



Silk beyond the Textile



The 25th International Congress on Sericulture and Silk Industry

19th-22nd November 2019, Tsukuba, Japan



PROCEEDINGS



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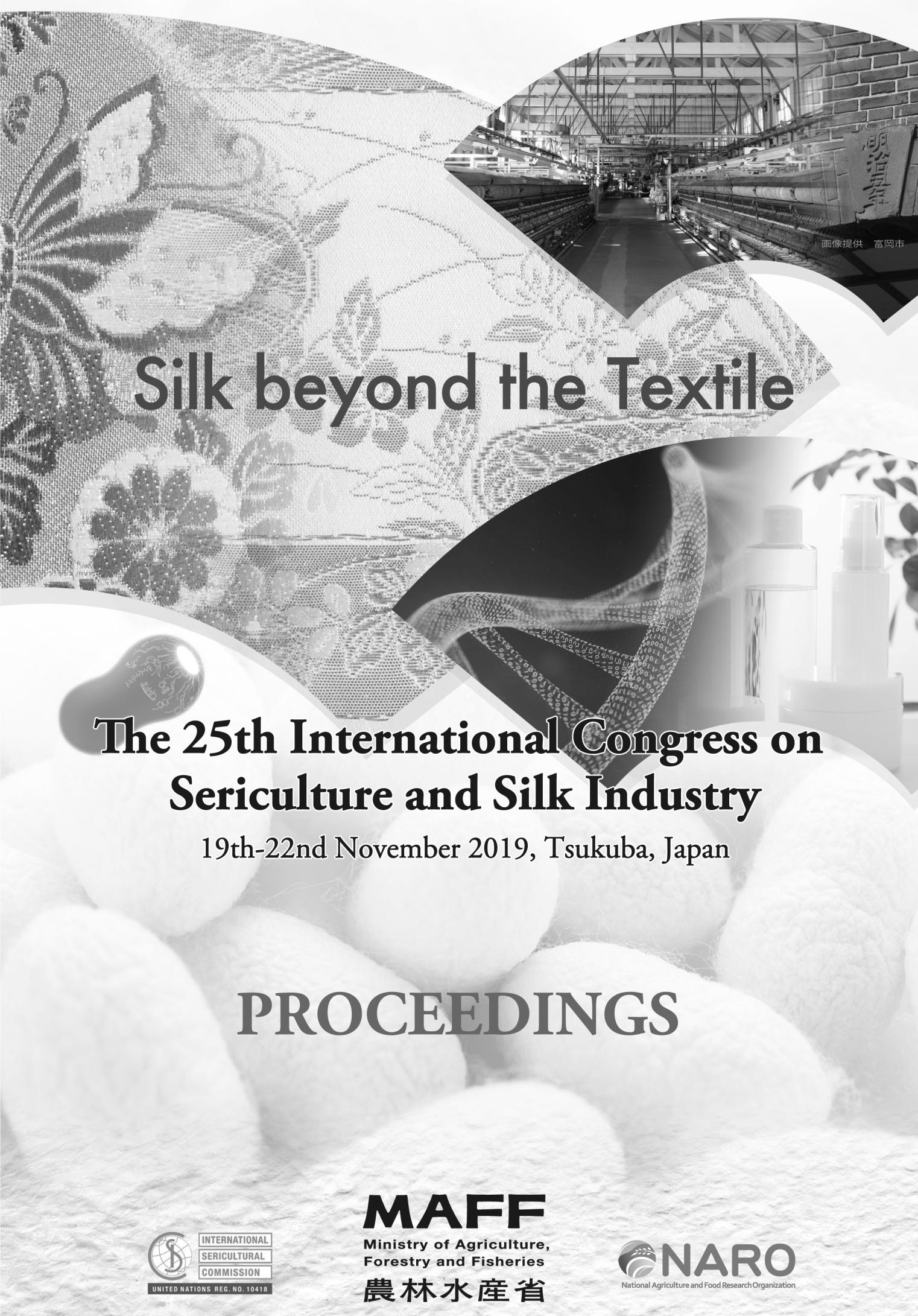
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Preface

The Ministry of Agriculture, Forestry and Fisheries is honored to be holding 25th International Congress on Sericulture and Silk Industry from November 19 to 22, 2019. The event is cosponsored by the National Agriculture and Food Research Organization and International Sericultural Commission , and this will be the first time it is held in Japan. I would like to express my sincerest gratitude to everyone both in Japan and overseas for their cooperation in organizing this event.

The theme for the conference is “Silk beyond the textile”. In the silk and sericulture industry, we expect silk to be utilized beyond conventional fibers, such as in protein production for pharmaceuticals and development of new materials processed with silk. This year’s event covers all areas of silk and sericulture research, from the use of textiles to application of new technology. There will be spoken and poster presentations on research and development in eight specific topics: 1. Mulberry, 2. *Bombyx mori*, 3. Non-mulberry Silkworms, 4. Bacology of the silkworms, 5. Post-Cocoon Technology, 6. Economy, 7. Sericulture in Non-textile Industries and New Silk Applications, 8. Silk Processing, Trading and Marketing. Researchers from across the world will join us to present, so we are expecting incredible results.

We will be visiting Gunma, Japan’s number one prefecture for silk and sericulture within a long-flourishing industry. Here, we will observe the prefecture’s 150-year history as well as the latest in silk and sericulture. We will also be showcasing the latest silk research, traditional silk products and sericulture technology at the venue.

Through this content, I hope we can introduce both new technology and traditional techniques in the Japanese silk industry to a wide range of people.

Finally, I would like to close by sharing my heartfelt hopes for the further development of the silk and sericulture industry.

水田 正和

Masakazu Mizuta

Director, Ministry of Agriculture, Forestry and Fisheries

November 19, 2019

Keynote Lecture

KEYNOTE LECTURE

Use of silkworms as an experimental animal for evaluation of food and medicine

Kazuhisa Sekimizu

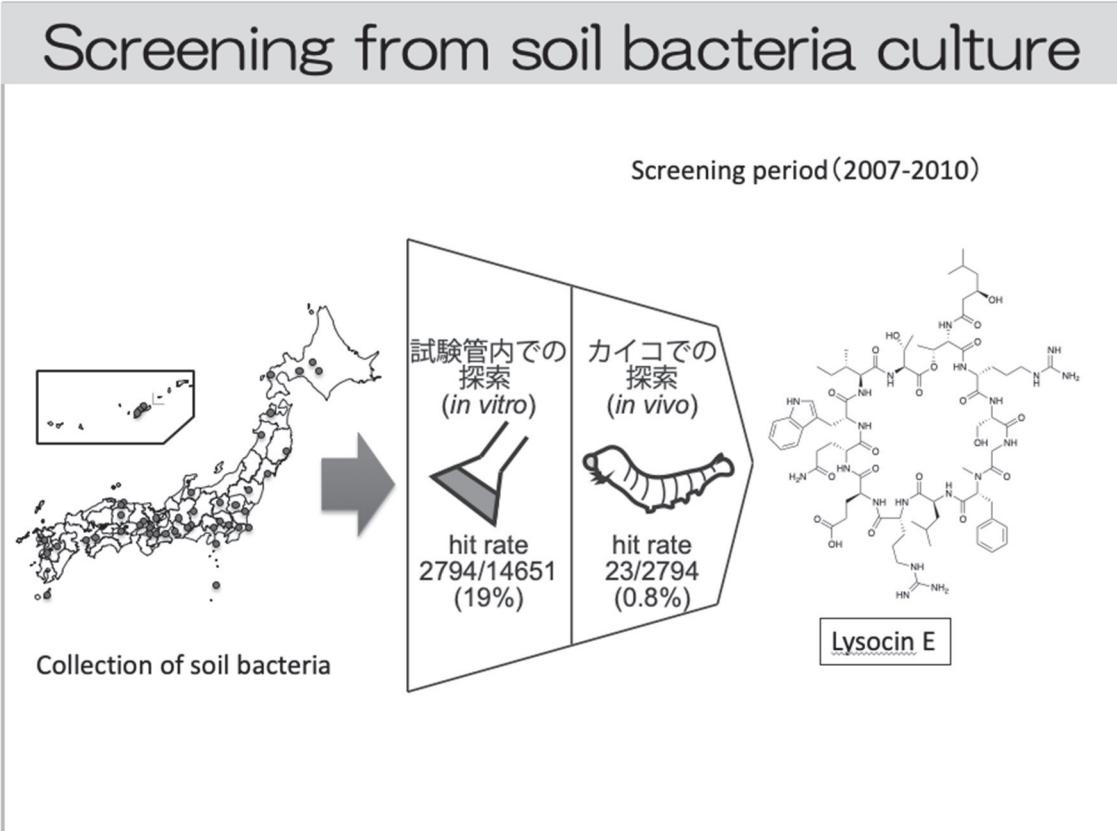
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Use of a large number of mammalian animals for evaluation of therapeutic effects of drug candidates becomes to be difficult due to high cost and ethical issues from the view of animal welfare. To solve the problems, we are proposing use of silkworms⁽¹⁾. In Japan, a long history of silk industry has established maintenance of silkworm strains and methods for taking care of silkworms. Thus, silkworm has a large number of advantages as an experimental animal. However, little attention has been paid for use of silkworms as experimental animals for evaluating functions of food and medicine.

Infection model with silkworms**Injection of saline****Injection of *S. aureus***Kaito et al., *Microb Pathog.* (2002)

To evaluate the system of food and medicine by using silkworms, we tried to establish disease models with silkworms including infectious diseases. When pathogenic bacteria (*Staphylococcus aureus*, *Pseudomonas aeruginosa* etc.) or true fungi (*Candida albicans* etc.) are injected into blood of silkworms, they die within several days⁽²⁾. Antibiotics clinically used for human patients showed therapeutic effects in silkworms. Furthermore, their ED₅₀ values, which show the amount of drugs needed to cure 50% of animals, of antibiotics in silkworms infected with *Staphylococcus aureus* were consistent to the values in mammalian animals⁽³⁾. This means that we can evaluate therapeutic effects of antibiotics by silkworms without sacrificing mammalian animals.

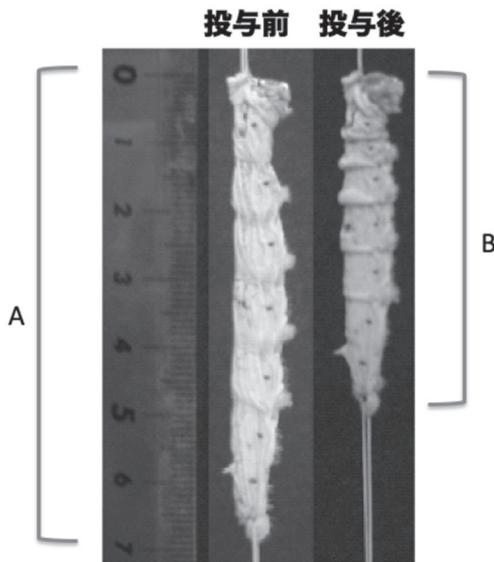
By searching samples obtained from culture supernatant of soil bacteria, we discovered novel antibiotics, lysocin E⁽⁴⁾. Lysocin E showed therapeutic effects in mouse models. Development of lysocin E for human patients is an important subject in future.



We established hyperglycemia model with silkworms. When we added glucose or sucrose in to the artificial diet of silkworms, we observed rapid increase in glucose concentration in the blood of silkworms. Silkworms with high concentrations of glucose in the blood showed termination of their developments. We found that insulin decreased in the concentration of glucose in the hyperglycemic silkworms, and that insulin recovered the silkworms from the suppression of the developments. By using the hyperglycemia model of silkworm, we demonstrated that a lactic acid bacteria, *Enterococcus faecalis* YM0831, was effective to suppress the blood glucose level in silkworms and that this strain also showed suppressive effects in sucrose tolerance test with healthy humans⁽⁵⁾.

When we injected peptidoglycans beta-glucans, bacterial and fungal cell wall components, into the blood of silkworms, paralytic peptide, a cytokine of silkworm, was activated resulting in muscle contraction⁽⁶⁾. By using this phenomenon, we can easily evaluate immuno-activating substances in food samples. We found that a strain of *Lactococcus lactis* 11/19-B1, has high activity of immuno-stimulation.

Coupling of the stimulation of innate immunity and muscle contraction



Muscle contraction by innate immunity stimulation

In summary, silkworms are highly valuable as experimental animals for evaluating functions of food and therapeutic effects of drug candidates. We can reduce number of mammalian animals needed to sacrificing for evaluation of these purposes.

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Section 1

Mulberry

ML-LP: Lead Paper

Variation of mulberries (*Morus* spp.)

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Mulberry is a plant belonging to the genus *Morus* that possesses several variations. Mulberry (*Morus*) consists of various species; one variation of the genus *Morus* is ploidy, and it comprises diploid and polyploid species. The examples of the reported ploidies are diploid ($2n = 2x = 28$; e.g., *M. alba* and *M. bombycina*), tetraploid ($2n = 4x = 6$; e.g., *M. boninensis*), hexaploid ($2n = 6x = 84$; e.g., *M. tiliifolia*), and docosaploid ($2n = 22x = 308$; e.g., *M. nigra*) (Machii et al. 2002). In addition, a haploid species *M. notabilis* has been reported (He et al., 2013). Polyploidization generally occurs in angiosperms and plays an important role in evolution. *Morus* may be just in evolution through polyploidization. For sericulture, some diploid species derived from the east side of Eurasia have been primarily used.

Morus species are naturally distributed in almost all continents, except in Australia and Antarctica. Each species is originally distributed in only certain continents and its neighboring islands or in more restricted regions. Some species are artificially distributed for use as silkworm food (leaf) and as fruits for human consumption. Especially, diploid species derived from East Asia, represented by *M. alba*, are artificially distributed around the world. For example, there is an indigenous cultivar from Africa, ‘Enbu’, in the Japanese NARO Genebank. ‘Enbu’ is not a cultivar of *M. mesozygia*, which is only an African native species; however, it is probably derived from some diploid species introduced into Africa perhaps from Asia.

Therefore, it is important to analyze mulberries using various methods such as follows.

1) Flow cytometry analysis

Flow cytometry is a technique performed using a flow cytometer. “A flow cytometer is an instrument that illuminates cells (or other particles) as they flow individually in front of a light source and then detects and correlates the signals from those cells that result from the illumination” (Givan, 2004). In the case of plants, protoplast and subcellular organelles, especially the nucleus, are primarily analyzed by flow cytometry (Vrána et al., 2014), whereas cells are not generally analyzed unlike in the case of animals.

Flow cytometry is often used to analyze the nuclear DNA content and the related parameters, e.g., genome size, ploidy, endoreduplication, and cell cycle. In general, the suitable plant tissue is chopped using a razor blade in a buffer solution, and the nuclei isolated in the buffer are stained using a fluorescent dye, followed by application into the flow cytometer. In general, two fluorescent dyes are used for staining nuclear DNA in plants, i.e., 4',6-diamidino-2-phenylindole (DAPI) and propidium iodide (PI). PI (an intercalator) binds to DNA and is not affected by base composition, whereas DAPI (a DNA-specific dye) binds preferentially to adenine–thymine (A–T)-rich regions of the DNA helix (Doležel et al., 1992). In the analysis of ploidy and endoreduplication, both PI

and DAPI can be used for staining nuclear DNA.

The presence of endoreduplication is represented by multiple peaks on a flow cytometry histogram. Only a single peak was observed when rice leaves were analyzed, whereas remarkable multiple peaks were observed when the leaves of some plant groups, e.g., Brassicaceae and Caryophyllaceae in which endoreduplication occurred, were analyzed.

In the case of mulberry, when its young leaves were analyzed, two peaks, large and small, were observed, in which the relative fluorescence strength (= parallel to the nuclear DNA content) of the small peak was double that of the large peak. This implies that some cells were in the process of division in the young leaves; the large peak represented the nuclear DNA content in the G₀ or G₁ stage of cell division cycle, and the small peak represented that in the G₂ stage. Conversely, only a single peak was observed when a mature leaf was analyzed. Exceptionally in mulberry, significant endoreduplication was observed in the anther.

