour the obligations as undertaken. Their failure is attributed mainly to stiff competition among Registered Chawki Rearers and the resultant loss of business. Quality issues and water shortage also played a major part. However, this did not in any way affect the DFLs off-take in general as obvious

from the overall performance. In fact, there was a substantial jump in the number of DFLs bought by the CRCs under the scheme. As per Table 1 in which only the CRCs which bought the DFLs has been included, the DFLs off-take jumped from 157.64 lakhs in the previous year to 169.76 lakhs in the year 2017-18, registering an impressive growth of 7.69 %. The amount of discount allowed witnessed an equally impressive growth of 11.53 %. The discount allowed stood at ₹171.44 lakhs in the year 2017-18 against ₹153.72 lakhs in the previous year. This resulted in the accrual of ₹9.72 crores to the Organization's working capital against the actual bill of ₹11.43 crores allowing a subvention of ₹1.71 crores.

Table 1: Details of CRC enrollment, DFLs consumption and the financial implications

SSPC	No. of CRCs	No. of DFLs	Total amount (₹)	Discount (₹)	Actuals received (₹)
Bengaluru	37	4048200	27274475	4091178	23183297
Chintamani	4	209350	1403800	210573	1193227
Chittoor	1	0	0	0	0
Dharmapuri	4	264200	1793550	269031	1524519
Hosur	7	1367750	9277275	1391597	7885678
Malavally	14	1073450	7177050	1076570	6100480
Madanapalle	1	0	0	0	0
Mysuru	49	7800200	52540600	7881124	44659476
Palakkad	2	1822000	12181350	1827214	10354136
Ramanagaram	0	11500	74750	11213	63537
Vijayapura	5	379000	2573975	386097	2187878
Total	124	16975650	114296825	17144597	97152228

Among the Silkworm Seed Production Centres, SSPC Mysuru turned out to be the top performer by distributing 78 lakh DFLs followed by SSPC Bengaluru with a distribution of 40.48 lakhs. SSPCs of Palakkad (18.22 lakhs), Hosur (13.68 lakhs) and Malavally (10.73 lakhs) followed with distribution of substantial quantity of DFLs under this scheme (Table 1). This is however, directly proportional to the number of CRCs enrolled. The percentage distribution is fairly clear in Figure 1 with SSPC Mysuru contributing 46 % of the total distribution followed by Bengaluru with 24 %. This make it clear that SSPC Mysuru and Bengaluru are the undisputed leaders

in bivoltine hybrid DFLs distribution. A closer look again reveals that SSPC Palakkad, Hosur and Malavally form the next cluster with reasonably good distribution with a share in the range of 6 to 11 %. The contribution from the remaining SSPCs was minimal or nil (Figure 1).

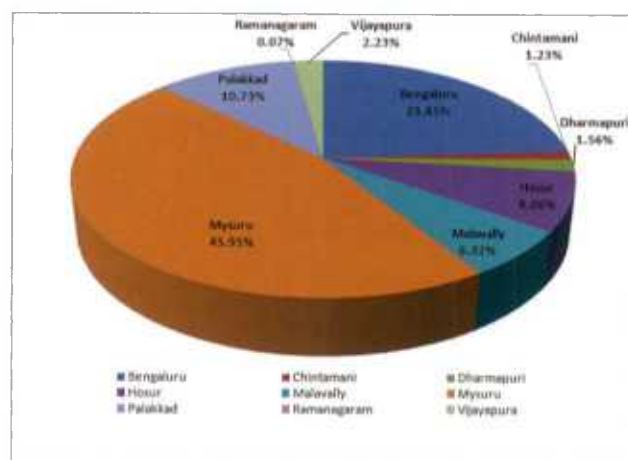


Figure 1: Percentage share of SSPCs in DFLs distribution under the CRC discount scheme

The CRC Discount Scheme is in force in the southern states only as of now. Quite understandably, the maximum number of CRCs enrolled under this scheme was from the state of Karnataka with a total of 94 CRCs. This was followed by Andhra Pradesh with 20 CRCs, Tamil Nadu with 6 CRCs and Telangana with 4 CRCs. Correspondingly, the CRCs of Karnataka bought a total of 141.19 lakh DFLs and enjoyed a discount of Rs. 142.59 lakhs. In the case of Andhra Pradesh, it was 24.29 lakh DFLs and Rs. 24.53 Lakhs discount whereas, the CRCs in the new state Telangana bought 2.86 lakh DFLs availing of a discount of Rs. 2.89 lakhs. The CRCs in Tamil Nadu, in fact nosedived in their DFLs purchase in comparison with the previous year (12.32 Lakhs) and bought only 1.42 lakh DFLs availing of a discount of Rs. 1.44 lakhs (Table 2).

Table 2: State-wise distribution of CRCs, DFLS distribution and discount allowed

State	No. of CRCs	Quantity of DFLs	Discount (Rs.)
Andhra Pradesh	20	2428920	2453095
Karnataka	94	14118630	14259142
Telangana	4	285750	288595
Tamil Nadu	6	142350	143765
Total	124	16975650	17144597

Attractive offers from the Govt. of Tamil Nadu to the Registered CRCs belonging to the home state on purchase of DFLs produced by its own production centres could be a possible reason for this notable decline.

Enrollment and DFLs consumption dynamics

CRC discount scheme being an open ended programme, the enrollment remains open to the beneficiary throughout the year. This is mainly because the registration of the new entrepreneur under the Central Seed Act is a continuous process and there are preset eligibility criteria for registration, a three months certificate training in the Chawki Rearing Technology from an institution approved by the Govt. of India being one of those. So, the registration is awarded only as and when the applicant meets the criteria. Post registration, they seek enrollment under CRC discount scheme. Thirty one such new enrollment happened in the latest completed financial year *i.e.*, 2017-18. But quite interestingly, all of them did not sustain their interest in buying the DFLs during the year and ten of the new enrollments stayed aloof. The buying trend of the new enrollment also varied widely albeit the period after the enrollment varied from 1 to 10 months (Table 3). The total DFLs bought by the 21 new enrollment was 6.44 lakhs with a satisfactory per capita buying of 30669 DFLs. This is quite encouraging taking the period of stay into consideration because the annual target fixed is 50000

DFLs. This is more relevant when a comparison is made between the new entrants and the RCRs with a full cycle of one year. There were 103 existing RCRs and their per capita DFLs consumption was worked out to be 158559 DFLs. Here again, the consumption ranged from as low as 2500 DFLs to the high of 728000 DFLs. This variation is principally due to the variation in the capacity to chawki rear bivoltine hybrid DFLs, the quality of the produce, clientele and brand loyalty, the Registered Chawki Rearers would enjoy.

Progress and popularity of the Scheme over the years

NSSO as an organization has been witnessing steady growth in its DFLs offload through the CRCs enrolled under this scheme. More and more CRC entrepreneurs are interested and inclined to avail of this benefit. The starting year of 12th Five Year Plan (2012-13) saw the number of bivoltine CRCs enrolled at 36 with DFLs off-take at 34 lakhs. In the next five years, the end-of-the-year number of enrollment that remained active did not add up as exponentially as the growth in DFLs off-take and cost subvention exhibited (Figure 2). This is quite evident in the comparison of the compounded annual growth rate (CAGR) of these three attributes. While the number of enrollment grew at a CAGR of 28.06 %, the DFLs off-take and cost subvention grew at a much higher pace of 37.91 and 45.98 %, respectively.

Table 3: New enrollments in the year 2017-18 and their buying statistics

Duration (Months)	RCRs	DFLs	RCRs with zero lifting
10	1	11000	0
9	3	89000	2
8	7	236700	2
7	2	16300	1
6	1	0	1
5	5	123150	0
4	2	62300	0
3	3	13000	2
2	5	90000	1
1	2	2600	1
Total	31	644050	10

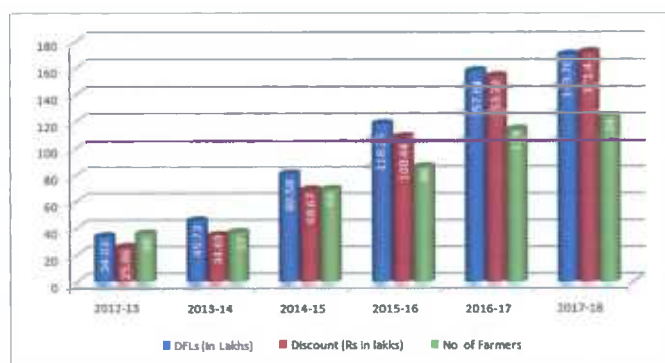


Figure 2: Progressive performance of CRC discount scheme implemented by NSSO

The role played by the SSPCs in distribution of high quality silkworm seed and the subsequent monitoring and follow-up at the CRC and farmers' level was remarkable as evidenced from the success of the cocoon crops across

various regions and seasons. The year on year increase in the number of DFLs sold under this scheme and the huge sum of amount allowed as discount is a testimony to the growing popularity of the scheme. NSSO states that it is committed to support the growth of CRC concept as a viable enterprise thereby contributing handsomely to the growth of bivoltine sericulture in the country.