Ploidy can be estimated by flow cytometry using an internal control. Polyploidy is important for mulberry breeding. In Japan and may be other countries, triploid cultivars generally indicate a higher yield than diploid cultivars. Triploids can be generated by crossing between a tetraploid and diploid. Tetraploids can be artificially improved by colchicine treatment to diploid individuals. In addition, the fruits of tetraploids are generally larger than those of the original diploid. However, not all cells treated by colchicine doubled their nuclear DNA content. Therefore, repeated cut back and selection of chromosome doubling shoots is necessary. Among the regrown shoots, complete tetraploids may or may not occur occasionally.

Most often, only cytochimera shoots occur. In the present study, only two types of periclinal cytochimeras were observed, i.e., 4-2-2 and 2-4-4 types of shoot apical meristem (SAM). Both types of cytochimeras are probably stable, although revertant shoots rarely occur from some 2-4-4 types. The tetraploid and the two types of cytochimera can be identified by the peak pattern on the flow cytometry histogram analyzed for its young leaves (Yamanouchi et al. 2008, Fig. 1).

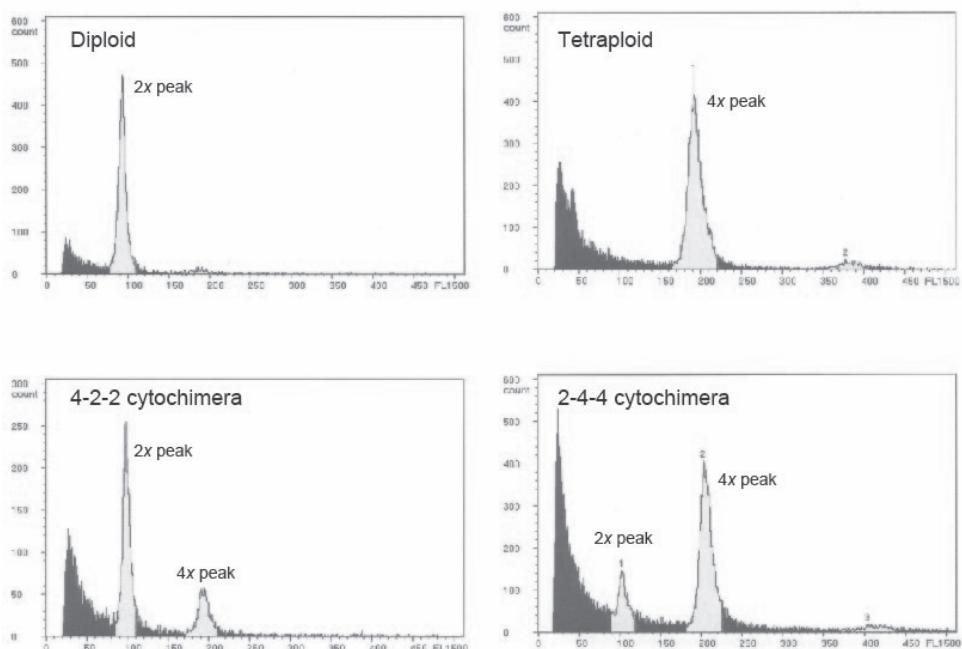


Fig. 1

Although complete tetraploidy is desirable, from a practical viewpoint, the stable 2-4-4 type cytochimera can be used for a tetraploid parent for triploid breeding and can even itself be used for new cultivars for fruits

Genome size can be estimated using flow cytometry, wherein an object sample and an internal control sample of a known genome size are co-analyzed. The AT contents of the nuclear DNA of the internal standard species may be different from those of the objective species; therefore, PI is used. The genome size generally implies holoploid (C value) and sometimes monoploid (Cx value) (). The C and Cx values of diploids are equivalent to each other. The C value of a tetraploid is double its Cx value. The estimated C value of diploid mulberry species was approximately 0.34–0.38 pg. In the polyploid species, the Cx values showed more variations than those within the diploids by 0.33–0.42 pg (Yamanouchi et al. 2017).

2) Mutants, in vitro induction of adventitious buds, and chimera separation

Several peculiar mutant mulberry cultivars are conserved in the Japanese NARO Genebank. There are several types of mutant cultivars, such as chlorophyll mutants (e.g., ‘Kiba Juumonji’: Fig/ 2), leaf morphology mutants (e.g., ‘Chijimiguwa’: Fig. 3 and ‘66-21-M’), and stem morphology mutants (e.g., ‘Unryuu’: Fig. 4). These cultivars comprise both spontaneous (e.g., ‘Kiba Juumonji’ and ‘Chijimiguwa’) and artificially induced mutants (e.g., ‘66-21-M’). Some mutant cultivars are practically used for ornamental purposes, e.g., for street and garden trees and for bonsai (Yamanouchi et al. 2009). These cultivars are generally propagated vegetatively by grafting and cutting. Vegetative propagation relatively tends to preserve the stable periclinal chimera state in the cultivars. The abovementioned stable 4-2-2 and 2-4-4 cytochimeras are the examples.



Fig.2



Fig. 3



Fig. 4

In vitro induction methods of adventitious buds (shoots) frequently separate the periclinal chimera state. Several methods have been developed for the induction of adventitious mulberry buds. As a basal medium, MS medium induced high percentages of adventitious buds compared with B5 medium. The ratio of ammonia nitrogen and nitrate nitrogen was one of the important factors, and 1 µM thidiazuron was found to be effective (Yamanouchi et al. 1999). Immature leaves isolated from winter buds were found to be extremely good material for the induction of adventitious buds, and the immature leaves in the terminal buds on the elongating shoot can be used for this purpose. It is difficult to induce adventitious buds on the matured leaves. Adventitious buds (shoots) appear to develop on the adaxial surface of the cultured leaf, especially on the

base of the main vein.

Immature leaves of some periclinal cytochimeras were cultured in vitro and adventitious shoots were regenerated. After several subcultures, the regenerated shoots were analyzed by flow cytometry. The peak patterns indicated that the regenerated shoots contained both cytochimera and complete single ploidy shoots. The number of single ploidy shoots was larger than that of chimera shoots. Interestingly, the ploidy of the single ploidy shoots comprised only one type depending on the original cytochimera. The ploidy of all the single ploidy shoots was identical to the ploidy of the L1 cells of SAM of the original cytochimera, except for one case among the studied samples, indicating that several diploids and a few chimera shoots were regenerated on the cultured leaves of the 2-4-4 cytochimera. Conversely, several tetraploids and a few chimera shoots were regenerated on the cultured leaves of the 4-2-2 cytochimera, except for one different case. As a result, the adventitious buds (shoots) are frequently derived from the L1 cells of SAM. This phenomenon probably correlates with that L1 cells of SAM that generally differentiate into epidermal tissues.

When a similar in vitro culture method was adapted to mutant mulberry cultivars, most regenerated shoots of some cultivars represented wild-type phenotypes, whereas only small numbers of the regenerated shoots represented the original mutant phenotypes. The frequency of regeneration of wild-type shoots was high among the cultures of 'Chijimiguwa' and 'Kiba Juumonji.' Considering the phenomenon of cytochimera, this probably indicated that the wild-type cells were preserved as the L1 cells of SAM for a long time. Conversely, no wild-type shoots were regenerated in some mutant varieties, among which whole plants probably consisted of only mutant cells. On the leaves of 'Kiba Juumonji,' a yellow-colored mutant, various sizes of green sectors were occasionally observed. The green sectors may indicate that the position of the cells derived from L1 and L2 cells rarely changes during leaf development (some L1 cells accidentally developed into mesophyll cells).

There are several variations in mulberries (*Morus*), indicating that various types of mulberries can be used. Therefore, a further in-depth study is important for making an efficient use of the mulberry plant.

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ML O 01: Screening and molecular characterization of resistance in worldwide collection of mulberry germplasm against root knot nematode (*Meloidogyne incognita*)

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The Root Knot Nematodes (RKN) cause most devastating soil-borne disease in mulberry, its infection leads to development of root disease complex with root rot pathogens, resulting in leaf yield loss up to 25% coupled with deteriorated leaf quality. The uses of chemical nematicides were restricted, due to environmental and public health issues and therefore breeding for RKN resistance is the most durable and economical way to manage RKN disease. Presently cultivated mulberry varieties in the farmer's field are highly susceptible to the RKN. To our knowledge, the availability of RKN-resistance sources are limited. In the present study, a total of 440 germplasm accessions were evaluated for RKN resistance from 2016 to 2019 under glass house conditions. Among them 60 were identified to be resistant and currently, the resistant accessions have been evaluated under field conditions in different hot spots of Karnataka, Tamil Nadu and Andhra Pradesh. SSRs were employed for molecular characterization of 127 representative mulberry accessions. Six SSR markers found to be polymorphic were used to assess genetic relatedness among the RKN resistance and susceptible germplasm. Selection of resistant parent's viz., BR-8, *Morus lambong*, Karanjtoli-1, Baragarh-3, Thai peach, ACC.115, Papua New Guinea, Thailand male, Gamettee and Thailand lobed can be used for mulberry breeding programme. Two mapping populations were developed using newly identified resistant (BR-8, *Morus lambong*) and susceptible (ERRC-103, S-523) genotypes for identifying RKN resistance QTLs leading to genetic improvement of mulberry through Marker Assisted Selection (MAS).

Key words: Mulberry, Root Knot Nematode, SSR Marker, Germplasm accessions

ML O 02: Occurrence, molecular characterization and standardization of screening techniques of fungal pathogens associated with root rot of mulberry: Current Trends and Future Perspectives

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Mulberry productivity is mainly reduced by several fungal diseases which often causes considerable damage to the crop and deteriorate the leaf yield and quality. Among them root rot disease of mulberry is more severe and destructive due to its epidemic nature and potentiality to kill the plants completely resulting in leaf yield loss up to 31.5%. It is prevalent in sericulture practicing countries including many states of India. The present study was conducted to assess the incidence of root rot of mulberry in four states of Southern India viz., Karnataka, Andhra Pradesh, Telangana and Tamil Nadu and apply molecular tools to differentiate fungal species associated with the mulberry root rot disease. The investigation started with collection of root samples of mulberry based on the severity of the fungal infection in more than 160 locations covering four states of Southern India, during the year 2016 to 2019. Among them *Fusarium solani* was most dominating (60%) followed by *Lasiodiplodia theobromae* (19.5%), *F. oxysporum* (14.4%) and *Macrophomina phaseolina* (5.7%). The advent of molecular tools for investigations in fungal identification has paved better way for easier and more accurate identification. Fifty representative isolates were chosen to identify, characterize and to perform phylogenetic analysis of fungal isolates using ITS markers in combination with other universal sequences (Tef & β -tubulin) for cryptic speciation. Morphological and molecular identification reveals the occurrence of *F. equiseti* and *Rhizopus* sp. as new records associated with root rot disease of mulberry and for the first time *Gongronella butleri* was isolated from root rot infested mulberry garden. Besides the above, *Sclerotium rolfsii*, *Aspergillus niger* and *Chaetomium species* were also found associated with the disease as saprophytic secondary invaders. Four different methods of inoculation, sorghum, root-dip, syringe and tooth pick method were used to standardize the root rot inoculation. Sorghum and syringe methods of inoculation were found to be effective for screening mulberry genotypes resistant to root rot caused by *Fusarium species*, similarly, root-dip method was effective for *L. theobromae*. In the present study, based on the morphological and molecular characterization *F. solani* was the major causal agent of root rot. Proper diagnosis of the exact fungal pathogens helps to apply suitable IDM practices and breeding region specific root rot resistant mulberry varieties.

Keywords: Mulberry root rot, ITS, *Fusarium solani*, *Lasiodiplodia theobromae*, screening techniques

ML O 03: New insight into early vigour and growth in mulberry by morpho-physiological and transcriptome analysis towards designing varieties for shoot harvesting system

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The advocacy of shoot harvesting technology and consequent repeated pruning leading to loss of vigour in mulberry has necessitated the understanding of genetic and molecular mechanism that control the key morpho-physiological processes. This will facilitate the breeding of early vigour and high-biomass yielding varieties. A total of 22 contrasting genotypes (CG) were shortlisted from a diverse set of germplasm (~300 accessions) based on the number of days for bud sprouting (NDBS), shoot elongation rate (SER), number of branches (NB) and fresh shoot biomass. Basing on the logistic regression analysis of CG expressed in odds ratio showed positive regression coefficient for traits *viz.*, internodal distance (IND), NB, total shoot length (TSL) and length of the longest shoot (LLS) for high growth. The linear mixed model also suggested the contribution of NDBS, SER, IND, NB and TSL in fresh leaf weight (FLW) and fresh shoot weight (FSW). The gas exchange factors like photosynthetic rate (A), stomatal conductance (gs), transpiration rate (Tr), light saturated photosynthetic rate (A_{max}) and apparent quantum yield (A_{QL}) were higher among high growth (HGG) compared to low growth genotypes (LGG). Linear regression, coefficient correlation and PCA studies also revealed the significant positive relationship of gas exchange factors with fresh biomass. Expression analysis of mulberry growth regulating factors (MnGRFs), which are putative transcription factors, suggested their role in initial growth of immature and young leaves. Significant difference in the transcript levels of MnGRF 1, 7 and 8 with higher expression in HGG than in LGG shed light on their functional role in mulberry growth. Molecular basis underlying growth using transcriptome profiling of CG was analysed. A total of 66.6 Mbp of primary transcriptomes from 2 HGG and 2 LGG resulting in 34096 pooled final transcripts. Functional annotation resulted in the categorization of 18970 transcripts into 3 GO terms and 7440 were assigned to 23 KEGG pathways. Based on the DEGs and gene enrichment analysis, over expression of photosynthetic related transcripts in HGG and defense related transcripts in LGG were identified. The genomic markers *viz.*, SNPs (390897), SSRs (3893), and InDels (8081) mined from the unique transcripts will find potential application in genetic analysis. The study identifies best suite of traits in mulberry that have substantial contribution in yield biomass in the changed harvesting system. Mulberry varieties may achieve higher yields using a unique combination of traits or genes suggesting the multiple genetic controls responsible for the crop productivity.

Key words: Early vigour, mulberry growth, photosynthetic factors, transcriptome analysis

ML O 04: Cutting edge technological interventions for sustainable mulberry sericulture in India

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Sericulture is an agro based avocation providing employment to 8.5 millions in the rural areas of India due to its labour intensiveness and suitability to a wide range of climatic conditions that prevail across the country. Unlike many other agro-based industries, sericulture is a unique combination of four entirely different but highly integrated components viz., the agriculture component cultivating the host plants, the insect component rearingsilkworms to produce cocoons, the post cocoon technological components reeling out silk fibers from the cocoons, and the textile components producing fabrics and apparels. Although India produces, all the four major commercial silks, the contribution of mulberry silk towards the annual raw silk production of 35468 MT during 2018-19 was 25344 MT accounting more than 70%. Thus, mulberry sericulture plays a vital role in the sustainability of silk industry in India and it is essential to make mulberry cultivation economically viable, robust and resilient in the context of the changing environmental and economic conditions of the country as mulberry leaf production alone accounts for more than 60% of the cocoon production cost. As a consequence of the increased industrialization and urbanization, large areas of arable land are being converted for non-agriculture purpose. Further, intensive irrigation based cultivation also enhancing the salinization process, rendering huge areas unproductive. The United Nations Environment Program estimated that approximately 20% of agricultural land and 50% of cropland in the world is salt-stressed and in India alone nearly 142 million ha of land is affected by drought and about 7.3 million ha of arable land is affected by salinity and alkalinity and this trend is going to be increased in the coming years. Further, the global warming and the rise of atmospheric CO₂ will also affect agriculture in a high magnitude, especially in the arid and semi-arid regions by making the productive mulberry varieties prone to different environmental vagaries. Escalation of input cost especially the labour requirement, once considered as a boon is now slowly turning into a bane, is another factor that will have serious impact on the profitability of sericulture in India. To overcome these challenges and to make the sericulture a sustainable avocation, it is envisaged that cutting edge technologies such as genomics, advanced information technologies, nano-technologies are to be employed for crop improvement, precision farming, plant disease monitoring, soil remediation, removal of heavy metals, water treatment, production of nano fertilizers and nano-pesticides. Further, artificial intelligence needs to be adopted for automated farming activities, management of pest and diseases, monitoring of biotic and abiotic stresses etc.. It is also essential to produce value added products such as mulberry leaf tea, jam and jellies from fruit, pharmaceutical compounds from stem, root and leaf to make mulberry cultivation more sustainable. This presentation, thus, focus mainly on the details of the constraints and the cutting edge technological interventions to make sericulture in India more sustainable, vibrant, eco-friendly.