Impact of the programme on the ground

The scheme's success is further reflected in the substantial increase in the bivoltine raw silk production in India, principally from the southern part of the country. The bivoltine raw silk production witnessed a decent growth of 12.20 % year on year and it reached 4810 MT in 2017-18 as against 4287 MT recorded in the year 2016-17 (Figure 3). This is largely in line with the increase noticed in bivoltine DFLs uptake under the CRC discount scheme. The increase in bivoltine raw silk production in the southern states over the past five years has been remarkable. It grew at a CAGR of 27.76 % during the past five years which was largely supported by the CRC concept and bivoltine DFLs consumption under the discount scheme. At the same time, the national CAGR in the bivoltine raw silk production recorded 24.16 %, one notch less than the collective growth of southern states.

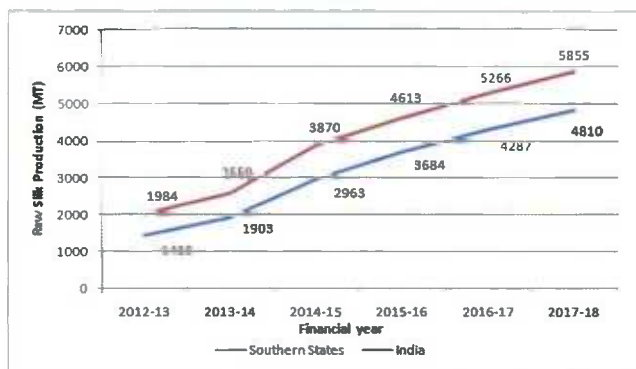


Figure 3: Growth in bivoltine raw silk production in India and in Southern states

Conclusion

The study gives a fairly clear idea that the subvention offered to eligible CRC entrepreneurs in the cost of bivoltine hybrid DFLs played a significant role in popularizing the concept of chawki rearing enterprise in general and bivoltine sericulture in southern India in particular as evidenced by the exponential growth in the bivoltine DFLs consumption and raw silk production.

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Article scientifique

COUT DES SUBVENTIONS AUX ELEVEURS DE JEUNES VERS A SOIE ET MONTEE CORRESPONDANTE DE LA PRODUCTION DE SOIE GREGE BIVOLTINE EN INDE DU SUD

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ABSTRACT

L'organisation nationale de graines de vers à soie (NSSO).a offert une subvention de 15 % du coût des pontes saines (DFLs) d'hybrides bivoltins lorsque qu'elles sont achetées par des centres d'élevage chawki (jeunes vers à soie) (CRCs) à certaines conditions. Cet article retrace l'histoire du schéma utilisé pendant trois années de plan c'est-à-dire le 10^{ème}, le 11^{ème} et le 12^{ème} et la croissance continue des éleveurs de chawki enregistrés qui courent les CRCs et le nombre de DFLs bivoltines achetées par eux pour les distribuer à leurs clients et le rapport avec les quantités données par le NSSO et le coût des subventions. Cette étude est centrée sur la période de cinq ans du 12^{ème} plan (2012-13 à 2016-17) et à l'année suivante. Le schéma est devenu très populaire parmi les entrepreneurs des CRC comme le montre la croissance impressionnante au cours des cinq dernières années quand la consommation de soie bivoltine a augmenté de 37,91 % en Inde du sud, la quantité distribuée comme subvention augmentant de 45,98 %. Cette croissance a ensuite été corrélée avec la croissance de la production de soie grège bivoltine de 27,76 % en Inde du sud. Le rôle joué par les SSPCs dans la distribution de graines de haute qualité et le monitoring au niveau des CRC et des fermiers qui contribuèrent à cette croissance remarquable.

Mots-clés: Hybrides bivoltins, centres d'élevages chawki, coût des subventions, pontes saines, production de soie grège.



BRIDGING OF GAPS IN ADOPTION OF DROUGHT MANAGEMENT TECHNOLOGIES IN MULBERRY CULTIVATION IN DROUGHT PRONE AREAS OF SOUTH INDIA

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ABSTRACT

Sericulture is an agro-based cottage industry substantially contributing for the rural development in south India. Mulberry cultivation is the basement of the industry. Of late, the impacts of climatic changes have been severely affecting the production and productivity of mulberry gardens in several sericultural clusters in south India. This demands for adoption of recommended drought management technologies in mulberry cultivation for quality leaf production and successful silkworm rearing. A study was conducted with the sericulture farmers of south India to find out the gaps in adopting these technologies with an intention to bridge the gap. Farmer-wise data on adoption gaps were collected for 12 identified technologies of mulberry cultivation. Even though 84 % of the farmers were affected by water shortage, the adoption gaps of the required technologies were high. Eighty, 20 and 56 per cent of farmers of Andhra Pradesh, Karnataka and Tamil Nadu state clusters, respectively have recorded high adoption gap (>66 %). The frequency of technology-wise adoption gap presented a range of 14 to 100 %. Hence, different extension communication programmes were conducted among the farmers for two years to increase the awareness and bridge the gaps in adoption, which in fact helped to bridge the gaps to the extent of 4 to 100 per cent and brought resultant improvements in leaf production. The impact of the programme on bridging of adoption gaps for all technologies in all states was statistically highly significant at 5 % level. Hence, the study suggests for taking up suitable efforts to increase the awareness among the farmers on drought management technologies and bridge the adoption gaps to enhance and sustain the quality linked silk production in the drought prone areas.

Key words: Bridging of gaps, drought management, mulberry cultivation, technology adoption gaps.

INTRODUCTION

Sericulture is an agro-based industry, comprising of activities viz., mulberry cultivation, silkworm rearing, reeling of silk cocoons and silk weaving. Sericulture which was considered as a subsidiary occupation in the past has at present become a major source of income for farmers. Production and productivity of Indian sericulture

has therefore increased many folds. However, mulberry cultivation is becoming a major concern nowadays. Climate change impacts such as scarce rainfall, high temperature, depleting water table and occurrence of prolonged drought had affected mulberry cultivation in south India. India Meteorological Department has classified drought as an occasion when the rainfall for a week is half of the normal or less, when the normal weekly

rainfall is above 5 mm or more. If such 4 consecutive weeks occur from middle of May to October, it is considered as agricultural drought (IMD, 2014). In order to increase the production of quality silk, 106 sericulture clusters comprising of 250 to 500 sericulturists were identified to rear bivoltine silkworm hybrids in groups in south India. Majority of these clusters encounter low rainfall and recurrent droughts severely affecting the quality and quantity of mulberry leaves produced (Mahimasanthi *et al.*, 2016 c). The silk cocoon produced during the drought period is inferior in quality (Rajaram *et al.*, 2006). Susheelamma *et al.* (2008) implied that even a small increase in leaf productivity in mulberry in dry areas, would have considerable impact on silk production. Simple adaptations could help to reduce the adverse effects of climate change to some extent (Mohapatra, 2017). Drought requires management actions, as water availability is insufficient to meet the needs of the same or even higher water demands. The ill effects of drought can be alleviated to a considerable extent by adopting Integrated Drought Management technologies as described by Mahimasanthi *et al.* (2016 a). Yadav *et al.* (2012) recommended that the full adoption of crop production technologies is very important in achieving the desired level of productivity in dry land crops. Mahimasanthi *et al.* (2016 b) confirmed that adoption of Integrated Drought Management technologies has significantly increased the production and productivity of sericulture in drought prone areas. But, these technologies are either fully, partially or never adopted by the farmers. Hence, this study was conducted to find out the gaps in the adoption of drought management technologies in the field, to educate and motivate the farmers for higher rate of adoption of the drought management technologies through various extension communication programmes and to bridge the adoption gap for quality linked silk production.

METHODOLOGY

The study was conducted at six sericulture clusters of south India comprising central and southern dry agro-climatic zones of Karnataka state, scarce rainfall zone of Andhra Pradesh state and southern dry zones of Tamil Nadu state. The average annual rainfall of the study area ranged from 450 to 600 mm. The hydrometric division of

India Meteorological Department reported that the rainfalls received in these areas were not uniform and highly uneven. Recurrence of drought is a common phenomenon in these areas. Accordingly, Tumkur and Ithandahally clusters from Karnataka, Penugonda and Hindupur clusters from Andhra Pradesh and Oddanchatrum and Adaikalapattinam clusters from Tamil Nadu were selected for the study based on crisis vulnerability. Six samples of 50 farmers each were selected randomly from these clusters by simple random sampling design to avoid bias, thus constituting a sample size of 300 farmers. Data were collected with the structured interview schedule.

Identification of adoption gap

Interview schedule was designed based on the objectives of the study, for data collection. Drought management technologies recommended by the Central Sericultural Research and Training Institute, Mysuru, India were included in the schedule. The schedule was pre-tested and necessary modifications were made. Data were collected through personal interviews of the sericulture farmers. Adoption levels of twelve identified technologies consisting of propagation of drought resistant mulberry varieties, water conservation and moisture management technologies and *in-situ* rainwater harvesting and conservation methods for mulberry plantations were studied.

Measurement of adoption gap

Farmer-wise adoption gap (AG) of drought management technologies and technology-wise adoption gap were computed for each state. The AG for each farmer was defined as the proportion of technology not adopted to total recommended technology of drought management and expressed in percentage. The following formula was used to compute AG (Sathish Kumar and Popat, 2008).

$$\text{Farmer-wise AG} = (\Sigma X_i / X_m) \times 100$$

Where, X_i = Total number of technology not adopted by

the individual farmer, $i=1$ to 12 items

X_m = Selected recommended technology (12)

The technology-wise adoption gap (TAG) was the proportion of respondents, who had not adopted the particular technology to the total number of respondents, expressed in percentage.

$$\text{Technology-wise AG} = (\sum Y_i / X_m) \times 100$$

Where, Y_i = Total no. of respondents in clusters of a state, who had not adopted the particular technology, $i=1$ to 100

X_m = Total selected respondents in a state (total of two clusters) = 100

Bridging of adoption gaps

After the identification of the adoption gaps, extension communication programmes were conducted at farmers' fields in the selected clusters to rectify the gaps. A total of 12 awareness programmes were conducted in six clusters (@ 2 programmes / cluster). Apart from awareness programmes, the farmers were motivated to adopt the technologies by individual visits, group discussions and demonstrations. Integrated technologies on drought management were compiled and a 'Handbook on integrated drought management for mulberry Sericulture' was prepared for use of farmers and extension officers in English and local vernacular languages *i.e.*, Kannada, Telugu and Tamil. These books were distributed to all the selected farmers to increase their awareness and adoption rate.

Impact analysis

Impact analysis was conducted after two years in all the six clusters to study the improvement in adoption of technologies with the same farmers. Same interview schedule was used of collecting the data. Increase in plantation acreages of drought resistant varieties, increase

in drip or micro irrigation technique installation, trenching and mulching areas, water harvesting and water conserving techniques followed, green manured gardens and increase of rain water harvesting tools were studied as the monitorable indicators of adoption. Adoption gaps were calculated, bridging of gaps were computed and significance was statistically analysed. The quantity of disease free silkworm layings reared annually by the farmers, cocoon productivity, yield performance of the silkworm rearing and the average rate of the cocoon were calculated as measurable indicators to find out the efficiency of IDM technologies. The data collected from the farmers before and after bridging of gaps were compared.

RESULTS AND DISCUSSION

Farmer-wise adoption gap

The farmer-wise adoption gap of drought management technologies computed at the time of bench mark survey, before conducting awareness programmes for all the three states are given in Figure 1. Eighty, 20 and 56 per cent of farmers, respectively of Andhra Pradesh, Karnataka and Tamil Nadu states have recorded high adoption gap (more than 66 %). Twenty, 66 and 36 per cent of farmers of the above respective state clusters have recorded medium adoption gap (33-66 %). Technologies *viz.*, drought resistant mulberry plant varieties, soil moisture conservation and rain water harvesting technologies *etc.* were noticed as less adopted. Krishnamoorthy and Radhakrishnan (2012) had earlier reported the low adoption of these technologies in mulberry cultivation and urged the need for special attention on these.

Technology-wise adoption gap

The list of drought management technologies identified and technology-wise adoption gap calculated for all the three states are presented in Table 1. The frequency of technology-wise adoption gap falls between 14 and 100 %. Technologies *viz.*, plantation of

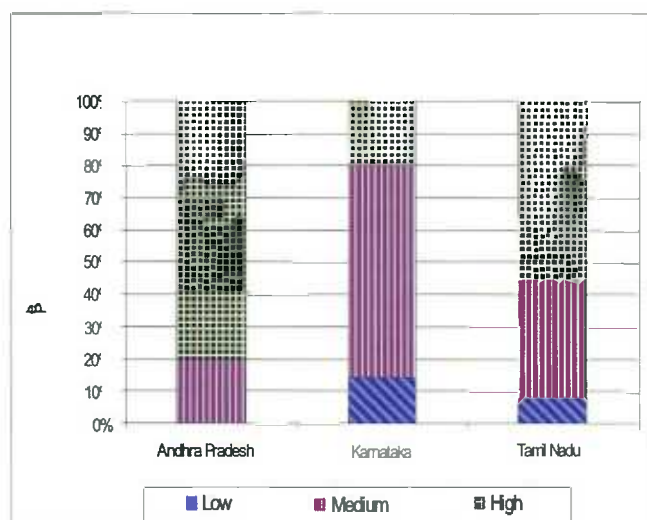


Figure 1: Farmer-wise adoption gap

drought resistant mulberry varieties, green manuring, borewell recharging, and rain water harvesting were not adopted by majority of the farmers. Mallikarjuna *et al.* (2004) while reporting the constraints of adoption of technologies, reported the less awareness by the farmers as the major reason. Singh Bhagavan, 2007 reported 53.7 % variation in the technological gap and predicted that knowledge level of the farmers was the most important decisive factor.

Adoption of all technologies in an integrated manner is required to overcome the ill effects of drought. The adoption gap in respect of selection of drought resistant mulberry plant varieties in drought prone areas was very high. As far as drip irrigation was concerned, the adoption gap was low in in Tamil Nadu which was in conformity with the findings of Krishnamoorthy and Radhakrishnan (2012). The soil moisture conservation technologies such as trenching, mulching and green manuring suffered very high adoption gap. Green manuring technique witnessed even nil adoption from 86 % of the farmers. The operations, such as summer ploughing, opening trenches and planting across the slope had very low level of adoption. The rain water harvesting techniques in mulberry garden were also considered a less priority area with very low level of adoption. Majority (74 to 94 %) of farmers presented the picture of nil adoption of these technologies. Praveena *et al.* (2014) reported that construction of farm ponds and other rain water harvesting structures should be encouraged in drought prone areas to mitigate water shortage. Since production of quality mulberry leaves with moisture content is essential for successful silkworm rearing during summer months, adoption of these technologies are essential to increase the

Table 1: Adoption gap on different drought management technologies in three major southern states of south India, before awareness (bench mark study)

Technology	Adoption gap (%)		
	Andhra Pradesh	Karnataka	Tamil Nadu
Plantation of drought resistant host plant varieties	100	98	50
Management of pruning schedule	92	14	30
Drip irrigation / Micro irrigation technique	78	18	8
Trenching & mulching	100	40	84
Green manuring /green leaf manuring	96	86	80
Sub-soiling	100	80	90
Summer ploughing	72	38	74
Opening trenches	100	36	96
Planting across the slope	100	48	100
Impounding rainwater in the garden	100	34	72
Run off collection pits / farm ponds	94	74	92
Bore well recharging	100	94	98

moisture holding capacity of the soil, prevent moisture loss and generate quality mulberry leaves. Lack of awareness on these technologies among the farmers led to low adoption.

Awareness programmes

From the benchmark study, the technologies with high adoption gap were identified and extension communication programmes were conducted to impart awareness on the identified technologies and to reduce/bridge the gaps. Farmers were also motivated to adopt the technologies by individual visits, group discussions, awareness programmes and field demonstrations. Books written on these technologies in local languages were distributed to all the selected farmers to enrich their awareness and enhance the adoption rate.