ML O 05: THE MULBERRY GENOMICS SAGA - *A tryst with destiny!*

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Mulberry silk comes from the silkworm, *Bombyx mori* L. which solely feeds on the leaves of mulberry plant. The mulberry tree is closely related to figs, breadfruit and banyan. Sericulture is directly correlated with production of high quality mulberry leaves. Since mulberry is a water loving plant, productivity is severely impacted by abiotic stresses. The pioneering efforts at deciphering the chloroplast genome has led to important insights and paved the way for evolutionary studies in mulberry. Biotechnology has energized research and fostered a surge of new ideas for mulberry improvement. Genomic technologies generating valuable information on molecular basis of stress tolerance is the starting point for targeted gene-based transgenic approaches for introgression of beneficial genes conferring stress tolerance in mulberry.

Mulberry genomic resources have provided novel candidate genes, important for enhancing its productivity. Mulberry transcriptomics have led to investigations on the influence of abiotic stress and to isolate novel genes associated with water availability. EST databases have been a useful resource for mining SNPs or developing DNA markers, for mapping expressed genes to a linkage map thus making the map more useful for QTL analysis and marker assisted selection. In addition to the transcriptome of *Morus indica*, we have sequenced and assembled the transcriptome of *M. laevigata* and *M. serrata*, and identified around 95,181 and 85,269 unigenes, respectively. The ESTs have been used to isolate SSR and SNP markers for development of genetic maps in Indian Mulberry. The *de-novo* assembled transcriptome is enriched in genes related to abiotic stresses such as salt stress, cold stress and defense responses including hypersensitive responses, signal transduction and plant microbe interactions. These findings corroborate the utility of these later two species in mulberry breeding programs where genes of desired traits can be introgressed. Functional genomics has the unrealized potential, and candidate genes relevant to the interest of the sericulture industry, may represent important molecular tools for understanding mechanisms of enhancing mulberry productivity.

Keywords: Abiotic stress, Comparative genomics, Functional genomics, Mulberry, Transcriptome, Transgenics.

ML O 06: USE OF REMOTE SENSING AND GIS TOOLS TO IDENTIFY SUITABLE AREAS FOR MULBERRY CULTIVATION IN FOUR NON-TRADITIONAL SERICULTURE DISTRICTS OF KARNATAKA

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ABSTRACT

The increasing interest in sericulture as an occupation for sustenance, has necessitated identification of new suitable areas for mulberry (*Morus indica* L.) cultivation for expansion of sericulture in Karnataka. Four non-traditional sericulture districts viz., Bidar, Bagalkote, Belgaum and Chitradurga, respectively with 628; 1086; 968 and 1978 hectares presently under mulberry were assessed using Remote Sensing data of 5.8m spatial resolution and GIS tools as there is scope for expansion of sericulture in these areas. The factors such as Land use/Land cover, slope, groundwater potential, soil depth, pH, texture, stoniness, soil drainage and weather were evaluated using FAO method of land evaluation. These factors were ranked highly suitable, moderately suitable, marginally suitable and not suitable with reference to growth requirements of mulberry. GIS layers of these classified themes were subjected to overlay analysis to identify suitability class of lands for mulberry cultivation in the four districts. — Bagalkote, Belgaum, Bidar and Chitradurga possessed 26412; 8816; 108941 and 107609 hectares under highly suitable category, 275976; 266204; 211403 and 105193 hectares moderately suitable and 33780; 133779; 86874 and 133048 were marginally suitable for mulberry cultivation respectively. The areas ranked as not suitable are not considered for mulberry cultivation. Thus, the present study shows that considerable area of 1498035 ha in the four districts is available for cultivation of mulberry for profitable expansion of sericulture in these districts.

Key Words: Remote Sensing, GIS, *Morus indica*, Mulberry, Sericulture, Karnataka.

ML O 07: New report of *Pythium* sp. causing soft root rot of mulberry (*Morus alba* L.) in southern Karnataka, India

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Mulberry (*Morus alba* L.), the chief source of food for silkworms is severely affected by soft rootrot disease in Maddur, Malavalli, Kanakapura taluks of Karnataka State, India. The pathogen is soil-borne causing rotting of roots followed by sudden wilting and drying of leaves, branches and death of plants. A survey conducted in 525 gardens has revealed that maximum soft root rot incidence was observed in Malavalli (20%) and Maddur (18%) taluks of Mandya district and Kanakapura taluk (22%) of Ramanagar district. The infected roots showed oozing of droplets having sporangia when placed in sterilized water for 24 hrs producing zoospores. The pathogen was isolated on V8 agar medium and identified as *Pythium* sp. The fungicides Dimethomorph, Propiconazole, Mancozeb, Captan, Metalaxyl and Metoloxyl + Mancozeb totally inhibited mycelial growth at 100, 250 and 1000 ppm under *in vitro* conditions. Dimethomorph and Metalaxyl and Mancozeb evaluated under field condition, effectively reduced the disease spread and some of the partially infected plants recovered from disease. These fungicides may be utilized for control of *Pythium* root rot in mulberry. The causal organism and the methods of disease management are discussed.

Key words: Mulberry, Soft root rot, *Pythium*, Sporangia,

ML O 08: PERFORMANCE OF SELECTED MULBERRY VARIETIES UNDER KARNATAKA CLIMATIC CONDITION

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ABSTRACT

In the modern sericulture and competitive world, high income generation per unit area is an important aspect. High income generation always needs the planning, adoption and updation of new technologies. Development of new technologies, improved silkworm races and high yielding mulberry varieties are most important in sericulture. Development and assessment of high yielding mulberry varieties suitable for different agro-climatic zones of India is a major task. Evaluation of high yielding mulberry varieties developed at different research centers and Institutes, at different test centers of India is an important programme at national level. Karnataka which comes under south zone of India contributes more than 50% of total raw silk production of India. In Karnataka area under mulberry is around 98,000 ha. Presently, V1 mulberry variety which occupies more than 99% of the total mulberry area of Karnataka is the ruling variety. Agro climatic condition and soil condition play a major role in the varietal performance. An evaluation study was taken up at Karnataka State Sericulture Research and development Institute (KSSRDI), Bengaluru, India, under All India Co-Ordinated Experiments for Mulberry at different test centers. KSSRDI evaluated five mulberry varieties viz.C-2038, G-4, Suvarna-2, Vishala (National check) and V1 (Regional check). Among the test varieties G-4 recorded the significantly highest leaf yield (56,718kg/ha/yr) followed by Suvarna-2 (53693kg/ha/yr) and C-2038 (52782 kg/ha/yr). Based on the study performance of the G-4 mulberry variety was good compared to the other two test varieties and hence, G4 variety has been recommended for the south zone of India.

ML O 09: SIMPLE E³ MACHINES, DEVICES & TOOLS' AGRO-ERGONOMICS FOR INCREASE INCOME TO MULBERRY SERICULTURE FARMERS

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India is basically an agriculture oriented country; about 70% people of total population lives in rural villages are mainly depending on agriculture for their lively good. The country's economic strength greatly depends on the growth and development of agriculture and related industries. The highness of agriculture was well defined several hundred years back in Thirukkural as

"சமுன்றுமர்ப் பின்னது உலகு அதனால் மூந்தும் உழவே தலை" (1031) "Farming though hard is foremost trade men ply at will but ploughmen lead" (1031)

[Agriculture, though laborious, is the most excellent (form of labour); for people, though they go about (in search of various employments), have at last to resort to the farmer]

In recent years farmers are facing various problems particularly in terms of irrigation water scarcity, manifold increase in cost of inputs, non-availability & high wage for skilled man power which all attribute increase in cost of production; to compensate it, limitations in achieving the quality linked increased unit productivity potential to fetch better price for the produces are big challenge to them. Sericulture being labour intensive agro-based cottage industrial nature of activity, the problem observed is still higher. Though scientifically proven technologies, management techniques and introduction of mechanization in mulberry sericulture help to reduce cost of production, all of them are not available to all farmers, particularly mechanization at marginal & small farmers' level due its high cost and operation & maintenance expenditure.

A simple clean sharp stick used before 2700 BC by the Chinese Queen Si Ling-Chi to remove a dropped foreign material [later found as cocoon & the filament retrieved was named as **silk** phonetic approximation of her name in Chinese language] in hot tea while she was sipping in the court garden beneath the gracious mulberry trees was the **first tool** in Silk Industry, thereafter large number of tools, devices and fully automatic sophisticated machines of different variants to carry out different work processes from silk reeling to fascinated artifacts silk fabric and garments production, equally in mulberry cultivation farm maintenance & silkworm rearing for silk cocoon and silkworm seed production sectors in the Silk Industry worldwide.

However smart unique innovations are always having demand in the field. In this paper few of E³ [Efficient Economic Eco-friendly] oil & fuel, clutch cable free and electric power operated cost effective simple new innovations namely **MPT©ICE.**, [Mini Power Tiller cum Inter Cultivation Equipment], **WM©SHPM.**, [Weed Mower cum Shoot Harvest Pruning Machine], **BPCM.**, [Biomass Peeling Cutting Machine] and **BAM.**, [Bed-disinfectant Application Machine] proved in reducing labour requirements with HRUEI of average 10:1 per horse power motor used in all innovations, natural resources savings, timely completion of inter-cultivation operations enabling quality linked increased productivity to the tune of 25%, removal of drudgery and feel comfort to work without pain to physique and mind through amicable management of agro-ergonomic issues in the field of mulberry cultivation and silkworm rearing etc., to reduce cost of production of cocoons for doubling of sericulture income to marginal, small & big farmers are discussed in detail.

Key words : Mulberry cultivation; Cost of production, Drudgery and Agro-ergonomics.
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ML O 10: Soil moisture regime management to increase leaf yield in mulberry garden in Southern Dry climatic Zones of Tamil Nadu

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Tamil Nadu state in South India is one of the best silk producing regions in South Asia and the state occupies 4th position in silk production in India with a production of 2072 MT raw silk during 2018-'19. The state continues to occupy the leading position in cocoon productivity @ >80 kg for 100 silkworm layings as against the national average of 60.24 kg. Recently the production and productivity of silk is severely affected due to acute water shortage. Rainfall is the main source of irrigation water in Southern Tamil Nadu, as there is insufficient water in the perennial rivers. The average annual rainfall of the state is about 945 mm with a share of 48% thro' the North East and 32% thro' the South West monsoons. Of the total rainfalls 73% is received in <100 days, are not uniform and highly uneven in these regions leading to dry condition in other seasons. The state received 23-37% deficit rainfall in last two years. The Deficit rain and excessive drawing of ground water caused lowering of water table level. The irrigations made to mulberry gardens were insufficient to meet the water requirements of plants, the hot dry wind removed moisture from the garden soil at faster rate and vigorous growth of plants were affected by less moisture in the soil. The situations necessitate to increase the moisture holding capacity of the soil to conserve water with the main objective of minimize the amount of water loss from the soil thro' evaporation and seepage. The response of mulberry to soil moisture is well studied under irrigated conditions.

A study was conducted in South Tamil Nadu in farmers' field covering 15 farmers to conserve the soil moisture in the mulberry garden with trenching & mulching, green manuring, windbreaks & shelterbelts, weed management, sub-soiling or hard pan breaking and rain water harvesting and the performances were compared with equal number of farmers' garden under traditional method of cultivation as control for two seasons. Trenching & mulching with organic manures facilitated the soil to improve the water holding capacity thro' more infiltration and storage of rainwater which resulted in increased organic content, ensured resistance to the plants against moisture stress. Windbreaks & shelterbelts filtered desiccating winds and protected the leaf quality. Effective weed control in mulberry garden increased the availability of soil moisture to mulberry crop. Sub-soiling or hard pan breaking facilitated for deep percolation of rainwater which favoured the growth of mulberry roots. Green manuring increased the fertility status, water holding capacity, reduced weeds growth in the soil and strengthened the mulberry plants resilience to mitigate the ill effects of moisture stress. Rain water harvesting provided irrigation water during dry spells between rainfalls and recharged the ground water.

The study results revealed that the average leaf yield, dfls uptake, cocoon production and income ha⁻¹ yr⁻¹ at farmers' who have adapted soil moisture regime management [treatment] vs. non-adapters [control] recorded as 37.11 & 20.83 MT; 2391 & 1306 Nos.; 1850.61 & 1003.23 kg and Rs.5,70,981.30 & Rs. 2,89,064.70 respectively with improvement percentage of 78.15; 83.14; 84.47 and 97.53 over the control and the statistical analysis of difference in performances in respect of all parameters showed highly significant @ 5% CD level. The study details are discussed in the paper.

Key words: deficit rainfall, water shortage, soil moisture conservation, mulberry leaf yield, cocoon production and sericulture income.

ML O 11: Rationalisation of mulberry fruit harvesting can represent an additional income opportunity for silkworm rearers

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Abstract

Recently in Europe a new interest for sericulture raised, especially in case this activity is practiced with a multipurpose perspective. Therefore, it might be interesting to explore additional utilizations of mulberry orchards, among which fruit production could be the main target. In fact, mulberry cultivation has become very attractive for the valuable nutraceutical properties of its fruit, which is a very important resource for its phytochemical composition, nutritional value, and antioxidant properties. Industry sources affirm mulberry fruit is presently appreciated on the European market and its demand is growing. Currently, these fruits are still mainly marketed as dehydrated material. Despite this interest mulberry orchards specialized in fruit production only are not very common in Europe, therefore an adequate harvesting technique has not been developed.

The object of this paper was to evaluate a particular harvesting tool, which is new for the mulberry: we assessed its efficiency, requirements in terms of labour and the amount of production losses. In addition, we tested fruit quality obtained by this harvesting method through chemical analyses and we carried out mechanical tests on the detachments force of fruits according to their ripening stage. Furthermore, a suitable training system for trees was also considered, studied for this kind of harvesting method.

According to our experiments, this harvesting system increased from two to three-fold the average productivity per hour, in comparison to traditional methods, although it requires to be managed by a working team constituted of minimum four persons. We investigated each different operation of harvesting to calculate the time necessary to complete it and to analyse how to efficiently organize the overall management in a logic sequence of actions. We observed that the system results in a very simple use and maintenance and, therefore, we believe it represents a good chance to exploit mulberry fields: in fact, in addition to fruit production, thinning of branches during the summer season might represent a source for silkworm feeding.

ML O 12: Phylogenetic analysis of mulberry varieties based on genome-wide SNP data using double-digest restriction site-associated DNA sequencing

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In order to investigate the genetic relationship between 54 diploid mulberry varieties belonging to seven different *Morus* species (*M. alba*, *M. indica*, *M. bombycina*, *M. acidosa*, *M. latifolia*, *M. kagayamae*, and *M. rotundiloba*) and one unspecified *Morus* species ('Enbu'), we conducted genome-wide SNP discovery and phylogenetic analysis using double-digest restriction site-associated DNA sequencing (ddRAD-seq). Genome-wide 2,229 homozygous SNPs of the 54 mulberry varieties in the eight species were generated by ddRAD-seq. Results of the phylogenetic analysis using the SNP markers identified three clear monophyletic clades in two Japanese native species, *M. acidosa* and *M. kagayamae*, which are found on different geographically isolated islands and a Thai species, *M. rotundiloba*, whereas the other species were non-monophyletic. Varieties of *M. bombycina*, another Japanese native species, were roughly classified into three groups. Of these, two groups were monophyletic with *M. acidosa* and *M. kagayamae*, respectively, while another group was not monophyletic. Varieties of *M. indica*, an Indian native species, were classified into two different monophyletic clades. Of these, one clade was clearly monophyletic with an indigenous variety in Kenya, 'Enbu', while another clade was monophyletic with *M. rotundiloba* and one *M. latifolia* variety. There were no clear monophyletic clades within *M. alba* and *M. latifolia* varieties, which could be a result of several hybridization events after their introductions from China to Japan. Our results suggested that it was difficult to clearly classify the hybridized mulberry varieties even with genome-wide DNA markers. In addition to phylogenetic analysis, we also evaluated two morphological characteristics of mulberry leaves (leaf tip ratio and leaf bottom ratio) for each variety. The results suggested that leaf tip ratio might be used for evaluating hybridization of *M. bombycina* varieties. Overall, our results may provide new insights into taxonomic debate of mulberry species.