IMPACT STUDY

Adoption gaps after conducting awareness programmes

The improvement in adoption gaps after imparting the awareness programmes was assessed and compared with

that recorded before. There was 8 to 66 per cent reduction of gaps recorded in Andhra Pradesh clusters. We observed remarkable levels of bridging with respect to adoption gaps in technologies, such as summer ploughing, drip irrigation and impounding of rain water. A wide range of 4 to 100 % reduction of gaps was recorded in Karnataka state clusters. Drip irrigation technology was adopted fully and trenching & mulching also witnessed a good degree of adoption. In Tamil Nadu, gaps in adoption of technologies viz., borewell recharging, trenching & mulching and subsoiling couldn't be rectified but, the practices, such as drip irrigation and management of pruning schedule have been fully adopted with no gaps. Other technological gaps were rectified to the extent of 16 to 60 %.

Bridging of adoption gap

Tables 2~4 display the data on impact analysis of the awareness programme. Out of the total 12 technologies studied in all the three states, in virtue of their economic importance, adoption gap was bridged. A few of the technologies were considered less important by the farmers before commencement of the project and hence,

Table 2: Bridging of adoption gap (%) on identified technologies in Andhra Pradesh clusters, after imparting awareness

Technology	Adoption gap (%)		Bridging of adoption gap (%) (average of two clusters)						
	Before (G1)	After (G2)	Before (B1)	After (B2)	Grand mean	Sed	CD @ 0.05	CV %	Significance level
Plantation of drought resistant host plant varieties	100	90	0	10	5.00	0.47	2.04	11.60	*
Management of pruning schedule	92	82	8	11	9.43	0.19	0.83	2.50	**
Drip irrigation/Micro irrigation technique	78	50	22	36	28.95	0.80	3.44	3.39	**
Trenching & mulching	100	72	0	28	14.00	0.30	1.29	2.62	**
Green manuring	96	88	4	8	6.17	0.20	0.84	3.88	**
Sub-soiling	100	64	0	36	18.00	0.60	2.59	4.10	**
Summer ploughing	72	24	28	67	47.34	0.25	1.09	0.66	**
Opening trenches	100	70	0	30	15.00	0.19	0.83	1.58	**
Planting across the slope	100	76	0	24	12.00	0.33	1.41	3.34	**
Impounding rainwater	100	32	0	68	34.00	0.56	2.42	2.03	**
Farm ponds	94	56	6	40	23.22	0.42	1.82	2.23	**
Bore well recharging	100	76	0	24	12.00	0.22	0.93	2.20	**

G1 & G2 –Adoption gap at the time of benchmark study and after imparting awareness, respectively. B1 & B2– Level of bridging of adoption gap at the time of benchmark study and after imparting awareness, respectively.

Table 3: Bridging of adoption gap (%) on identified technologies in Karnataka clusters, after imparting awareness

Technology	Adoption gap (%)		Bridging of adoption gap (%) (average of two clusters)						
	Before (G1)	After (G2)	Before (B1)	After (B2)	Grand mean	Sed	CD @ 0.05	CV %	Significance level
Plantation of drought resistant host plant varieties	98	75	2	23	12.73	0.26	1.11	2.49	**
Management of pruning schedule	14	10	86	29	57.28	0.26	1.12	0.56	**
Drip irrigation	18	0	82	100	91.00	0.36	1.55	0.49	**
Trenching & mulching	40	2	60	95	78.50	0.98	4.22	1.53	**
Green manuring	86	75	14	13	13.40	0.15	0.66	1.40	*
Sub-soiling	80	60	20	25	22.50	0.33	1.41	1.78	**
Summer ploughing	38	28	62	26	64.34	0.41	1.78	0.79	**
Opening trenches	36	30	64	17	40.33	0.09	0.38	0.27	**
Planting across the slope	48	30	52	38	44.75	0.26	1.14	0.72	**
Impounding rainwater	34	10	66	71	68.30	0.43	1.84	0.77	**
Farm ponds	74	60	26	19	22.46	0.07	0.31	0.39	**
Bore well recharging	94	90	6	4	5.13	0.39	1.67	9.25	*

Table 4: Bridging of adoption gap (%) on identified technologies in Tamil Nadu clusters, after imparting awareness

Technology	Adoption gap (%)		Bridging of adoption gap (%) (average of two clusters)						
	Before (G1)	After (G2)	Before (B1)	After (B2)	Grand mean	Sed	CD @ 0.05	CV %	Significance level
Plantation of drought resistant host plant varieties	50	20	50	80	75.0	0.31	1.31	0.50	**
Management of pruning schedule	30	0	70	100	85.0	0.12	0.50	0.17	**
Drip irrigation	8	0	92	100	96.0	0.52	2.24	0.66	**
Trenching & mulching	84	84	16	0	8.02	0.15	0.63	2.24	**
Green manuring	80	72	20	10	15.0	0.32	1.39	2.63	**
Sub-soiling	90	90	10	0	5.00	0.12	0.51	2.90	**
Summer ploughing	74	62	26	16	21.1	0.23	1.00	1.34	**
Opening trenches	96	94	4	2	3.04	0.08	0.33	3.05	**
Planting across the slope	100	50	0	50	25.0	0.31	1.31	1.50	**
Impounding rainwater	72	42	28	42	34.8	0.38	1.65	1.35	**
Farm ponds	92	92	8	0	4.00	0.20	0.86	6.12	**
Bore well recharging	98	98	2	0	1.00	0.12	0.50	14.14	**

the bridging levels varied from 0 to 90 % in all the states.

Overall, the programme experienced good response in Andhra Pradesh as gap-bridging of all the 12 technologies were realized only after implementation of the project

through repeated efforts of awareness towards farmers, though none of the technologies attained 100 % bridging of gap due to various reasons. The series of events warranted the continued support from technical staff who were assigned with the task. The variations in the levels of

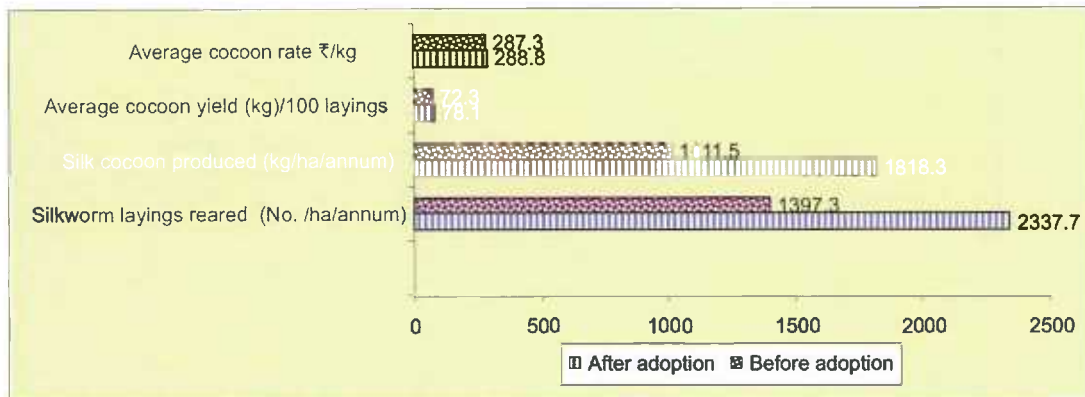


Figure 2: Efficiency of bridging the gaps in adoption of technologies

adoption before and after the awareness programme were statistically highly significant at 5 % level. Similar response was recorded in Karnataka state too. In the case of Tamil Nadu also, the impact made on bridging of adoption gaps were statistically highly significant at 5 % level.

Certain technologies, such as run-off collection pit / pond, bore well recharging *etc.* require external support from government / banks whereas, the other technologies *viz.*, planting of drought resistant host plants, green manuring, sub-soiling *etc.*, can be achieved through repeated attempts on creation of awareness. Continued monitoring of adoption of technologies and forewarning through different media would be an add-on support in all sericulture pockets for sustenance of the technologies. This can be continued as Transfer of Technology programmes for the benefit of sericulture farmers to combat drought in sericulture.

Efficiency of bridging the gaps in technology adoption

Post programme improvement in average number of disease free silkworm layings reared by the farmers in a year followed by increased cocoon productivity and yield performance could well be considered as the success indicators (Figure 2). The adoption of IDM technologies increased the soil moisture and fertility which in turn increased the quality and quantity of mulberry leaves which is reflected in increase in cocoon productivity.

Adoption of IDM technologies has significantly increased the silkworm rearing capacity of the farmers, enabling them to produce more silk cocoons per unit area. The cocoon productivity increased by 79.82 % in the rearings. The average cocoon yield of the farmers who recorded higher adoption of technologies was significantly higher.