ML O 13: A defense protein MLX56 found in mulberry latex: Its roles in mulberry-silkworm interaction, its unique mode of function, and its applications to pest management

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From ancient times, people have been observing the silkworm, *Bombyx mori*, feeding on mulberry, *Morus spp.* without noticing the hostile interactions between them. Recently, we found that mulberry leaves are toxic to insects other than *B. mori* because of two types of defensive components in mulberry latex, sugar-mimic alkaloids (1-3) and MLX56 family proteins (MLX56 and its close homolog LA-b) (4). MLX56 is a 56 kDa protein consisting of 394 amino acids with a unique sandwich-like structure composed of an extensin domain (Gum Arabic-like domain) surrounded by two hevein (chitin-binding) domains (4). MLX56 inhibited the growth of *Spodoptera litura*, *Mamestra brassicae*, and Eri-silkworms, *Samia ricini*, in 0.01-0.04% concentrations (4). MLX56 has a unique mode of toxic action (5). MLX56 swells the peritrophic membrane (PM, thin chitin-based membrane existing between midgut epithelium and food materials) of Eri-silkworms fed MLX56 into an extraordinary thick gel-like structure that functions as obstacle to digestive processes, by binding to chitin-framework of PM with hevein domains, and swelling PM with extensin domain (5). Interestingly, *B. mori* is resistant to MLX56 as well as to sugar-mimic alkaloids, suggesting the physiological adaptation in the mulberry specialist, and the involvement of the latex components in the evolution of silkworm-mulberry interactions (1-5). We are attempting to make pest-resistant crops using MLX56 (6-7). Tomato, tobacco, and *Arabidopsis*, transiently (6) or stably (7) expressing *mlx56* gene (MLX56 protein) showed strong resistances to various important pests including *Spodoptera litura* (6,7), *Mamestra brassicae* (6), *Plutella xylostella* (Lepidoptera) (6), *Henosepilachna vigintioctopunctata* (Coleoptera, ladybirds larvae) (7), and *Frankliniella occidentalis* (Thysanoptera, thrips) (7) suggesting that MLX56 can be a promising substitute of *Bt* toxin in making pest-resistant crops in future.

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ML O 14: Comparative gene expression profiles among contrasting mulberry varieties under abiotic stress condition

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Mulberry leaf is a sole food source for the economically important insect, *Bombyx mori*. Abiotic stress severely damages buds and young leaves which in turn affect growth and leaf productivity. Therefore, it is required to identify genes which are responsive and impart abiotic tolerance and utilize them to develop improved mulberry varieties. In the present study, candidate gene sequences of cysteine proteinase inhibitor (CPI), 14.3.3, Universal Stress Protein (USP), LEA protein, TIFY10, Cold regulated 413 plasma membrane protein 2 (COR413), Dehydrin, and WRKY46 were retrieved from the mulberry database through NCBI and bioinformatics tools. Based on the comparative sequence analysis, primers were designed from conserved region of the sequences. Comparative gene expression analysis was performed in different mulberry varieties under abiotic stress condition. Results depicted that cysteine proteinase inhibitor (CPI), 14.3.3, Universal Stress Protein (USP), LEA protein, TIFY10, Cold regulated 413 plasma membrane protein 2 (COR413), Dehydrin, and WRKY46 genes displayed differential up-regulation under abiotic stress condition.

Keywords: Temperate sericulture, Mulberry, abiotic stress, Dehydrin, 14.3.3, Universal Stress Protein (USP), LEA

ML O 15: EFFECT OF MIDDLE PRUNING ON GROWTH AND QUALITY PARAMETERS OF MULBERRY VARIETIES

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Abstract

Mulberry (*Morus indica*) is considered as sole food plant of silkworm *Bombyx mori* L. The quality of leaf considered as one of the important factor not only for growth and development of mulberry but also silkworm. The nutritive value of leaf is most important factor influenced by environment, technology adopted and pruning. Therefore pruning of mulberry to the height of 60-90 cm above the ground level (Middle pruning) is a very common practice adopted under rainfed condition. This enhances all the growth parameters viz., number of shoot, number of leaves /shoot, internodal distance, leaf area, moisture percentage and moisture retention capacity of mulberry leaf (6 hr, 12 hr & 24 hr). The study revealed that maximum of number of shoot (12.44, 16.40, 19.57) and shoot length (29.85, 76.87, 109.32 cm) was observed in Tr-10 variety and minimum number of shoots was observed in Mysore local (3.53, 3.80 and 4.73) and minimum shoot length (8.31 27.11 and 63.00 cm) was observed in DD genotype on 15, 30th and 45 days after pruning and results are found significant. Further, the data on maximum number of leaves (9.20, 15.89, 21.99) was recorded in S-34 variety whereas the internodal distance (5.67, 7.69 8.08 cm) and leaf area (58.32, 175.12 and 224.04 cm²) was recorded in Tr-10. However, the next increased leaf area was recorded after 30 (123.72 cm²) and 45 (163.37 cm²) days after pruning in S-34 followed by MR-2. Further, the maximum leaf moisture content of 78.42 per cent was recorded for S-36 followed by S-54 (76.95 %) and S-34 (76.31 %). The trend was same even in moisture retention capacity (6hr - 84.87, 12hr - 80.62 and 24hr - 77.58 %). The data on moisture content was found non significant after 30 DAP but moisture retention capacity of the leaf found significant in all the mulberry varieties.

Key words: Mulberry genotypes, Middle pruning, mulberry growth parameters

ML P 01: ANTIAGING POTENTIAL OF NATURAL PRODUCTS FROM *MORACEAE* spp. IN HUMAN SKIN CELL LONGEVITY

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Resveratrol (trans-3,4',5-trihydroxystilbene) is a trihydroxy derivative of stilbene used in cosmetics for its anti-proliferative or photoprotective effects. Also it is known that may induce apoptosis in different human cell lines. In the present study, the concentrations of flavonoids, polyphenols and resveratrol in fruits and leave extracts of mulberry species grown in Romania and China were examined using HPLC-PDA method. Chemical composition of fruits and leaves extracts exhibit higher concentrations of: rutin, iso-quercitrin, chlorogenic acid and 3-4 dihydroxybenzoic acid. Effect of extracts (C1-C4) on the human skin fibroblast Hs27 cell lines after 48 h (n=5) represents significant results ($p<0.05$) compared with untreated Hs27 cells. The proliferative effect increased collagen synthesis with increasing concentration in bioactive compounds from *Moraceae*.

More than seven natural products as a gel base, containing ethanolic extracts from fruits, roots and leaves of mulberry have been made in the GCEARS PSP.

The results obtained for the nano-emulsion gel products shown that the mulberry products are rich sources of polyphenols and resveratrol, with high biological properties. To the best of our knowledge, this is one of the few studies regarding the use of mulberry extracts in developing different skin treatment products.

Keywords: *Moraceae*, anti-proliferative effects, anti-aging, polyphenols, stilbene.

ML P 02: Health risk assessment of heavy metals in mulberry leaves from controlled cultivation area

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Keywords: Heavy metals, Mulberry leaves, ICP-MS, controlled cultivation area

Introduction: Mulberry (*Morus alba* Linn.) is one of Thai economic plants. Its leaf is processed into tea products with many bioactivities especially antioxidative and blood glucose lowering activity. Heavy metal contamination in herbal products is an important quality regulation and affects health risk of human. According to ICH, Q3D, Arsenic (As), lead (Pb) and cadmium (Cd) are classified as element impurity class 1 that is highly toxic to human. The limits of As, Cd, and Pb contents from ASEAN and WHO guidelines are 5, 0.3, 10 mg/Kg, respectively. Sources of contamination may come from pollution in cultivation area such as air, soil and water.

Objective: The aim of this work was to determine As, Cd and Pb contents and evaluate health risk from contamination of As, Pb and Cd in mulberry leaves from controlled cultivation area (environmental control), compared with those from uncontrolled area and the limit.

Method: Two varieties (var. Buriram 60 and Khun Pai) of mulberry leaves from 3 provinces were supported from the Queen Sirikit Department of Sericulture in Buriram, Kanchanaburi, and Nakhon-Ratchasima provinces, and were defined as samples from controlled cultivation area. Other five samples collected from different places of uncontrolled area were used to compare health risk. All samples were digested with 65% nitric acid for 30 min using a High Performance Microwave Digestion System before injected into an ICP-MS ($n=3$) to determine the amount of As, Cd, and Pb. Metal contents were expressed as mg/kg (mean \pm SD). Statistical analysis for comparison was performed using independent t-test at 95% confidence level.

Results: All metal contents of samples from both controlled and uncontrolled area were under the limit for herbal products of ASEAN and WHO. The mean content of each metal in samples from controlled area are significantly lower than those in uncontrolled area at 95% confidence level. As, Cd and Pb contents in leaves from controlled area were only 39, 54, 46% of those from uncontrolled area. There was no difference in As and Pb amounts; while Cd content was significantly different at 95% confidence between both varieties.

Conclusion: Although the amount of heavy metals in mulberry leaves from both controlled and uncontrolled area was under the limit, the environment with less pollution in the cultivation area will reduce contamination and make it safer for consumption of products from these sources. There was no significant difference in health risk based on As and Pb contamination from these 2 different varieties. The next assessment will be continued with commercial mulberry tea products.

ML P 03: GC-MS fingerprints of mulberry leaves from Thailand

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The Gas Chromatographic-Mass Spectrometric chemical profiles of mulberry leaves from 2 varieties of *Morus alba* Linn. grown in 3 provinces of Thailand were studied. Leaves of var. Buriram 60, a certified variety by Department of Agriculture, Ministry of Agriculture and Cooperatives, and var. Khun Pai, a native variety were collected from The Queen Sirikit Department of Sericulture Centers in Buriram, Kanchanaburi, and Nakhon-Ratchasima provinces.

The ethanolic extracts of mulberry leaf samples were subjected to GC-MS to obtain the GC-MS chromatograms. Identification of chemical constituents in each ethanolic leaf extract was achieved from the comparison of both the mass spectrum with NIST-MS Library Data (NIST05.LIB) and their retention index. A total of 83 compounds comprising terpenes, saturated fatty acids, unsaturated fatty acids and benzofurans were found from both varieties in all 3 provinces. Fifteen compounds such as phytol, oleic acid and palmitic acid, with respect to % peak area (detected at > 0.04%) from high to low, were found in var. Buriram 60. Eighteen compounds such as phytol, palmitic acid and oleic acid, respectively were found in var. Khun Pai.

In this study, the GC-MS fingerprints from 2 varieties of Thai mulberry from 3 provinces were determined as preliminary data for the authentication of mulberry leaves. Further study will include the GC-MS fingerprints from other certified varieties, which will be employed to establish the GC-MS fingerprint characteristics of mulberry leaves from Thailand.

Keywords: GC-MS, fingerprint, chemical profile, mulberry, *Morus alba*

ML P 04: Development of drought tolerance mulberry by increasing the expression of genes in proline biosynthesis pathway

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Abstract

Mulberry (*Morus spp.*) is a vital plant for silk industry. The quality and quantity of mulberry leaves decrease due to global warming situations. Drought is one of the main factors limiting mulberry yield. Under drought condition, plants produce amino acid proline to help preserve the water content in plant cell. *Delta-1-pyrroline-5-carboxylate synthase (P5CS)* and *Pyrroline-5-carboxylate reductase (P5CR)* are the key enzymes in the proline biosynthetic pathway for increasing drought tolerance in plants. Therefore, this study aims to study gene expression pattern in drought condition and construct the vector that contained *P5CS* and *P5CR* genes for introducing to mulberry. Gene expression under drought stress of 10 mulberry varieties was examined. The results demonstrated that all mulberry varieties showed increased in gene expression of both genes with SRCM9809 had the highest level of genes expression. In addition, the gene expression level in 3 organs of mulberry (root, leaves and shoot tip) was observed and the results showed the similar gene expression level of both genes. For the development of drought tolerance mulberry, coding sequence (CDS) and promoter of *P5CS* and *P5CR* genes were amplified. All of fragments were cloned and will be transformed into mulberry callus using *Agrobacterium tumefaciens*. The transgenic mulberry will be evaluated for the drought tolerance and will be used for improving mulberry production in the future.

Keywords: Gene expression, Mulberry, Proline, *P5CS*, *P5CR*

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ML P 05: Molecular Marker Development for assisted selection of mulberry salt tolerant variety

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Abstract

Mulberry, mainly growing in the Northeast of Thailand, has been affected by saline soils, resulting in low quality and productivity. Feeding silk worm with low quality mulberry leaf will reduce cocoon production and cause poor quality fiber. Using salinity tolerant mulberry varieties is an alternative way other than the use of organic fertilizer and lime to improve saline soils. This study was aim to develop DNA markers for the selection of salinity tolerant mulberry varieties. 142 mulberry varieties were grown and treated with sodium chloride 150, 200 and 250 mM 100 mL for one day and water for 2 days for a total period of one month. Plant growth and electro-conductivity were measured. The result was used to classify mulberry into 4 separate groups namely: highly tolerance, medium tolerance, low tolerance and no tolerance to salinity. Leaf samples from 76 mulberry varieties were used for DNA extraction and produced the DNA fingerprinting using SRAP and ISSR markers. 26 SRAP and 19 ISSR markers were successfully amplify DNA of mulberry. The results showed that 10 primer pairs namely: ISSR2, ISSR4, ISSR11, ISSR14, ISSR16, SRAP8, SRAP10, SRAP13, SRAP16 and SRAP30 could be used to separate between salt tolerance and none tolerance mulberry varieties. These 10 primers could be developed to specific DNA markers for the directly selection from DNA of salinity tolerance mulberry varieties, which will help to reduce the time of selection and increase the accuracy of the selection without checking the phenotype.

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Keywords: Molecular Marker, Salt tolerant

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ML P 06: Assessment of genetic diversity in *Morus alba L.* growing in China using sequence repeat markers

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Abstract Mulberry is an ecologically and economically important woody plant that is widely distributed in tropical and temperate zones, and is used as a street tree in several areas in South China. Its fruits are nutrient rich, and its leaves, branches, and bark have medicinal values. In this study, to improve future breeding, hybridization, and long-term conservation strategies, 30 simple sequence repeat (SSR) markers were developed to determine the genetic diversity of 221 mulberry plants, from 17 regions across China. A dendrogram was constructed using a similarity matrix among the genotypes, and a principal component analysis (PCA) was performed to further identify and cluster the genotypes. The 30 SSRs detected 304 distinct bands in the 221 samples, among which 302 were polymorphic (99.34%). The polymorphic information content of 17 SSR primers ranged from 0.0128 to 0.2392, with a mean of 0.1117, indicating low diversity. The results of the cluster analysis and PCA were similar. The genotypes of the mulberry trees were found to have a relationship with the content of polyphenols and other extracts, which affect the value of mulberry plants. Additionally, the association between mulberry diseases and their genotypes was also noted. The results show the potential applications of SSRs in studying the association between disease resistance and the extracts of mulberry.

Keywords Mulberry, Genetic diversity, Sequence repeat markers

Section 2

Bombyx mori

BM-LP: Lead Paper

Bombyx mori - the immemorial partner of mankind - ready for the SMART solutions in the Agriculture 4.0

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Bombyx mori is one of the species that has accompanied humankind since ancient times. It has been a loyal partner, who has offered, constantly, optimal solutions for clothing, but also for food and environment or for economic development of the world on the famous and more and more present Silk Road. Not long ago, towards the end of the past century, the main objectives in exploitation of this species were those related to rearing, amelioration and pathology. Throughout several thousands of years, the species has continuously offered humankind opportunities for scientific progress application in biology, physiology, biochemistry, endocrinology, genetics and recently, genetic engineering or biotechnologies. To all these objectives, from an breeding point of view, the *Bombyx mori* species, the star of the classical sericulture, has answered very well and progressively to farmers, as well as to processors or consumers. Progress has been made at biological material quality level – highly varied number of mutations is known, there are genes banks for indigenous breeds or breeds obtained through hybridizations; at rearing level, adapted to population categories or geographical areas with certain climatic characteristics, at global level. The rearing and exploitation systems for silkworms have reached the ability to satisfy the needs of the farmers for classical production and are adapting to the dimensions. Family farms can alternate with highly performant magnaneries included in organic production systems. However, even though it seems that *Bombyx mori*, at a state of art level, offers an insurance policy and a warranty for the progress of sericulture, this must raise up to new challenges and to induce attractiveness and performance characteristic to the new millennium. The opportunities that *Bombyx mori* species are offering to the new era, those of the Agriculture 4.0 with its performances towards future trends of farming, exploitation as bioreactor or for the Pharma-farming of the silkworm must be known by the researchers, as well as the farmers and the consumers. Currently, the *Bombyx mori* species needs to have its value harnessed to its full potential, so it can generate a revolution in sericulture.

Key words: *Bombyx mori*, perspectives, breeding, rearing, agriculture4.0

BM O 01: Utilization of exotic hybrids as genetic resources in south Asian Countries for development of sustainable productive silkworm, *Bombyx mori* L.

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Most of the sericultural countries in Asia and Pacific region are experiencing serious constraints namely, lack of genetic resources and information on simplified breeding techniques. Generally, the breeding material introduced is useful as a source of genes leading to high cocoon yield with superior quality silk. Genetic materials from exotic sources obtained despite of some legal restrictions have contributed much for developing improved hybrids in the past. It has always been rather difficult to obtain promising silkworm genetic material for improved cocoon production by direct contact between silkworm breeders in different countries. Hence, organized programmes of introduction might be desirable at the government level. International Sericultural Commission is supporting member countries of ISC for exchange of genetic resources. It is easy to obtain desirable commercial hybrids from sericulturally advanced countries such as Japan, China, Bulgaria, and Uzbekistan. The inbreds selected from segregating population would tend to be good combiners with other desirable inbreds as parents in crosses for hybrid production. Therefore, inbreds may derived from commercially available high yielding hybrids. There is immediate necessity to exchange genetic resources having desirable traits such as high productivity, high silk quality, tolerant to biotic / abiotic stress etc. between leading sericultural countries following biodiversity regulations governing the donor/recipient countries through Material Transfer Agreement (MTA) or Memorandum of Understanding (MOU). The import/export of genetic resources between bilateral / multilateral treatise would be quite convenient and easy understanding of collaborative research programme. The collaborator could utilize the sericulture research organization such as International Sericultural Commission (ISC) Japan International Cooperation Agency (JICA) Block Caspian Seas and Central Asia Silk Association (BACSA) as a channels for exchange. Besides, exchange of scientific knowledge and breeding techniques, expertise between counter parts could be quite useful through visits of researches from respective countries.

In India utilizing eight Japanese commercial hybrids having desirable qualitative and quantitative traits were chosen as genetic resource material and developed sustainable productive breeds in technical collaboration with Japanese experts under BSTD project assisted by JICA. The selected hybrids recorded above 90% pupation, above 23% cocoon shell percentage and neatness above 93.0%. One single and one double hybrid were selected and are well accepted by the farmers in a big way for commercial rearing. The average cocoon yield for 2 boxes recorded by the farmers was 66.72 kg and 70.0 kg / in single and double hybrid respectively. Most of the countries usually utilize double hybrids (wide genetic base with four parents) than single hybrid for commercial cocoon and raw silk production (3A – 4A grade silk). Of late, Central Silk Board in India has undertaken initiatives at CSRTI Mysore through collaborative projects. (Bulgaria, Japan, China and Uzbekistan) on exchange of genetic resources. The developed breeds and hybrids could be exploited commercially by the farmers of both the countries. The breeds and hybrids with greater adaptability/, higher production and better quality cocoons could be economically exploited by the collaborative countries. The paper delineates the elements required for the international collaboration to develop productive silkworm breeds / hybrids in South Asian Countries through simplified information on silkworm breeding techniques.

Keywords : *Bombyx mori* L. genetic resources, collaboration, double hybrid

BM O 02: Breeding of new silkworm strains for Kenya from Japanese commercial F1 hybrids

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Sericulture is the process of rearing the mulberry silkworm, *Bombyx mori*, to produce silk. The mulberry silkworm originated from China more than 4000 years ago. Later it spread to other areas such as Europe, Japan and India. In Kenya rearing of the silkworm started in 1973 by Japanese International Corporation Agency (JICA). However, much of the work was purely on capacity building and basic silkworm rearing. As a result, the production went down and the industry almost collapsed. In 2014, a feasibility study, Kenya High Technology Silk Project, was carried out to assess the suitability of the Kenyan conditions in the production of silk using hybrid silkworm strains and advanced technology. Therefore, Japanese government agreed to form a partnership with Kenyan government through a SATREPS Project to ensure breeding of better strains for reviving the silk industry in Kenya. Since 2015, two commercial F1 hybrid strains, Kinshu x Showa and Asa·Hi x Tou·Kai were introduced successively from Japan. Starting from these F1 hybrids, we began breeding of new silkworm strains which will express comparable performances to their parent F1 hybrids. Up to the present, six separate lines, KSK1, KSK2, KSK3 and KSK4 from Kinshu x Showa, and ATK1 and ATK2 from Asa·Hi x Tou·Kai, have been reared by selecting cocoons with preferable quantitative and qualitative characteristics. The oldest line, KSK1, (for example) has been reared for as many as 14 generations. Though the rearing results varied/fluctuated because of seasonal fluctuation of mulberry quality, the efficiency of cocoon shell production was found to increase gradually. It is suggested that more rearing be done to obtain a more stable strain that can fit in the Kenyan conditions.

Keywords: Sericulture, silkworm, breeding, cocoon weight, shell weight, shell ratio

BM O 03: Effective utilization studies on the paternal inheritance of diapause inhibiting sex-limited non-diapause breed, HNID of silkworm, *Bombyx mori*.

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ABSTRACT

Diapause is a maternally inherited character and males do not have any role in determining the voltinism of the offspring. However, an exception to this well-established phenomenon was recorded where bivoltine females lay non-hibernating eggs when they are mated with special race, KS-10 males. This kind of paternal influence on diapause has opened up many views on the diapause phenomenon in silkworm *Bombyx mori* L. from the point of view of its expression under tropical conditions. From bivoltine sex-limited race HND a new breed, HNID has been developed at this institute. This is probably the rare polyvoltine diapause inhibiting sex-limited race in the sericulture industry in India. Hence, crossing experiments were conducted to study the rearing performance of the hybrids namely, BRO-2 X HNID, NK-2 X HNID and (BRO-2 X NK-2) X HNID. The data on the traits like fecundity, hatching percentage, larval duration, larval weight, yield/10,000 by number, yield/10,000 by weight, single cocoon weight, single shell weight, cocoon shell ratio and pupation rate was collected. The rearing data was statistically analyzed and discussed in this paper.

Key words: Diapause inhibiting character, HNID, KS-10, Polyvoltine, Sex-limited breed.

BM O 04: USING THE WILD SILK MOTH BOMBYX MANDARINA MOORE IN MULBERRY SILKWORM, BOMBYX MORI L. BREEDING IN BULGARIA

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ABSTRACT

A cross between females of wild silkworm *Bombyx mandarina* and males of the Bulgarian highly productive Japanese type pure breed Vratsa 35 was made. The F₁ hybrid was characterized by larvae having the wild silkworm markings, yellow-green cocoon color and oblong cocoon shape. The F₁ cross had significantly lower values of the fresh cocoon weight, silk shell weight and shell ration characters, compared with the pure breed Vratsa 35.

Selected individuals of the F₁ hybrid *Bombyx mandarina* x Vratsa 35 were crossed with the pure Bulgarian breeds Vratsa 35 and VB 1 of Japanese type and Merefa 2 of Chinese type, following a breeding program, conducted during the period 2013 - 2019. The aims of the breeding work were to create three new populations, characterized by larval markings, similar to *Bombyx mandarina*, white cocoon color and nature of grains like in the uni-bivoltine breeds, two of them with oblong cocoon shape and one with oval cocoons, and with comparatively high productivity.

Three new silkworm populations, MND 1, MND 2 and MND 35 were created and tested in 2018 – 2019. It was detected that the silkworm egg hatchability in the newly bred populations was very high and not significantly different from those in the Bulgarian pure breeds, used in the selection process. The pupation rate in all the three new populations was significantly higher than in the Bulgarian breeds. The fresh cocoon weight and silk shell weight character values in the new populations were comparatively high – from 2044 mg to 2149 mg and from 404 mg to 459 mg respectively. The new populations MND 1 and MND 35 fresh cocoon weight and silk shell weight were not significantly different from those in the pure breeds VB 1 and Vratsa 35, while the new population MND 2 manifested significantly lower values of the both characters, compared with the pure breed Merefa 2. The silk shell ratio in the new populations varied from 19.77 % to 21.79 % and was not significantly different compared with the pure Bulgarian breeds.

The silk filament length in the new populations was from 1067 to 1097 m, the reeliability was from 94.96 % to 97.30 % and the raw silk percentage was from 36.55 % to 40.42 %, thus within the normal values, typical for the uni-bivoltine silkworm breeds, reared in Bulgaria.

The newly bred populations have larval markings, very similar to those of the wild silkworm *Bombyx mandarina*, white cocoon color and nature of grains, typical for the uni-bivoltine silkworm breeds. The new populations may be further tested as parents of F₁ commercial hybrids.

Keywords: Wild silk moth, *Bombyx mandarina*, silkworm, *Bombyx mori* L., breeding

BM O 05: Quantification of 20-Hydroxyecdysone titer in the non-spinning larvae of silkworm *Bombyx mori* L.

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ABSTRACT

Cocoon spinning and pupation are instinctive physiological traits of silkworm *Bombyx mori*. Like all living organisms silkworm respond to stressful changes of the environment in strikingly various ways, both at the cell level and the level of the organism. The neurohormones are the master regulators of all life processes in insects and in some cases the same neurohormonal signal has different effects on insects, depending on the which stage of life cycle the insect is in and on the duration and type of the stressor effect. The silkworm developmental trajectory is co-ordinated primarily by two hormones; 20-Hydroxyecdysone (moultling hormone) and Juvenile hormone (JH). Various pathological, physiological, nutritional, environmental reasons and genetic abnormalities can be attributed for the occurrence of non-spinning silkworms. In the physiological prospective, the non-spinning behavior of silkworms has necessitated the quantification of 20-HE titer in both control and affected batches. During the present study, it was aimed to investigate the 20-Hydroxyecdysone titer in the hemolymph of non-spinning larvae of *Bombyx mori* by using High Profile Liquid chromatography (HPLC). It was observed that the ecdysone titer of 10th day non-spun larvae exhibited the peak at 11.614 minutes with ecdysone titer of 0.017 ug/ul of hemolymph, when compared to control which exhibited the peak at 11.964 minutes with ecdysone titer of 0.209 ug/ul of hemolymph. It is opined that the ecdysone titer in the non-spinning larvae is lesser than the critical value which elicits the initiation of moultling/maturation. The titer of 20-Hydroxyecdysone in the hemolymph and its biochemical influence on non-spinning behavior of silkworm are discussed in the paper.

Key Words: Silkworm, *Bombyx*, Ecdysone, Moultling, Non-spinning

BM O 06: Nutritional Composition of Wild and Cultivated Mulberry Varieties in Egypt and their impact on Silkworm *Bombyx mori* L. (*Bombycidae: Lepidoptera*)

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Abstract: Two mulberry varieties, the cultivated variety, *Morus alba* var. Morittiana and the wild variety, *M. laevigata*, grafted on *M. alba* were investigated to assess the effect of their nutritional components on larval haemolymph biochemical constituents, the protein profiles and economic traits of silkworm, *Bombyx mori* L. Results indicated that there were significant differences ($p \leq 0.05$) between the two tested mulberry varieties leaves in their nutritional composition and larvae biochemical analysis. Results also showed some differences in the number and abundance of protein bands in the two studied mulberry variety leaves as they were 5 bands in *Morus alba* var. Morittiana ranged between (47.27-344.47 kDa), while, were 10 bands in *Morus laevigata* leaves ranged between (17.79-350.11 kDa). However there were close similarity in haemolymph and silkgland protein patterns of larvae fed on the both studied mulberry varieties. There were no significant differences between male full grown larvae fed on both mulberry varieties, while female full grown larvae weights were significantly high in larvae fed on *M. laevigata* leaves. No significant differences were found between cocoon incidences produced from larvae fed on the both mulberry varieties.

Keywords: *Bombyx mori*, mulberry varieties, protein patterns, biochemical study

BM O 07: The effect of selenium on the supramolecular structure and thermal characteristics of fibroin *Bombyx mori* L

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Annotation: The enrichment of selenium atoms with the molecular structure of SF led to an increase in the branching of fibroin macromolecules. As a result, the amorphous fraction of fibroin microfibrils increases which leads to an increase in the strength characteristics of the silk thread. At the same time, such a change in the supramolecular structure of fibroin involving selenium atoms gave us the opportunity to study the two-modification mechanism of crystallization of fibroin microfibrils. Based on studies on the use of temperature-gravimetric and X-ray diffraction (XRD) analysis and relative changes in the proportion of amorphous and crystalline regions, we came to the conclusion that fibroin microfibrils consist mainly of extended crystallites CSC - crystallites with the stretched chains. They alternate along the axis of microfibrils with amorphous layers, the sizes of which are smaller than the sizes of the folded crystallites (CFC). Therefore, CFC - crystallites with folded chains cannot be located in amorphous layers between the CSC along the microfibril axis. This suggests that the formation of fibroin fiber first forms the central core of crystallites with the stretched chains (CSC). When atoms of selenium are introduced into the fibroin structure, new side branches form in the macromolecules which cannot enter the crystal lattice at all. As a result, the ability to fold decreases, and (due to a decrease in the number of CFCs) the proportion of amorphous portions of fibroin microfibrils increases.

In this model, on the sides, the non-crystallized segments of the molecules that are attached to the central core restore their folded structure (CFC - in the form of folds of plate crystallites). The crystallization of such segments of fibroin macromolecules occurs in the form of CFC and with such designs microfibrils of fibroin take the form of a “microshish-kebab”.

Keywords: formation of silk I, formation of silk II, effect of selenium, supramolecular structure, crystalline, amorphous, sections of fibroin microfibrils, DTA method, TGA method, DTGA curves, formation of two modifications, crystallites with the stretched chains, crystallites with the folded chains, X-ray diffraction studies of fibroin, model of fibroin microfibrils, “microshish-kebab”

BM O 08: HETEROsis AND COMBINING ABILITY ESTIMATION IN BIVOLTINE×BIVOLTINE HYBRIDS OF SILKWORM, *BOMBYX MORI* L.

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Abstract

Qualitative and quantitative cocoon productions of bivoltine×bivoltine hybrids are better than multivoltine×bivoltine hybrids in specific favourable season of tropical and subtropical region. To find out the best combiners for the preparation of bivoltine hybrids, heterosis and combining ability have been estimated through a line×tester analysis for four economic parameters viz. single cocoon weight, single shell weight, SR% and cocoon yield/100dfls in silkworm, *Bombyx mori* L. in favourable post winter commercial silkworm rearing season, Chaita (February-March) in Bangladesh. Different crosses showing heterosis was not consistent over characters. The estimates of δ^2_{gca} and δ^2_{sca} and their ratio revealed the predominant role of non-additive types of gene action and the preponderance of additive gene action. The variety BSRB-06(2) was the best general combiner for all the characters. Considering high magnitude of heterosis, general and specific combining ability, the best cross was BSRB-04(1)×BSRB-06(2) which may be recommended after field trial for the exploitation of heterosis in Chaita silkworm rearing season in Bangladesh.