CONCLUSION

In the present study, 84 % of the farmers reported insufficient water to carry out the sericultural activities during the drought period. But, at the same time, wide gaps existed in the adoption of drought management technologies. The soil moisture management and rain water harvesting technologies still existed with high adoption gap. This situation posed a negative impact on the cultivation and leaf production of mulberry under drought prone areas. Extension Communication Programmes conducted with an intention of implementation of 'Integrated Drought Management' technologies instilled awareness and reduced the gaps in adoption of technologies. The degrees of bridging of adoption gaps realised on different technologies were statistically highly significant. This eventually reflected in the efficiency of the farmers to take up higher quantity of silkworm rearing with simultaneous improvement in cocoon productivity and yield performance. The findings of the study reiterate that the farmers should be well motivated on the specific needs and imparted awareness to adopt the drought management technologies to overcome the ill effects of drought in all drought prone areas to augment quality linked silk production in India.

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Article scientifique

COMPLEMENT DES FOSSES DANS L'ADOPTION DES TECHNOLOGIES DE GESTION DE LA SECHERESSE POUR LA CULTURE DU MURIER DANS LES AIRES SOUMISES A LA SECHERESSE EN INDE DU SUD

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ABSTRACT

La sériciculture est une agro-industrie qui contribue de manière substantielle au développement rural en Inde du sud. La culture du mûrier est la base de cette industrie. Les changements climatiques ont affectés fortement la production et la productivité des mûraies dans différentes zones séricicoles en Inde du sud. Ceci demande l'adoption de technologies de gestion de la sécheresse dans la culture du mûrier pour obtenir une production de feuilles de qualité et le succès de l'élevage de vers à soie. Une étude a été menée avec des fermiers afin de déterminer les écarts pour adopter ces technologies afin de les combler. Les données des fermiers ont été collectées pour 12 technologies. Bien que 84 % des fermiers étaient affectés par le manque d'eau, l'adoption des technologies requises fut élevée. Quatre-vingt, 20 et 56 pour cent des fermiers de l'Andhra Pradesh, du Karnataka et du Tamil Nadu respectivement ont montré une forte adoption (>66 %). La fréquence se situe entre 14 et 100 %. Différents programmes de formations ont été conduits parmi les fermiers pendant deux ans afin d'augmenter l'adoption des recommandations, ce qui a aidé à combler les lacunes de 4 à 100 % et améliorer la production de feuilles. L'impact du programme pour toutes les technologies dans tous les Etats est significativement élevé au seuil de 0,05. L'étude suggère que des efforts adaptés doivent être faits pour accroître la capacité des fermiers à mettre en œuvre les technologies de gestion de la sécheresse et soutenir la qualité de la production de soie dans les régions soumises à la sécheresse.

Mots-clés: Comblement des trous, gestion de la sécheresse, culture du mûrier, adoption de technologie.



Technical Report

ENHANCING INCOME GENERATING PROJECTS (IGPs) IN A SERICULTURE R&D MANAGEMENT SET-UP: THE DMMMSU-SRDI EXPERIENCE

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ABSTRACT

The paper discusses how the income generating projects were enhanced in a Sericulture R&D Management set-up as experienced by the Don Mariano Marcos Memorial State University - Sericulture Research and Development Institute (DMMMSU-SRDI). The SRDI, is mandated to conduct research and extend technologies through education and training. The State Universities and Colleges (SUC) Normative Financing Scheme resulted in reduction of R&D budgets, thus, compelling us to look for strategies in enhancing Income Generating Project (IGP) in support of R&D and to meet criterion of policy makers in budget evaluation – returns from research. The strategies are: IGP Unit creation, income sources identification, research prioritization, processes and equipment to achieve efficiency in the production system, stronger R&E linkages, and deposition of policies in R&D for monitoring and evaluation. In five years (2005 to 2010), SRDI accumulated P 8,970,829.00 income from R&D based products and services *i.e.*, mulberry (*Morus alba*) cuttings, saplings, leaves, silkworm (*Bombyx mori* Linn.) eggs, silkworm larvae, cocoons, novelty items, raw silk and silk fabrics and cocoon-processing services. The hand-woven, suksuk designed, 100 % silk fabric contributed to 46 % of the income amounting to P 4,713,824.00, indicating a market niche. A practical solution to sustain research activities can be attained by developing strategies, even in an atmosphere where academic excellence is of prime consideration.

Key words: Cocoon, hand-woven *suksuk* designed fabric, mulberry, raw silk, sericulture, silkworm.

INTRODUCTION

Sericulture is an agro-based industry. It involves rearing of silkworms (*Bombyx mori* L.) for the production of raw silk, a natural fibre and ecologically harmless product (FAO, 1990). The major activities of sericulture comprises of mulberry plant (*Morus* spp.) cultivation to feed the silkworms which spin silk cocoons and reeling the cocoons for unwinding the silk filament followed by its processing and weaving for value-added benefits. It is estimated that sericulture can generate employment of 11 man-days per kg of raw silk production (in on-farm and off-farm activities), throughout the year. This potential is *par-excellence* and no other industry generates this kind of employment, especially in rural areas, hence, sericulture is used as a tool for rural reconstruction (FIDA, 2000).

In the Philippines, the silk industry is given due attention in recent years. Specifically in Region I, it

started as a research project of the Don Mariano Marcos Memorial State University (DMMMSU) under the operations of the University Research & Extension. In 1987, the Sericulture Research and Development Center (SRDC) was created through the Board Resolution 372-87. On April 8, 1992, through R.A. 7359, SRDC was abolished with the creation of the Sericulture Research and Development Institute (SRDI). Created as the national institution for silk industry, it has specific mandates to: conduct research, educate and train sericulturists and extend technologies. The mission of the Institute is to make our country self-sufficient, net exporter of silk allied products and contribute to the attainment of the government's program on countryside development, accelerate economic growth, promote ecological balance and generate economically viable technologies, so that labor opportunities are created to sustain agro-based industry (SRDI, 1997).

The rationalization of State Universities and Colleges

(SUC) in the country created a challenge to the R&D sector. A government policy directive on Normative Financing Scheme poses a significant reduction in R&D budget of the University. Furthermore, DMMMSU is apprehensive that IGP is not that strong to maintain its Level IV status. The Institute would have to coordinate to boost its IGP, and rise to the challenge of the need to intervene in a reduced R&D financing in constructive and meaningful ways.

SRDI operates as one unit of the University which is headed by a Director and consists of three divisional heads manning over various sections and units which carry out general powers and functions of the Institute. SRDI has a collaborative working relationship with various SUCs, Department of Agriculture (DA), Local Government Unit (LGUs), Philippine Textile Research Institute (PTRI) and other government and non-government agencies which comprise the national network for sericulture research and development, in order to accelerate the initial setting-up of the support systems of sericulture industry.

The Institute's R&D is focused on five major programs pertaining to Mulberry, Silkworm, Pest Management, Post Cocoon and Socio-Economics, to support, supplement and facilitate the development of sericulture and silk industry in the country. SRDI also takes on responsibilities for disseminating sericulture among rural smallholders and buying fresh cocoons produced by them for further processing. Simultaneously, it also takes care of marketing to guarantee sustainability of their project. SRDI buys the silk cocoons produced by the farmers and provides technical assistance to improve their skills. These enable them to produce better cocoons. SRDI has the facilities to process cocoons into raw silk, thrown silk, fabrics and diversified products. These products generate income and in turn, guarantee sustainability of its various programs.

The diminishing budget of the University as a result of the Normative Financing Scheme is restricting the capacity of the Institute to support the sustainability of sericulture. For the maintenance of mulberry and silkworm germplasm and further breeding needs, upgrading of research and laboratory facilities has to be

worked out. Limited support resources resulted in insufficient dissemination, transfer and adoption of technology packages developed through R&D efforts, including minimal increase in mulberry area. To sustain sericultural activities in the public sector, funds should be provided to ensure regularity in development activities. Technical support services must be provided to farmers. Fund constraint also hampered the nationwide activities of SRDI in providing R&D support on sericulture.

In the midst of the decreasing Maintenance and Other Operating Expenses (MOOE) allotted to the University, the Institute began to strengthen and harness income generating projects (IGP) under the Research, Development and Extension (RD&E) set-up to sustain its activities and meet the criterion of policy makers in evaluating agency's budget – the returns from R&D investments.

This study made an attempt to present the management strategies utilized in the R&D management set-up to enhance its income generating projects and problems associated with its implementation. Our aim was to demonstrate that income generating projects can be enhanced under the R&D management system.