Key Words: *Bombyx mori* L., bivoltine hybrids, combining ability, heterosis, line×tester.

BM O 09: Genetic diversity, population structure and key phenotypic traits driving variation in Silkworm (*Bombyx mori* L) genotypes of India

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The success of breeding is depends on the variability available in the population and genetically variable populations are expected to evolve morphological, physiological or behavioural mechanisms to cope with the novel conditions. In order to access the reservoir of favourable alleles within germplasm, knowledge about the genetic diversity and the population structure is needed. In this study, 100 silkworm genotypes were genotyped with 20 SSR markers and concurrently evaluated for nine quantitative and five qualitative traits. Twenty SSR markers were polymorphic with mean allele number of 4.3, polymorphic information content (PIC) of 0.47 and gene diversity of 0.51. Molecular analysis based on unweighted paired group arithmetic mean (UPGMA) clustering and principal coordinate analysis (PCoA) was similar in explaining the extent of diversity within the genotypes. Structure analysis placed most of the accessions into the five subpopulations with 16.5% as admixtures. Principal component analysis (PCA) based on phenotypic traits (PC1 and PC2) revealed first two components (PC1 and PC2) accounted for the variation of 75.5% of which PC1 alone explains 61.3% of the total variation. The dendrogram based on the hierarchical cluster of the quantitative traits revealed 8 distinct groups Group II exclusively represented 3 silkworm accessions [Sarupat, M12 (W) and Nistari] which are having higher NPV and thermo tolerance and survival rate. Both UPGMA clustering-based SSR data and PCA from phenotypic data showed similar results. The assembled germplasm is genetically diverse with high variation in pupation rate , thermotolerance, Cocoon weight, Shell weight, Shell%, and key yield components which could be exploited in developing superior genotypes for tropical conditions of India.

Keywords: Silkworm Genotypes, Genetic Diversity, Quantitative traits, SSR marker

BM O 10: Evolution of Practical Silkworm Varieties Adopted in Main Sericulture Regions in China

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Abstract

China is the major cocoon producer, the production of mulberry silkworm cocoon accounts for about 75% of the world cocoon production at present. Chinese silkworm breeders have been trying to breed new silkworm varieties with different characteristics so as to meet the requirements of silkworm farmers in different regions with varied rearing techniques, climate conditions, rearing facilities, and raw silk quality. It is well known that breeding good silkworm varieties are the most economical and effective means to increase cocoon production and improve silk quality. As early as the second half of the 20th century, silkworm varieties were replaced almost every 10 years in key silkworm areas in China. However, in the 2000's, although new silkworm varieties with different characteristics were continuously developed and promoted, for example: newly released varieties such as NPV resistant "Huakang No 1-3", only male silkworm "Qiuhua × Ping30", pathogenesis silkworm "Zhefeng No, 2", gold yellow cocoon "Jinqiu × Churi" and etc., however, the major change of practical silkworm varieties was not obvious as last century. The most obvious examples are: the hybrid Jingsong × Haoyue with high cocoon yield and excellent silk quality, bred by the Silkworm Institute of the Chinese Academy of Agricultural Sciences, has been formally popularized after being approved by the National Mulberry Variety Examination and Approval Committee in 1982. After 38 years, it is still the national major silkworm hybrid raised in the spring season. Another example is the healthy silkworm variety "932. Furong × 7532. Xianghui (also named as Liangguang No. 2)" for summer and autumn silkworm rearing season, was certified by the National Crop Variety Examination Committee in 1995, and it is still the most popular hybrid used in the regions and seasons relatively poor rearing facilities and techniques, or unfavorable climate and environmental condition over the 26 years. According to the survey in 2015, the annual rearing amount of this silkworm variety in China had reached 8.02 million boxes, which accounted for 50.8% of the total rearing amount in the whole year in China. The above mentioned two pairs of silkworm varieties are expected to be continually used for a considerable period in the future. To show a brief picture of the silkworm varieties popularized and applied in the top eight sericulture regions of China, the relevant data are arranged in table 1. Table 1 shows the ranking of top eight provinces in cocoon production, and the major silkworm hybrids adopted in that provinces. In each check, the first line is the province name and followed by silkworm variety name. It also shows that the important sericultural regions were shifted from south-east China such as Zhejiang and Jiangsu provinces to South-west China, such as Guangxi and Yunnan Provinces.

BM O 11: ROLE OF COMMERCIAL YOUNG INSTAR SILKWORM REARING IN THE GROWTH OF BIVOLTINE SERICULTURE IN SOUTHERN INDIA

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India has traditionally been a cross breed sericulture country and more so, the southern States. A decade ago, the share of bivoltine sericulture was only 10% which grew at quite a faster pace to reach 28 % of the total share, presently. Ninety per cent of India's bivoltine raw silk production is contributed by the southern region including the state of Maharashtra. Higher probability of crop loss in comparison with the cross breeds and lack of incentives to commensurate with the elevated risk level were some of the reasons for poor bivoltine adoption. Efforts by National Silkworm Seed Organization (NSSO), the seed production arm of Central Silk Board, comprising of certain perceived benefits such as increase in the crop cycles at the farmers' level and consistency in crop success with reduced labour consumption helped not only in popularizing the commercial chawki rearing as a viable business enterprise, but also increased the bivoltine seed off take. Initial discount on the price of bivoltine hybrid dfls by NSSO coupled with Government's seed sector reforms played significant role in popularizing bivoltines. The enterprise package developed ensured taking up 32 crop cycles per year by a CRC entrepreneur with a minimum of 2 acre mulberry garden. The total chawki rearing a year thus reaches 3200 boxes of dfls. With an investment of INR 2.44 million, a revenue of INR 40 million is assured by selling the chawki larvae at a base price of INR. 1250 per box leading to a net profit of INR 1.56 million. This works out to a cost benefit ratio of 1:1.64. The impact studies showed average bivoltine cocoon productivity jumping to 33 kg/box from 28 kg /box during the past five years. This also resulted in increase in consumption of bivoltine hybrid seed at an annual rate of 24.38 % and ultimately leading to growth of bivoltine raw silk production at a compounded annual growth rate (CAGR) of 14.5 %. The prospects of further growth of bivoltine sericulture spurred by CRCs in India is discussed in the light of possible challenges ahead.

Key words: Bivoltine raw silk, chawki rearing, hybrid seed, silkworm, productivity.

BM O 12: STRATEGIES ADOPTED TO IMPROVE BIVOLTINE SILKWORM HYBRID SEED PRODUCTION AND PRODUCTIVITY TO MATCH THE RAW SILK PRODUCTION TRAJECTORY OF INDIA

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National Silkworm Seed Organization (NSSO), the mulberry silkworm seed production arm of Central Silk Board, India has a coveted place in Indian Sericulture. NSSO has been producing close to 80 % of the total bivoltine silkworm hybrid seed India need (14.2 million disease free layings (dfls) during 2012-13 to 40.67 million dfls during 2018-19, at an annual growth rate of 16.21%) and selling it consistently to its satisfied customers. India as a silk producing country has aimed at bringing down the import of bivoltine raw silk in the next two years and at becoming self reliant with the import-substitute high quality bivoltine raw silk. The country aims to produce 20000 MT of bivoltine raw silk by the year 2030 and has drawn ambitious and elaborate plans to expand the mulberry plantations horizontally apart from concentrating on the linear growth of productivity if not faster, to cope up with this projected growth trajectory. NSSO would remain highly relevant in this scenario by remaining in the leadership position by bolstering its strategies as follows: 1) The organization would strictly comply with the maintenance procedure of silkworm pure races and one way multiplication of basic seed leading to supply 563 gold standard Parent 3 (P3) dfls, 49300 Parent 2 (P2) dfls and 4.7 million P1 dfls to produce a total of 280 million commercial (5.6 million boxes) dfls, 2) NSSO would contribute in excess of 40 million (800 000 boxes) of in-house production of high quality bivoltine hybrid seed, 3) linkage of progressive silkworm seed rearers with seed production following quality linked pricing, 4) encouragement of commercial level young age silkworm rearing and 5) upholding brand strength and development of private players in bivoltine silkworm seed production. Following the above listed strategies, NSSO is confident of maintaining the in-house production efficiency and dissemination of techniques to the peers in public and private sectors. The paper deals with the prospects of NSSO going forward maintaining its leadership positions and the key challenges it would face in the process.

Key words: Bivoltine raw silk, chawki rearing, growth trajectory, hybrid seed, silkworm, productivity.

BM O 13: Targeting the late expression factor (*lef-1*) gene for inducing virus resistance against NPV in *Bombyx mori* by RNA interference technology

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RNA interference (RNAi) is a promising gene regulatory approach in functional genomics that has significant impact on crop improvement which permits post transcriptional gene silencing (PTGS) triggered by double stranded RNA (dsRNA) molecules, to prevent the expression of specific genes without affecting the expression of other genes. *Bombyx mori* L. (Lepidoptera: Bombycidae) nucleo polyhedrosis virus (BmNPV) is a highly pathogenic virus encountered in the sericultural industry, often causing severe damage for cocoon production in tropical countries. Effective management of the virus has been a challenge because of its sturdy nature and the lack of control strategies. RNA mediated silencing technology (RNAi) has become the tool of choice for induction of virus resistance in all the organisms. A significant feature of this technology is the presence of double stranded RNA (dsRNA), which is not only the product of RNA silencing but also the potent triggers of RNA interference (RNAi). In this study, *E. coli* are engineered to produce dsRNA of the cloned genes from a plasmid (L4440) containing gene of interest under the control of double T7 promoter which efficiently produces dsRNA once it is transformed into *E.coli* HT115 host strain and upon induction with IPTG. Our study targeted the BmNPV late expression factor-1 (*lef-1*) gene because of its association with the DNA primase involved viral DNA multiplication. The quantitative real-time analysis of the genomic DNA using Gp41 revealed relative high copy numbers of approximately 1×10^5 copies at 48h pi in the NPV infected and in the NPV+L4440 treated silk-worms. In contrast, the viral proliferation rate was significantly low in the larval mid-gut of the dsRNA lef-1fed infected larva, with the relative copy numbers remaining below 100 copies until 48 hpi. The RT-PCR analysis of viral genes revealed that larva fed with 30 μ g of *E.coli* expressing *lef-1* dsRNA showed significant ($p < 0.05$) reduction in the expression of target genes involved in the BmNPV multiplication ie., there was approximately 6-fold decrease in the *lefs* gene expression in dsRNA fed infected silk-worms compared to infected silkworms and showed increased survivability upto 50% of infected silkworms. Therefore, the results are clearly evident that the relative decrease in the expression of the late genes especially Lef-1, Lef-3 and Gp41 may be attributed to the effect of RNAi induced by lef-1 dsRNA on the late genes. These results demonstrate the successful use of *E.coli* expressing dsRNA as an efficient and alternative tool for insect pest management.

Key words: Bacterial dsRNA, BmNPV, late expression factors, RNA interference, Quantitative PCR, Viral copy number.

BM O 14: Identification of mulberry host plant volatiles to stimulate egg laying in bivoltine hybrid of *Bombyx mori* L.: Development of a synthetic blend

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ABSTRACT

Silk moth (*Bombyx mori*, L) lays 400-600 eggs depending upon the breed and environmental conditions. Some of the moths retain the eggs inside the body and fail to lay them fully. As a result there is egg retention to the tune of 5-15% based on seasonal variation. To enable the release of eggs completely from the ovarioles and to stimulate the egg laying from the moths, used the mulberry volatile blends for releasing eggs completely and to enhance the egg laying. Suitable oviposition enhancers in the form of external stimuli certainly help to increase egg laying number in the individual moth and also egg recovery. The current study has been targeted towards silk moths by making use of host plant volatiles and its synthetic blends to instigate oviposition in them. Natural Volatiles were extracted from 11 Mulberry varieties (host plant) and its influence on the egg laying of FC1 x FC2 hybrid was studied. Chemical analysis was carried through GC-EAD and GC-MS identified chemical compounds that elicited antennal response in moths. Various synthetic chemical blends were prepared based on GC-EAD response and evaluated, standardized based on the egg laying and egg retention of bivoltine hybrids (FC1 x FC2) for loose egg production. The standardized blend *Arka Bieggstra* enhanced loose eggs by weight 10.589g per kg of cocoons. A total of 30 dfl were obtained additionally per kg of cocoons over control. The *Arka Bieggstra*, an identified chemical blend has performed ably for enhancing the egg laying in Bivoltine hybrids. These results will be further evaluated in large scale in collaboration with National Silkworm Seed Organization (NSSO) for further commercialization of this synthetic oviposition stimulant at Silkworm Seed Production Centres (SSPC's) for enhanced egg production.

Key words: Mulberry plant volatiles, Bivoltine hybrid, Egg laying, Egg retention, GCMS, GC-EAD and Synthetic Chemical Blend.

BM O 15: Prototyping Construction of Geothermal Silkworm Rearing House for enhancing productivity in Mulberry Sericulture

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Abstract:

Maharashtra province of India has emerged highly potential state for silk production during last one decade. Many modern technologies have been adopted by the farmers which have resulted in increase in quality and quantity of silk production. Among various technologies, construction of ideal silkworm rearing house is one of the most important aspects for successful silkworm rearing. It is observed that the farmers of Maharashtra have constructed silkworm rearing houses with large variability in design, construction materials, etc., hence , it is a high time to study different structures of rearing house available and alteration, modification is must for enhancement in silk production. It was felt that intervention of civil engineers is essential in planning, designing and construction of ideal silkworm rearing house. A study was conducted in three districts of Western Maharashtra during the period August -2018 to March-2019 to know present status of rearing house, designs, materials used for construction, durability of structures, construction cost and various other parameters for rearing of mulberry silkworm *Bombyx mori* L. The data was collected from sericulture farmers by personal visits and interaction at their sites. It was found that only 12.5 percent farmers were found with modern amenities for silkworm rearing. About 25 percent were with medium level structures whereas 62.5 percent of the farmers constructed low cost rearing house without scientific foundation. The development and installation of the geothermal ventilation system found useful to achieve cool and warm impact with required environment for .silkworm rearing. The geothermal ventilation system prototype and actual installation was carried out .The silkworm rearing results in geothermal ventilation system shows encouraging results as far as productivity and quality of cocoons is concerned. Hence, it can concluded that installation of geothermal ventilation system is easy and cost effective, useful found effective to maintain conduce internal environment in silkworm rearing as well as to boost productivity in sericulture .

Keywords: Silkworm, Rearing house, geothermal ventilation system.

BM O 16: INTERACTION EFFECT OF *LYSINIBACILLUS SPHAERICUS* WITH PATHOGENIC MIBROBES ON REARING AND COCOON PARAMETERS OF SILKWORM, *Bombyx mori* L.

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Abstract

Silkworm (*Bombyx mori*) is one of the beneficial and fascinating insect which has its own potential to produce silk naturally. The silkworms are very sensitive to altered micro-environment in the bed and microbial load of different species of bacteria, viruses in rearing house which inturn cause diseases and reduces cocoon crop loss. The survey was under taken to collect diseased silkworm (*BmNPV*) during 2014 -2016 in Chikkaballapur and Kolar districts of Karnataka. Further, among several bacterial isolates only three common isolates identified as *Lysinibacillus sphaericus* (L), *Alcaligenes faecalis* (A), *Bacillus subtilis* (B) and studied per oral inoculation of pathogenic bacterium *Lysinibacillus sphaericus* along with viz., *Alcaligenes faecalis* (A), *Bacillus subtilis* (B) and NPV (N) to third instar PM×CSR₂ (50 silkworms/ replication) revealed significant reduction in rearing and cocoon parameters which resulted minimum of 7.87 and 9.85 days for ET₅₀ for symptom expression and mortality in treatment T₆- *Lysinibacillus sphaericus* + *Alcaligenes faecalis* +NPV (T₆). Further, number of larvae entered to fourth instar was noticed minimum in T₆-*Lysinibacillus sphaericus* + *Alcaligenes faecalis* + NPV (30) and maximum in T₂-*Lysinibacillus sphaericus* + *Alcaligenes faecalis* (44). The less number of worms entered to spinning (30.04 %) and low per cent ERR (19.71%) was noticed in T₆. In addition to rearing parameters, cocoon parameters viz., single cocoon weight (1.00 g), shell weight (0.08 g), shell ratio (8.00) and silk productivity (0.69 cg/ day) was noticed minimum in treatment T₆. The interaction effect of *Lysinibacillus sphaericus* with other pathogenic bacteria and virus viz., *Bacillus subtilis*, *Alcaligenes faecalis* and NPV had synergistic effect compared to *Lysinibacillus sphaericus* alone.

Key words: Interaction effect, *Bombyx mori* , Rearing and cocoon parameters

BM O 17: Development of Productive Multi-Viral Disease Tolerant Bivoltine Breeds

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Bombyx mori Densonucleosis virus (BmDNV1), *Bombyx mori Infectious flacherie virus* (BmIFV) and *Bombyx mori nuclear polyhedrosis virus* (BmNPV) are the primary viral pathogens that infect silkworm and causes huge crop loss in sericulture. The main objective of this work is to develop productive bivoltine breeds/hybrids tolerant/resistant to the three viral infections through conventional and molecular marker-assisted breeding. 120 bivoltine silkworm breeds from different geographical origin of India were reared and inoculated individually with BmDNV1, BmNPV and BmIFV inoculums at 10^{-2} , 2×10^6 , 10^{-2} respectively, immediately after second moult. Tolerant/resistant populations were recorded for percentage survivability. The tolerant/resistant breeds were selected through directional selection and molecular assisted markers (SSR-S0803-R). The tolerant breeds expressed a 216bp amplicon, which was sequenced and it represented identity with silkworm microsatellites located on chromosome 8. The primer blast search for S0803-R had the identity with isocitrate dehydrogenase mRNA as the target template. Thus, marker-S0803-R could be used in breeding programs involved in development of viral diseases resistant/tolerance. The potential characteristics with respect to pre and post cocoon properties were also analyzed. Based on the results, few promising bivoltine breeds (Oval and Dumbbell) were short-listed for pyramiding tolerant genes and developing productive multi-viral tolerant/ resistant breeds/hybrids.

Keywords: *Bombyx mori*, Densonucleosis virus, Infectious flacherie virus, Nuclear polyhedrosis virus, marker-assisted breeding

BM O 18: Effect of age, size, and mating combinations in *Trichomalopsis uziae*, an ecto-pupal parasitoid of the tachinid (uzi) fly, *Exorista bombycis*, on its reproductive performance

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ABSTRACT

The tachinid (uzi) fly, *Exorista bombycis* (Louis) (Diptera: Tachinidae), is a major pest of the silkworm, *Bombyx mori* L., which inflicts a cocoon yield loss of 15-20% in the traditional sericultural regions of south India. Recently, a new parasitoid, *Trichomalopsis uziae* Sureshan & Narendra Kumar (Hymenoptera: Pteromalidae), has been reported to parasitize the puparia of this fly pest. Preliminary studies have indicated that the parasitoid possesses immense potential to serve as a bio-control agent of *E. bombycis*. As such, it is contemplated to exploit the parasitoid for the management of *E. bombycis*. Before doing so, it becomes imminent to generate information on various aspects of the parasitoid. In this regard, attempts have been made in the present laboratory investigation to understand the impact of age and size of the parasitoid in addition to mating combinations on its reproductive performance when the pupae of *E. bombycis* were offered.

The results revealed that age of the parasitoid female had an influence on rate of parasitism, brood allocation, progeny production, and sex ratio that decreased with increase in parasitoid age from zero to 10 days. With regard to parasitoid female size, bigger females showed significantly superior reproductive efficiency when compared with smaller females. In size-related mating combinations, all the reproductive parameters under consideration were significantly greater with bigger females irrespective of the size of males they mated with. Among sib, conspecific, and random mating combinations, the latter led to substantially superior reproductive performance. The findings of the investigation have been discussed to explore the possibilities of undertaking the mass production of *T. uziae* on *E. bombycis*.

Key words: Bio-control agent, brood allocation, *Exorista bombycis*, parasitism, progeny production, *Trichomalopsis uziae*

**BM O 19: Technology to increase egg laying/egg farming in silk moth,
Bombyx mori L. (Lepidoptera: Bombycidae)**

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Improving or increasing egg-laying ability of silkmotth, *Bombyx mori*, is one of the major objectives of sericulture programs around the world. Increasing egg production of silkmoth with exogenous stimuli may increase cocoon production, there by silk. Egg-laying by silkworm is a decisive factor associated with the commercial silk production and grainage. Lepidopterans are evoked by specific host plant cues that are recognized by gravid female moths during oviposition. Previous studies on egg-laying behaviour of lepidopterans have cited host plant fractions as critical cues during host search and oviposition. Here, using novel behavioral bioassays, we demonstrate that specific host plant fractions of silkmoth serve as potential ‘oviposition augmenters’. Gravid moths exposed to treatments of different fractions positioned significantly ($P = 0.05$) more eggs, with increased hatchability and reduced egg retention. These fractions further formulated in to a patented synthetic blend *Arka Eggstra®* and evaluated in National Silkworm Seed Organization (NSSO), India we presume are commercially viable and can be used to enhance egg production in silkmotths, thereby serving as a boon to the sericulture industry.

Key Words: Mulberry silk moth, oviposition stimulant, commercial grinage, synthetic blend

BM O 20: Chawki Rearing Centre: an effective tool for technology dissemination in sericulture

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Abstract

Sericulture is a highly remunerative labor oriented activity positively favoring the rural mass especially poor because of its relatively low requirement of fixed capital and long term returns on investment with shorter gestation period. In order to maintain the higher profit margin of the occupation, many cost effectives technologies have been developed and transfer of these new interventions to the field has helped in transforming the sericulture industry from its traditional sustenance status and cultural bondage to a commercial venture. The extension experts have come out with many new methods for effective transfer of these technologies to the field. However, it is always true that there is a large gap exists between lab to land because of certain inadequacies in translation and adoption of the technologies in the field. Silkworm rearing during young age (Chawki) demand specific conditions for optimal growth and performance. Meeting such conditions is not possible by the majority of the farmers due to marginal land holding, socio economic conditions and work pressure due to continuous engagement in the rearing activity. Of late most of the rearers depend on chawki rearing centers (CRC) where, silkworms are reared under specified controlled conditions up to 2nd age and distributed to rearers. CRC system has become an integral component in intensive sericulture belts and creates an opportunity for different groups of the sector to meet each other for exchange of views. Considering the advantages of CRC system where the congregation of rearers and input dealers takes place for collection of chawki and product promotion respectively, an attempt was made to transfer the technologies through establishing a link between Institute, Department of sericulture and the rearers by supplying quality chawki worms along with other technology based products for up-grading technological skills of the farmers. The attempts made to transfer new interventions using CRC as nodal point in new sericulture areas of Karnataka resulted in improved economic returns per unit area of land with higher cocoon production. The paper discusses the role of CRC in technology dissemination and its impact on cocoon production.

Key words: Chawki, CRC, Technology dissemination, Input dealers

BM P 01: *Bombyx mori* L. Cocoons Synchronization upon Treatment with *Spinacia oleracea*

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Abstract:

One of the biggest problems encountered during silkworm rearing is the non-uniform larval maturation and synchronization of cocooning process at one time, which negatively affect the net cocoon production. The study was an attempt to use *Spinacia oleracea* (Spinach) as a source of phytoecdysteroid. Spinach can biosynthesize polypodine B and 20-hydroxyecdysone, which is the predominant insect - molting hormone.

Mulberry leaves were dipped in two different concentrations of the aqueous extract of plant leaves (0.5 % and 1 %) and offered to larvae during different time periods of the fifth instar (24 hrs after 4th moult, 72, 120, 168 and every 48 hrs). The larval maturation events, cocooning process, as well as biological and economical characters for all tested larval groups were studied and compared the results with controls.

The results showed that, the larval group fed every 48 hrs with treated mulberry leaves matured faster than all the other tested larval groups and succeeded in spinning cocoons by 80 % for both concentrations, whereas in control groups the cocoons ratio did not exceed 42 % at the same time. The effective rate of rearing was increased in almost all tested larval groups, compared to controls. The 72 hrs larval group showed the best cocoon characters.

It may be concluded that, *Spinacia oleracea* leaf aqueous extract is able to hasten the larval maturation events and synchronize cocooning process when applied during the final larval instar. The labour, the rearing time and mulberry can be saved and Spinach is a cheaper source for commercial application in sericulture.

Key words: *Bombyx mori* , phytoecdysteroid , *Spinacia oleracea* (Spinach), cocooning process, biological and economical characters.

BM P 02: ARTIFICIAL DIET OF SILKWORMS (*BOMBYX MORI*) IMPROVED WITH BEEPOLLEN - BIOTECHNOLOGICAL APPROCH IN GCEARS-PSP

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Abstract

Global Centre of Excellence for Advanced Research in Sericulture and Promotion of Silk Production (GCEARS-PSP), recognised by the International Sericultural Commission is an important organisation for Romanian sericulture; the main aim of the centre is the revival of Romanian sericulture, the maintenance of Bombyx mori gene pool and the development of research themes in this domain. It functions in the University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Romania; the moderate continental climate of the Transylvanian highlands in Romania makes the year-round production of mulberry leaves impossible. This is especially problematic for the rearing of silkworms all over the year and consequently for the production of silk.

A dietary substituent for the mulberry leaves is therefore needed, which is usually made up of dehydrated and powdered mulberry leaves. Although sufficient for the rearing of silk worms, this alternative food source has proven to be far too expensive to be used in large scale production. We herein tried to develop an alternative food recipe by including different concentrations of beepollen (a great source of protein), to the conventional artificial diet recipe and measure its impact on the growth of the silkworms and the production of silk.

The silkworms' breeds and hybrids are positively influenced by the presence of beepollen. This pollen recipe could be a potent food source for the silkworm's biological parameters (larvae length, larvae weight and the middle part of sericogene gland) and the artificial diet is a valuable method for obtain Bombyx mori eggs, larvae, chrysalis or moths for biotechnological determinations developed in GCEARS-PSP.

Key words: silkworms, artificial diet, biological parameters, biotechnologies, GCEARS-PSP

BM P 03: Cryopreservation of *Bombyx mori* and other wild silkworms using frozen gonads

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Suitable techniques are required for the long-term and safe preservation of silkworm strains. A technique for obtaining eggs from cryopreserved ovaries has been successfully established for *Bombyx mori* (Banno et al., 2013), whereby immature ovaries are extracted from larvae and stored frozen in liquid nitrogen, following which they can be thawed and transplanted into other castrated larvae. However, cryopreservation of the testes using the same method has shown very low efficiency compared to that of the ovaries. To examine the suitability of this technique in other wild silkworm species, we applied it to *B. mandarina*, *Trilocha varians*, *Samia cynthia ricini*, *S. cynthia pryeri*, *Antheraea pernyi*, and *A. yamamai*. We confirmed sufficient egg formation following frozen ovary transplantation in all species except *A. yamamai*. By contrast, frozen testis transplantation only resulted in the emergence of fertile moths in *S. cynthia ricini* and *S. cynthia pryeri*, with much higher numbers for the former, and no development of the transplanted frozen testes was observed in *T. varians*.

These findings confirmed that the gonad cryopreservation method that was developed in *B. mori* can be applied to other wild silkworm species, with the transplantation of frozen ovaries resulting in sufficient egg formation, although slight differences were observed among silkworm strains and species. However, there were large differences in the success of transplanting frozen testes among the silkworm strains and species, some of which had a high proportion of fertile moths emerging from the testis-transplanted larvae. However, the majority of species were less efficient, indicating the need for further testing.

BM P 04:

This Presentation was incorrectly Assigned by
Organizing Committee

BM P 05: Improvement of Pure Mysore race for productivity and silk quality by directional selection

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Pure Mysore (PM) race is the most popular indigenous polyvoltine silkworm race among the farmers of south India. Pure Mysore race is known for low shell weight, high floss percentage, low neatness, filament size variation, low tenacity and less elongation. Attempt was made to improve the Pure Mysore race for productivity and silk quality, directional selection method was applied for maximizing the fecundity, cocoon weight, shell weight, filament length and neatness etc. To improve the said traits, 20 dfls from each source *viz*, DOS Karnataka, NSSO CSB and CSRTI Mysore were collected and reared. Cocoons were selected from each source with higher cocoon weight for female and males with higher shell weight. The same were reared for three generations and directional selection was applied to improve above said parameters. In the subsequent generation mono-cocoon cold reeling was employed to select cocoons with higher filament length. Based on filament length of female and male cocoons, the pupae were collected and the sub lines were categorized as PM-1 to PM-5. The same was repeated over generations and the lines were stabilized

The Average Evaluation Index (AEI) was calculated for the rearing and post cocoon parameters along with the controls of the respective source. The rearing parameters included fecundity, ERR/10000 larvae, cocoon weight, shell weight & shell ratio. The AEI values were, PM-(1) 47.07, PM-(2) 52.11, PM-(3) 48.11, PM-(4) 58.06 and PM-(5) 46.0 and control 46.40. The PM-(4) which showed fecundity 498 nos (404), ERR/10000 larvae 8456 by nos (9575), cocoon weight 1.286g (1.1g), shell weight 0.207g, shell ratio 16.1. After evaluation PM-5 was eliminated. Similarly the AEI was calculated for the post cocoon parameters *viz*, reability, filament length, non breakable filament length, denier, renditta, raw silk percentage, raw silk recovery and neatness. The AEI for PM-(1) 52.89, PM-(2) 52.10, PM-(3) 53.00, PM-(4) 58.57 control 41.45 and 40.87. In both the parameters the PM-4 performed better over the other PM lines and the control with a scoring of 58.06

The improvement of PM-4 line was compared with the control. The shell ratio, reability, filament length, denier, neatness, tenacity, cohesion stroke and elongation of PM-4 were 16.88% (14.2%), 73.3% (65.9%), 396m (263m), 2.59 (2.35), 89% (68%), 3.7g/d (3.5g/d), 45 (34) and 19% (18%) respectively.

The performance of PM-4 x CSR2 was studied in comparison with the control (PM x CSR2) for fecundity of 495 (466), pupation 93.0% (93%) ,single cocoon weight 1.72g, (1.47g), shell weight 0.34g (0.27g), shell ratio 19.78% (18.61%), reability 86% (84%), filament length 681m (548), raw silk % 15 (14.8), raw silk recovery 73.49% (69.49%) and neatness 85 (80). Thus establishing the directional selection effect and substantiating the earlier studies.

Key words: Polyvoltine, Pure Mysore, Directional selection, Productivity

BM P 06: “Bengaluru Belli”- a new improved cross breed for silk productivity and quality.

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Ramegowda, DR Siddhalingaswamy,Latha, Meera.P**

ABSTRACT

KSSRDI has developed an improved cross breed named has “*Bengaluru Belli*” producing white oval shaped cocoon through line breeding. The pure line is improved addressing to post cocoon characters and rearing performances of the improved cross breed, shorter larval duration, conversion efficiency and higher ERR percentage and rearing in all the seasons found to be encouraging and it can be good alternate for kolar gold. The rearing performance of Bengaluru belli is found to be superior over kolar gold and also recorded improved post cocoon characters like filament length, higher shell percentage and neatness. Performance of Bengaluru belli was studied at the field level and success in both pure race rearing and hybrid rearing have been realized. Farmers are offered higher price for the cocoons of Bengaluru belli invariably. Further it was observed that these cocoons can be reeled on automatic reeling machines. These details are being discussed in this paper.

Key Words: Improved cross breed, Rearing performance, Cocoon character, Reeling on Automatic Reeling Machines, Silk quality.