METHODOLOGY

Subsequent to brainstorming sessions and intensive analysis of the programs of the Institute, the following strategies were made: (1) identification of sources of incidental income in the R & D programs; (2) constitution of the IGP Unit; (3) streamlining of research on development of cost effective, technologies, processes and equipment to achieve efficiency in the production process; (4) enhancing research and extension capabilities and management through stronger research and extension linkages; and (5) deposition of policies in R & D for monitoring and evaluation.

Identification of sources of income in the sericulture R&D programs

Pursuant to Rule 2, Sec. 13 of RA 7359, the Institute has to establish sources of income to augment its budget. An inventory of the R&E projects was made and for identification, products made and project in-charge /

coordinators were indicated.

Constitution of the IGP unit

The Income Generating Projects Unit (IGPU) of SRDI was constituted to implement, coordinate, monitor and evaluate the income generating projects of the Institute that covers all the production aspects, *i.e.*, cocoon silk products, silkworm, mulberry, fabrication of seri-tools and machineries rental and technical services derived or emanated from the R&D programs. For a more coordinated implementation of the IGPs, the IGP guidelines were consolidated in a brochure, incorporating all the procedures followed through all these years.

Streamlining of research

Currently, the strength of the Institute is directed towards the conduct of research on development of cost effective technologies and processes in support of the agro-industrial productivity in sericulture, the output of which create a positive impact on IGPs of the Institute.

Enhancing R&D capabilities and management

Research and extension capability and management was enhanced through stronger research and extension linkages:

(a) Whereas before, sericulture was not a priority commodity in Region I. Through our networking and linkages and with proper representation, it was programmed as one by the Regional Agriculture and Food Council (RAFC). Thus, access for funding support requiring RAFC recommendation became possible. Hence, the Regional Fiber Industry Development Program submitted to National Economic Development Authority (NEDA) for one million pesos (P-1M) funding is presently under consideration.

(b) The effort in sustaining and extending linkages to identified R&D institutions / centers and policy-making entities brought success in the conduct of research. In fact, the University forged alliances through signing of memorandum of agreement (MOA), implementing the 1.5M, Commission on Higher Education (CHED) funded

project Silk Technology Promotion and Commercialization: CHED-DMMMSU Strategy for Employment Generation of Young Graduates as Agribusiness Entrepreneurs and in support to RA 9242 (prescribing for the use of natural fibers in uniforms of government employees). This project is aimed to benefit 11 families.

(c) The presentation of research results in different venues called the attention of the public to the research outputs of SRDI and served as effective promotion vehicle of silk products. This was clearly manifested by the interests shown by various entities, which included television networks who visited SRDI to showcase sericulture, such as in ABS-CBN's programs "*Kumikitang Kabuhayan*" and "*Ating Alamin*" and GMA's program "Born to be Wild", among others.

(d) Last year, the Institute participated in 'Technology Application and Promotion Institute' of the Department of Science and Technology (TAPI-DOST) Regional Invention Contest and Exhibit where SRDI exhibited two research outputs, and the paper, Commercialization Potential of *Suksuk* Silk Fabrics, won the top prize and later competed at the National level, garnering the 2nd prize in the Likha Award.

(e) The Silk *Suksuk* Technology was further disseminated by sending letters of offer to executives of government offices in the region (in support of RA 9242), including Congressman Victor Ortega of La Union. This resulted to 300 orders of the silk *suksuk* fabric for barongs of members of the Philippine Congress, including some of the wives. This is aside from those supplied for regional executives of NEDA, Integrated Bar of the Philippines (IBP), DBP, Central Bank, *etc.* Clearly, the silk commodity had established a market niche in the region. In our University, silk fabric was required as uniform of faculty and staff and were worn during formal gatherings and meetings.

(f) To increase cocoon production and create greater opportunities for gainful employment in rural areas through the spread of scientific sericultural practices, the extension arm of the Institute continuously promotes sericulture enterprise as an agro-based industry. Technology dissemination and implementation of various

extension strategies, such as farm and home visits, training and publication, led to the establishment of model sericulture farms in the provinces of La Union, Ilocos Sur, Rizal, Batangas and Quezon producing tons of fresh cocoons providing additional income to farmers.

The Institute entered into a Memorandum of Agreement (MOA) with farmer-cooperators (FCs) employing the activities as follows:

Establishment of Demo-farms: As a new crop, sericulture requires an introduction program for farmers. It should be first shown in a demonstration farm to showcase the best management of sericulture production and innovative technologies, and illustrate that farmers can increase their income through sericulture. It was shown that cocoon production for a ¼ ha farm could have a return on investment even at ROI as high as 27.12 % (SRDI, 2008). Farmer cooperators were provided with sustainable livelihood while the Institute was provided with raw material (cocoons) to operate the filature to produce silk yarn, sold at a reasonable margin of profit.

Provision of inputs: Sericulture requires investment capital. Since we cater to the low level income farmers, the institute provides the FCs, all basic inputs required in mulberry establishment, construction of rearing house, *etc.* The farmers were assisted on the labor requirements for the mulberry plantation establishment. Certain construction materials for the rearing house were provided on soft loan and silkworm eggs or larvae as well as disinfectants were provided free in the first three rearings.

Recovery of inputs: Starting on the fourth silkworm rearing, SRDI deducts 10 % from the total gross sales of cocoons produced by the farmer as payment for inputs, until its completion.

Training and technical assistance: The farmers were trained with practical skills in sericulture. Training and technical assistance boost the farmer's productivity. Refresher courses were offered to keep abreast with the latest technology. Soil analysis, cocoon quality assessment and pest management services were provided.

Marketing assistance: The Institute buys all the

cocoons produced by the cooperators, process into silk yarn and sell them to weavers. Cooperators may opt to process their cocoon into silk yarn for value addition.

Monitoring and Evaluation

Monitoring and evaluation is crucial to ensure the smooth and effective implementation of RDE projects and at the same time, to the accounting of incidental products.

Creation of IGP unit/team: The IGP Unit/Team was created to make the frequent supervision and provide feedback to the Director.

On-site monitoring: To ensure efficient and effective project implementation, on-site/field monitoring of demonstration farms and sericulture projects were done by Project-in-Charge who has the responsibility to find out if the project has been implemented based on the operational plan (OP) and the target production is met with.

Progress reports: All project coordinators/in-charge are required to submit quarterly and a year-end report for assessment and review.

IMPACT

Identification of sources of income in an RD & E set-up

Figure 1 shows the flow of products in the sericulture industry. The income generating projects of SRDI were identified and laid out covering all production areas presented in the sericulture industry flow, *i.e.*, mulberry and silkworm egg production, silkworm rearing and cocoon production, raw silk and silk yarn processing, weaving and handicrafts and garments production. Products from the Mulberry R&D programs are mulberry cuttings and saplings as planting materials and leaves as feed for silkworms (Figure 2). Pruned branches / mulberry stumps could be utilized as driftwood for novelty products making. Silkworm R&D program in its breeding and egg production and silkworm rearing studies produce silkworm eggs, larvae, pupae, cut cocoons, moth and silkworm litter. Post Cocoon R&D program with cocoon and silk processing studies produce dried pupae, palade

layer of cocoons, cocoon floss and silk fabrics. Under the Extension program, fresh cocoons and various silk products and services *viz.*, soil analysis, cocoon processing and egg production were identified.



Figure 1: Flow of products in the sericulture industry (SRDI-DMMMSU)

Constitution of IGPU

The IGPU was constituted without hiring additional staff to man the unit. Designated staff of the unit were actually based at their regular research assignments and report whatever products / goods / services in terms of sales / fees they collect. Multitasking / complementation and efficient work loading was implemented and given the corresponding performance credits. Additional production was handled by staff that are under load and trained through in-house trainings and soon become adept in the skills of production. Since silkworm rearing requires feeding even beyond office hours, through the policy on compensatory time-off (CTO), staff were allowed to accumulate extra hours rendered which they can use when they apply for leave of absence.

The Unit Head coordinated all activities of the IGP and reported directly to the Director. His team is composed of the following product coordinators who in turn are in charge of income generated under the respective divisions as follows:

(a) Mulberry Coordinator – Products, by-products and services derived from mulberry R&D (cuttings, saplings, leaves, mulberry stumps for driftwood, *etc.*).

(b) Silkworm Coordinator – Products, by-products and services derived from silkworm R&D (eggs, silkworm

larvae, cut cocoons, pupae, moth, *etc.*).

(c) Post Cocoon Coordinator – Products and post cocoon services (silk fabrics, raw silk and silk allied products, novelty products, cocoon processing and weaving)

(d) Dormitory and other Rental Services Coordinator – Dormitory fees, and training hall, table, and chair rentals and other related income within the unit.

(e) Motorpool Coordinator – Products and services of motorpool and other incidental income within the unit.

(f) Carpentry and other Rental Services Coordinator – Carpentry works, services and other related incidental income within the unit.

(g) Marketing / One-Stop Shop Coordinator - Marketing analyst who validates the data from the book / store keeper as well as the business flow and income from the different IGPs.

All units under the IGP prepared their project plans, budget and OP for a periodic duration as basis for project monitoring and evaluation (M&E), a copy of which was submitted to the IGP chairman. The One-Stop Shop (OSS) was established for the product / services disposal/marketing. All marketable products were turned-over to the OSS for disposal except for products impractical to move out from the project site which were disposed with proper coordination and recording. The designated head of OSS worked in close contact with the coordinators of all IGPs, the internal auditor and accounting office. All business transactions were accomplished as per the rules and regulations set by Commission on Audit (COA). Section 13 of the RA 7359 provides that “any and all savings and income of the Institute shall constitute a revolving fund which shall not be reverted to the General Fund and which shall be used by the Institute to further pursue its objectives”. Collections from IGPs were deposited to the revolving fund (Fund 161). No additional budget aside from the regular allotments from the university budget office was provided

for the IGP activities. Procurement of supplies / inputs for IGP production activities was attained out of these allotments.

Streamlining of research

Prioritization and streamlining of research, focused on development of cost effective, technologies and processes made direct impact on IGPs of the Institute. Efficiency in the production process was achieved. During the last five years, 11 projects with research components were completed resulting in the development of a good number of high-yielding and good quality mulberry and silkworm varieties. The complete package of practices of mulberry cultivation and silkworm rearing, including the sericulture-based farming system that improved soil fertility, mulberry leaf yield, cocoon yield and quality, were tested and demonstrated at farmer's level. More cocoons were produced by farmers to satisfy the raw silk requirements of weavers.

Suksuk-designed silk fabrics were identified as having high potential for commercialization. Among the products of SRDI, silk fabric production using newly developed *suksuk* designs significantly enhanced the IGP of the institute. DMMMSU-SRDI became an icon in the region as far as silk *suksuk* fabric is concerned.

Enhancement of R&D capability and management

SRDI sustained and strengthened its linkages with identified institutions for the needed funding in conduct of projects particularly in the transfer of sericulture technology and promotion and commercialization. Research and extension management was improved with the direct involvement of researchers or technology generators in the R&D process. In farm and home visits, training and publication extension strategies, the dual function scheme was utilized - researchers themselves

perform the functions of extensionists as technology promoters and are continuously involved in the R&D continuum: from technology generation to commercialization, while development component is taken care of by the extensionists. This scheme of R&D management has helped ensure that technologies generated are disseminated and utilized.

Mature technologies were identified, packaged and showcased in demo-farms. To increase cocoon production and create greater opportunities for gainful employment in rural areas through the spread of scientific sericultural practices, the extension arm of the Institute continuously promoted sericulture industry as an agro-based enterprise. Technology dissemination and implementation of various extension strategies led to the establishment of 32 model sericulture farms in the provinces of La Union, Ilocos Sur, Rizal, Batangas and Quezon producing 6.5 tons of fresh cocoons providing additional income to farmers. In return, the cocoons produced by the farmers were bought by the institute at P 140.00 per kilo of fresh cocoons.

Problems encountered in the use of above mentioned extension strategies were mostly on the lack of resources - insufficient budget and lack of mobility. Extension workers forego per diems / travel allowance through conversion to compensatory time - off. For the mobility problem, the management requested the university a little additional budget (less than P 200,000.00) for the repair of the lone dilapidated pick-up vehicle.

The strategy of enhancing research capability and management through attendance in fora, conferences and exhibits were great promotional activities for the products and services of SRDI. Presented in Table 1 is the wide coverage of distribution channels and market outlets - from La Union to Manila, Quezon City, down to Aklan and Palawan provinces - of different sericulture products and its by-products.

Table 1: Distribution channels and market outlets of different sericulture products and its by-products

Product/Service	Market	Location
A. Raw Silk 1. Dupion Silk (undegummed to fully degummed)	• Jennifer Vargas • Bogie Bandiola • Jocelie Ricafuerte • Randy Maniquiz • Luisa Velasco • Arlene Tombocon • Randy Culdora • Nenet Paderes • Czarina Lim • Salmie Beltran	Aklan -do- -do- -do- -do- -do- -do- Palawan Manila
B. Thrown Silk 1. Thrown Silk (21 denier / 4-6 ply) undegummed to fully degummed 2. Spun Silk	• Arlene Tombocon • Sapilang Weavers Association • FIDA & PTRI assisted weaving entrepreneurs	Aklan La Union Region I
C. Silk Fabric 1. Silk Fabric (4 ply) - plain (undyed, dyed) (synthetic indigenous) - with design (undyed, dyed & synthetic-indigenous) - with suksuk design 2. Dupion Silk fabric (undegummed to fully degummed) - plain (undyed, dyed) (synthetic-indigenous) with design (undyed, dyed) (synthetic-indigenous)	• DMMSU Employees • Office of the Congressman (Hon. Victor Ortega) • League of Mayors of La Union • Municipal Officials of Kapangan • RECOM • Integrated Bar of the Philippines, Region I • LGU's and other government agencies • NEDA Region I • Boyet Dysico • Narda Capuyan of NARDA • Graal Cawed of TOPSKILLS • FIDA buyers, (Jessica Tuscano) • Designers (Patis Tesoro, Anthony Legarda, etc.) • Walk-in Buyers, etc.	La Union Benguet La Union/Manila La Union La Union Benguet Baguio City La Union Manila La Union
D. Sablay	• DMMSU graduates and faculty	La Union
E. Finished Silk Products	• Frank Almodovar • Walk-in buyers • DTI	La Union
F. Cut and dried cocoons	• Walk-in handicraftsmen and buyers • SRDI staff • Elementary Schools of LU • Municipality of Bacnotan • Rural Health Center (Bacnotan) • Private Entrepreneurs	La Union
G. Novelty Items (corsages, leis and the like) 1. Hanky 2. Scarf 3. Shawl (Big-small) 4. Pouch bag 5. RTW 6. Bags 7. Sablay 9. Silk fan 11. Silk Tapestries 12. Labor (barong) 13. Wall Décor 14. Flowers (rose/tulip, sunflower, Bouquet / wand / Head dress, Wreath) 15. Corsage (special & ordinary) 16. Leis (special & ordinary)	• St. Christopher Academy • LORMA College • St. Anthony Montessori • Bungol High School • St. Paul College • Sablan Farmers • DOT (Region I) • DA (Region I) • LGU's • La Union School of Nursing • ASIALINK • Walk-in handicraftsmen and buyers	La Union

Cont'd.....

17. Flower vase, mini pot 18. Tokens(fan/paper weights, Basket lovebird) 19. Mini park 20. Wall décor (Birds, Bird chimes, Animated series) 21. Topiary	Walk-in SRDI staff Elementary School of LU Municipality of Bacnotan BRHC Entrepreneurs	La Union
H. Mulberry Products 1. Cuttings 2. Saplings 3. Leaves	SRDI assisted farmers Tiffany Chan	La Union Quezon City
I. Silkworm Products 1. Silkworm eggs 2. Silkworm larvae	Tiffany Chan SRDI & FIDA assisted farmers	Quezon City La Union Ilocos Sur Quezon province
J. Silk Processing 1. Raw Silk (21 -60 denier) 2. Dupion, Thrown silk, Spun silk 3. Dyeing of Thrown Silk (Synthetic,Indigenous) 4. Pre-treatment 5. Partial degumming 6. Full degumming 7. Bleaching 8. Warping	Aurora Batangas Organizational Intellectual, Spiritual and Cultural Advancement (OISCA) Lorenzo Castillo	Aurora Batangas Bacolod City Manila

Monitoring and evaluation

Monitoring and evaluation provided a clear picture whether the things were working well or not. Constant monitoring were done in all aspects of the IGP implementation, such as periodic recording of stocks, inventories of products and expenses, issuance of sales receipts as per IGP guidelines and submission of progress reports by coordinators on quarterly and year-end basis.

Significant progress resulted with the strategies harnessed on enhancing SRDI's IGPs. From 2005 up to 2010, SRDI accumulated a total of P 8,970,829.00 incidental income from various sericulture R & D based-products, and services. Presented in Figure 2 is the distribution of income generated from the different IGPs of SRDI during five years. Hand woven, *suksuk* designed 100 % silk fabric and other silk fabrics as shown in Figure 3, captured the highest demand of silk buyers posting the maximum incidental income of P 4,713,824.00, thus significantly contributing 46 % of the total income. The impact was so high that the silk fabrics have truly created a niche in the market. *Suksuk* designed fabric generated an income of P1,929,034.00, while a total of P 1,192,480.00 was derived from raw silk / silk products including

dupion silk. Meanwhile, a total amount of P497,401.00 was collected from *sablay* (sash) sales and rentals, and other products and services. The surge of demand for handwoven silk fabrics, however, put a strain on the capacity of the limited number of weavers trained in *suksuk* technology. During peaks of order of silk fabrics, the eight weavers had to render overtime to meet the demand. Accumulated overtime hours were converted to CTO. This was resorted to, at a time that we did not have funds to hire contractual.

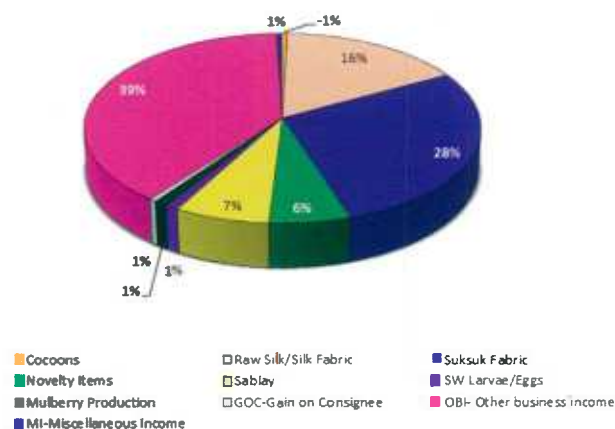


Figure 2: Share of income generated from the different IGPs of SRDI (2005-2010)

From cut cocoons which are considered waste materials of silkworm breeding and genetic studies, large number of novelty items were developed of which the most saleable items were leis, corsages, bouquet and flowers (Figure 3 d) that contributed a total income of P409,996, 1.00. In the conduct of silkworm eggs verification studies on the performance of different silkworm strains at farmers' field, a total of P 37, 382.00 incidental income was generated. As result of an action research, in collaboration with one of the pet shop in Metro Manila, silkworm larvae were also sold as feed to aquarium fish, birds and other animals that eat insects (Figure 3 b).

Mulberry products contributed P46,845.00 from sales of planting materials (mulberry cuttings, saplings), leaves and mulberry stumps used as driftwood (Figure 3 c). These materials are normally generated after mulberry pruning following every phase of silkworm rearing and utilized by farmers in the establishment of their



Figure 3: Innovations of the Institute from major and incidental products of sericulture industry

Conclusion and recommendation

The paper has discussed how the income generating projects were enhanced in an R&D Management set-up as experienced by the DMMMSU-SRDI.

Based on the strategies set and implemented, the following were accomplished: from 2005 up to 2009, a total of P 8,090035.00 was generated as incidental income from various sericulture R & D based-products,

by-products and services *i.e.*, mulberry cuttings, saplings, leaves; silkworm eggs, 3rd instar silkworm larvae, cocoons, novelty items, raw silk, silk fabrics and others. The hand woven 100 % *suksuk* silk fabric captured silk buyers the most, thus creating a niche for the industry and significantly contributed to 46 % of the total SRDI income.

The following strategies are therefore recommended: (a) explore more on diversification of products; (b) come up with more designs accepted by different types of clients; (c) increase number of farmers supplying raw materials; and (d) develop more markets through increased participation in exhibits, product promotion *etc.*

Having established a market niche, the challenge lies in production of more cocoons. Extension activities should be intensified to encourage more farmers to produce cocoons; though this is a big load (burden) on the shoulders of our extension workers. Re-tooling of our existing manpower, who are predominantly researchers (actually through complementation they are already serving as both researchers and extension workers) on effective Extension approaches, should be addressed.

It is our belief that IGP at SRDI has been well-placed and organized by addressing all possible problems and applying all provisions for control systems at all aspects. What we do now is to sustain this and introduce more management interventions as the need arises.

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Rapport technique

PROJETS POUR GENERER L'AUGMENTATION DES REVENUS (IGPs) DANS LA MISE EN PLACE D'UNE GESTION R&D: L'EXPERIENCE DMMMSU-SRDI

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ABSTRACT

Cet article discute de la façon dont les projets générant des revenus sont mis en valeur dans la mise en place de la gestion R&D en sériciculture expérimentée au Don Mariano Marcos Memorial State University-Sericulture Research and Development Institute (DMMMSU-SRDI). Le SRDI est mandaté pour conduire des recherches et des technologies par l'éducation et la formation. Les schémas de financement normatifs des Universités d'Etat et des collèges 5SUC) entraîne une réduction des budgets ce qui oblige à envisager des stratégies pour engager des projets générant des revenus (IGP) comme support à la R&D et pour rencontrer des faiseurs de politiques dans l'évaluation des budgets à partir de la recherche. La stratégie repose sur la création d'unités IGP, l'identification des sources de revenus, la priorité à la recherche, des équipements et des process pour obtenir une efficacité dans le système de production, des liens plus forts R&E et le dépôt des politiques en R&D pour enregistrer et évaluer. En cinq ans (2005-2010) le SRDI a accumulé 8.970;829,00 P de revenus à partir des produits de la R&D et des services comme les boutures de mûrier, le bouturage, les feuilles, les œufs de vers à soie, les larves, les cocons, la soie grège et les tissus de soie et le traitement des cocons. Les tissus 100 % soie au dessin suksuk tissés à la main contribuent pour 46 % aux revenus qui s'élèvent à 4.713.824,00 P ce qui correspond à une niche commerciale. Une solution pratique pour soutenir les activités de recherche peut être trouvée par des stratégies de développement, même lorsque l'excellence académique est une considération primordiale.

Mots-clés: Cocon, tissu suksuk tissé à la main, mûrier, soie grège, sériciculture, ver à soie.

ISC delegation visits Japan



The ISC delegation comprising of Mr. R. R. Okhandiar, Secretary General and Mr. Dileep Kumar, R., Programme Coordinator visited Japan during 21-23 May 2018 to finalize the arrangements for the 25th ISC Congress scheduled to be held at Tsukuba, Japan during 18-22 November 2019. The delegation inspected the venue of the event, hotels for accommodation of delegates and undertaken a preview visit of the field tours. Detailed discussions were held with the authorities of the Congress Convention Centre and finalized the halls for scientific proceedings, poster display, exhibition, banquets, Congress Office and the venue for the Executive Committee of ISC scheduled on 18th November 2019.



An interactive meeting between the delegation and the officials of Ministry of Agriculture, Forestry and Fisheries (MoFF) and National Agriculture Food Research Organization (NARO) was held to discuss and finalize the various minute aspects related to the organization of this prestigious event. Many decisions were taken with respect to the Congress activities like; congress theme, registration fee, type of registrations, scientific proceedings, accommodation, travel arrangements, field tour, post congress tours, etc.

The delegation met the senior officers of the Ministry of Agriculture, Forestry and Fisheries (MoFF) at Tokyo and briefed them on the organization of the ISC Congress for the first time being held in Japan. The ISC team also visited the sericulture areas and laboratory facilities of National Agriculture Food Research Organization, located in Tsukuba.



Visit of Swedish Delegation to ISC



A four member Swedish delegation led by Dr. Olle Terenius, Associate Professor, Swedish University of Agricultural Sciences, visited the office of the International Sericultural Commission on 24th April 2018. The main purpose of the visit was to launch the Indo-Swedish collaborative project entitled "Studies on the genetic characterization, transmission and tissue distribution of Iflavirus infecting the Indian tropical tasar silkworm, *Antheraea mylitta*". The project is being funded by the Swedish Research Council. The ISC has facilitated both the partners to take up this collaborative project, for the first time in sericulture sector.

ISC to host the 6th Asia-Pacific Congress of Sericulture and Insect Biotechnology (APSERI) at Mysore, India



Based on the discussions between Mr. R. R. Okhandiar, Secretary General and Mr. Shimada TORU, President, Japanese Society of Sericultural Science at Tokyo, Japan on 21st May 2018, the ISC has decided to host the 6th Asia-Pacific Congress of Sericulture and Insect Biotechnology (APSERI) at Mysore, India. The tentative dates finalized for the event are 2nd to 4th March 2019, of which two days would be devoted for scientific proceedings and one day to visit the sericulture areas and facilities in and around Mysore. The official announcement of the Congress would be released soon.



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