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BM P 07: *IN-VIVO EFFICACY OF FORMS AND METHODS OF APPLICATION OF ADHATODA VASICA ON ECONOMIC PARAMETERS OF SILKWORM, BOMBYX MORI L.*

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Abstract

Mulberry silkworm (*Bombyx mori*) is highly susceptible to different diseases, among which bacterial flacherie incidence was found more and it causes drastic reduction in cocoon production. In recent years use of botanicals having antimicrobial property, non-toxic, biodegradable and non-pollutant, is found to be an alternate strategy to control diseases of silkworm. Therefore an attempt has been made to use different forms and methods of *Adhatoda vasica* against haemolymph bacteria (*Bacillus*) and are found effective in controlling the bacterial flacherie disease and enhance all economic parameters of cocoon. Among liquid forms of application, the alcoholic extract of *A. vasica* was recorded maximum economic parameters viz., cocoon weight (6.04 and 6.32 g/5), shell weight (0.980 and 1.016 g/5) and shell percentage (16.24 and 16.32 %), followed by acetone (6.03 and 6.14/5; 0.945 and 0.975/5; 15.68 and 15.89 %) and aqueous (5.91 and 5.92/5; 0.920 and 0.931/5; 15.56 and 15.73 %) extract against *Bacillus* sp. of 10^{-7} spore dilution. Among dust forms of botanical application, dust form with dusting method was recorded maximum cocoon weight, shell weight and shell percentage of 5.63 and 5.79 g/5., 0.861 and 0.886 g/5., 15.29 and 15.30 per cent and minimum was recorded in dusting with spraying method (5.62 and 5.55 g/5., 0.845 and 0.845 g/5., 15.05 and 15.23 %) of *Adhatoda vasica* administration for both fourth and fifth instar larvae of PM \times CSR₂ inoculated with 10^{-7} bacterial spore dilution.

Key words: *Adhatoda vasica*, *Bacillus* sp., Economic parameters of cocoon

BM P 08: Parent offspring regression a tool to analyse the performance of popular bivoltine races under silkworm race maintenance in India

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The bivoltine races *viz.*, CSR2,CSR4, CSR6,CSR26 and CSR27 developed in India with the joint efforts of Japanese experts and Indian Scientists under Japan International Co-operative Agency (JICA) are popular even today and their hybrids CSR2 x CSR4 (single hybrid) and (CSR2 x CSR27) X (CSR6 x CSR26) (Double hybrid) are being commercially exploited in India from past one decade. As these races are continuously exploited for the production of hybrids, it is very much essential to know the performance of pure races as they are being inbred over a decade. Continuous inbreeding of races leads to inbreeding depression over years and finally results in decline in the expression of economic characters such as fecundity, average cocoon weight, shell weight and cocoon shell percentage. To know whether there is any decline in the expression of economic traits in the five popular bivoltine races, Parent Offspring regression analysis has been utilized as a statistical tool to know the variation between years and the data was compiled from 2011-12 till 2017-18. Marginal Inbreeding depression/Enhancement over the previous generation and their analysis for parent offspring regression showed non significant regression co-efficient indicating less variation over the previous generation. The regression co-efficient (R^2) in the five races when analyzed from 2011-12 till 2017-18 for fecundity varied from 0.008 to 0.71; 0.087 to 0.326 for average cocoon weight ; 0.22 to 0.437 for average shell weight and for cocoon shell percentage it ranged from 0.030 to 0.358. The analysed data for inbreeding depression for the four economic characters over its previous year data clearly indicates non significant regression co-efficient indicating no deviation in the expression of the economic traits. The methodology adopted over the years to maintain the racial characters without significant decline in the expression of the characters over years at P3 level of bivoltine silkworm race maintenance is discussed.

KEY WORDS: Bivoltine race, Parent Off spring regression, Regression Co-efficient, Inbreeding depression

BM P 09: Prospects of strengthening Bivoltine Silkworm Seed Sector in the Indian State of Andhra Pradesh

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ABSTRACT

Popularization and practice of Bivoltine hybrid rearings, a base for quality grade raw silk production has taken a leap in southern states of India, especially in Andhra Pradesh which stands Second in Silkworm Cocoon production. This was possible due to the continued support from the Central Silk Board in terms of its technical expertise in extension related activities including in the supply of quality seed to the Dept. of Sericulture, Govt. of Andhra Pradesh to accelerate Silk production in the State. Efforts are being made in the State to create self sufficiency in Bivoltine silk production through various measures. The authors acknowledge the technical knowhow imparted by National Silkworm Seed Organization of Central Silk Board in bivoltine seed production. As such, Registered Seed cocoon Producers have been identified in the Districts of Anantapur and Chittoor in the production of the Quality Bivoltine Double Hybrids at the Govt. grainages located at Penukonda and Palamaner.

Quality Silkworm Seed production assumes special significance in harvesting stabilized cocoon crops which in turn results in the production of Quality cocoons and as such the linkage between “Feed-Breed-Seed” is being carefully nurtured. The grainage performance is being carefully monitored in terms of Sex separation and Egg recovery which is greater than 65 gm/kg of cocoons through the technical expertise available at Andhra Pradesh State Sericulture Research and Development Institute. The performance of Double hybrids is being carefully monitored in the State wherein, the yield/100 DFLs has gone up to 90 Kgs. This has encouraged the staff involved in seed production in setting higher targets in the coming years. The Seed production activity is well supported with the availability of State-of-the-art Cold storage at Madanapalle which is taking care of the preservation of Bivoltine silkworm DFLs in different hibernation schedules resulting in timely supply of DFLs to the farmers. The prospects of Bivoltine silkworm seed production in the State of Andhra Pradesh is discussed with the support of few success stories in this very important aspect of Sericulture.

BM P 10: Strengthening Silkworm Hybrid Egg Production of *Bombyx mori* L.in India: Empowering Private Sector

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The multidimensional progress achieved by the Indian silk industry is greatly due to the improvements made in the production and supply of quality hybrid eggs. Indian sericulture is predominantly multivoltine oriented and the demand for hybrid silkworm eggs is spread over throughout the year and do not follow any definite pattern. Thus silkworm hybrid egg production and supply is a big challenge in India, unlike other temperate countries.

Before organized seed production came into existence in India, State Governments, especially of the traditional states like Karnataka, Andhra Pradesh, Tamil Nadu and West Bengal had encourage participation of private egg production centres to take up the production of silkworm hybrid eggs. Silkworm seed Act was also promulgated in few states for licensing and regulating the hybrid egg production in late 1950s. Considering the increasing demand, it was inevitable for the government to further encourage participation of private agencies in the silkworm egg production. Responding promptly, the private sector grabbed the opportunity, and elevated the silkworm seed production to a highly lucrative and remunerative profession from a mere service oriented activity, besides augmenting the production considerably.

The current (2017-18) production of the silkworm hybrid in India is about 4,22,300 million boxes and is met by three agencies *viz.*, State Government, Central Silk Board and Private egg production centres. Their share of production is 14%, 19% and 67% respectively . The requirement of silkworm hybrid eggs is likely to increase by 136% in 2023-24 and by 175% in 2029-30 to produce the targeted quantity of mulberry raw silk. The State government and Central Silk Board egg production centres have limitations for increasing their production owing to the manpower crunch. Hence, the responsibility of meeting silkworm egg demand of the country solely rests on the private sector. Private sector which is still clinging on to the conventional production system has to transform and modernise. In this direction sufficient technical and monitory assistance needs to be provided to upgrade their status and augment the production. This paper discusses the problems and challenges of private sector in the changed scenario besides providing policy ambience and suggest ways and means for accomplishing the task.

(Key words: Silkworm hybrid egg, Private sector, Indian silk industry)

Section 3

Non-mulberry silkworms

NM-LP: Lead Paper

Biodiversity in *Antheraea mylitta*: A boon for tasar culture in India**Alok Sahay***Central Tasar Research & Training Institute, Central Silk Board,
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Abstract: Indian tasar silkworm, *Antheraea mylitta* is an economically important wild silkworm species distributed across India. A number of morphologically well defined ecoraces are known for this species that differ in their primary food plants specificity. Most of these ecotypes do not interbreed in nature but are able to produce offspring under captive conditions. India has a rich and varied heritage of biodiversity, encompassing a wide spectrum of habitats from tropical rain forest to alpine vegetation and from semi-humid vegetation to coastal wetlands. India figured with two hotspots- the Western Ghats and Eastern Himalayas- out of 25 biodiversity hotspots defined by Myers (1988). *Antheraea mylitta* occurs only in the Asiatic continent but it is reported by a number of similar forms, many of which are treated as distinct species, though they are merely ecoraces viz., *A. Fascita*, *A. pulchra*, *A. ochripicata*. Due to its variable appearance, it was described under a number of synonyms. *A. nebulosa* as a distinct form, from that met in Chhotanagpur and Central India. *A. sivalika* and *A. pattrena* have been reported as a synonym of *A. paphia*. *A. paphia* is extremely difficult to distinguish from *A. mylitta*. *A. mylitta* was earlier distributed throughout the Indian Peninsula but with gradual depletion of forest and urbanisation, habitat lost its continuity and resulted in geographical isolation. This geographical isolation allowed the populations to continue separately for generations to attain equilibrium in its phenotypic, genotypic and life history traits. The differences in the characteristics identified with particular ecological niche led to consider them as separate units within the same species and referred as ecoraces. These ecoraces vary in geography, topography, ecology, food plants, flora and frequency of life cycle in latitudinal and altitudinal gradients. They exhibit diversity in phenotypic behavioural, physio-genetic and commercial characters. Recent studies on ecoraces have revealed variability in DNA level also. These variations are genetic treasure thus, in an exploratory survey in 17 states and one Union Territory revealed the availability of so far 44 ecoraces. Of which 9 distinct ecoraces are economically important. These ecoraces are mainly distributed in the tropical moist deciduous forest zone with average rain fall up to 1200-2000 mm and the tropical dry deciduous forest zone up to 1000 mm. Major economically important ecoraces are distributed within 16-32°N latitude and 72-96°E longitude. The variations in commercial characters of these ecoraces provide immense opportunities for various non textile applications.

Key words: Tasar silkworm, *Antheraea mylitta*, hotspots, ecoraces

NM O 01: Taxonomic and Functional Annotation of Midgut Bacterial Communities of Tasar Silkworm (*Antherea mylitta* Drury, *Saturniidae, Lepidoptera*)

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ABSTRACT

Insect herbivory is an evolutionary process with complex mechanisms to overcome the host defenses. One such mechanism is the insect-microbial symbiosis. Bacterial symbionts help the host insect in its growth and development. Such information on the bacterial symbiosis is lacking in tasar silkworm. We have made a successful attempt to annotate the taxonomic and functional profile of fifth instar larval midgut bacteria of daba ecorace reared on asan using Illumina Next-Generation Sequencing of 16S ribosomal RNA amplicons. The dataset consists of 660138 high quality paired end reads with average 250 base pairs. Highly diverse bacterial communities were present in the sample containing approximately 1759 operational taxonomic units (OTUs). A total of 19 phyla, 40 classes, 99 orders, 164 families, 239 genera and 168 species were identified from the sequence analysis. The dominant phylum, family, genera and species in larvae are presented here in percentages. Among the phyla, Proteobacter, Actinobacter and Firmicutes are dominant. The dominant genera is Pseudomonas followed by Brevundimonas, Bacillus, Acinetobacter, Methylobacterium, Corynebacterium and Stenotrophomonas. Over 76 % species were Unknown. The identified species are *Desulfovibrio alaskensis* G20, *Pseudomonas palleroniana*, *Pseudomonas psychrophile*, *Sphingobacterium multivorum*, *Burkholderia gladioli* and *Enterobacter hormaechei* subsp. *hormaechei*. Detailed KEGG based functional analysis through PICRUST, revealed many important roles of gut bacteria in digestion, detoxification, amino-acid synthesis etc. This demonstrates the beneficial role of gut bacteria and silkworm which helps to enrich our knowledge through which we can manipulate these functions for the enhancement of the yield and quality of the silk in future.

KEY WORDS: gut bacteria, metagenomic analysis, carbohydrate degradation, 16SrRNA, herbivory.

NM O 02: Identification of potential phosphate solubilizing bacterial strains from tasar silkworm host plant rhizosphere to establish native biofertilizer in tasar culture

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ABSTRACT

Tropical tasar culture is being mainly practiced through intensive silkworm rearing on systematic plantations of *Terminalia arjuna* and *T. tomentosa*. Owing to its increased productivity under block plantation, the growing area is increasing over years. However quality of cocoons is decreasing due to decreased leaf quality, which in turn due to depletion in soil nutrients. Plantations rarely receives manures and fertilizer due to poor economic condition of tribal famers. Under this situation application of plant growth promoting microorganism (PGPMs) in the form of biofertilizer is most appropriate approach as it is economic, sustainable and eco-friendly. Phosphorous (P) is vital macronutrient for plants, most of the tasar rearing soils are deficient in available form of P to plants, despite having abundant P in non-available form. Among PGPMs some bacterial species are capable of solubilizing non-available P to available P. The efficiency of P-solubilisation varies among bacterial isolates, identification of high P-solubilizing isolate(s) is essential for the preparation of biofertilizer. In present study 128 phosphate solubilizing bacterial (PSB) isolates have been isolated from 29 rhizosphere soils of *Terminalia arjuna* and *T. tomentosa* tropical tasar silkworm host plants, including forest and block plantations of West Singhbhum, Jharkhand, India. PSB isolates were isolated on Pikovskayas agar by employing serial dilution technique. Unique colonies showing clear zones were purified and used for further screening. Enumeration of PSB load revealed that, forest plantation soil has highest PSB load (139×10^6 CFU/g) over block plantation (112×10^6 CFU/g). Wide range of PSB load ($33-253 \times 10^6$ CFU/g) was noticed in *T. tomentosa* rhizosphere than *T. arjuna* ($53-140 \times 10^6$ CFU/g). Number of isolates per sample was ranged from 2 to 9 with an average of 4.5 per sample; for which no significant difference was observed in plantation types and host plants. For biofertilizer preparation native bacterial isolates are preferred as they are more adaptive and competitive with naïve microbes. Hence an attempt was made for the first time in tasar culture to identify native potential PSB isolate. A total of 128 PSB isolates were tested for Tri Calcium Phosphate (TCP) solubilization efficiency in National Botanical Research Institute's phosphate (NBRI) growth medium, in duplicates after four days of incubation at 28°C and 120 rpm. Phosphate solubilized by PSB in liquid culture was estimated using the Fiske and Subbarow method. Twelve PSB isolates have shown very high TCP solubilization i.e. $>200 \mu\text{gP/mL}$, 33 isolates showed $150-200 \mu\text{gP/mL}$ and most of the isolates (47) solubilized low TCP. Twelve high P solubilized ($>200 \mu\text{gP/mL}$) isolates were assessed for other beneficial properties under *in vitro*, eight isolates synthesized Indole-3-Acetic Acid (IAA), which has vital role in plant growth and development and all 12 PSB isolates produced Ammonia. These multi-functional PSB isolates would be assessed under pot condition to identify potential isolates to prepare biofertilizer for tasar host plants.

KEY WORDS: Rhizosphere phosphate solubilizing bacteria, PSB isolates, P-solubilization, biofertilizer and tasar host plants.

NM O 03: Development of SCAR Markers for Specific Identification of Thermo-tolerant Tropical Tasar Silkworm, *Antheraea mylitta*

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Antheraea mylitta Drury is a wild sericigenous insect which produce economically important tasar silk. It is reared in central and eastern parts of India, experiences extreme thermal conditions during its lifecycle. Daba is a ruling commercially exploited semi-domesticated ecorace reared in almost all tasar growing states of India. The environmental conditions prevailing during pupal diapause play a vital role as the pupae have to survive extremes of climatic conditions. Large quantities of cocoons are lost due to high temperature especially during peak summer. The high temperature stress induces the changes in the physiology and biochemical composition and in turn the fecundity and other commercial traits in the silkworm. During preservation of seed cocoons, the higher temperature affects about 30% of the stock. The thermo-tolerant line of Daba is imperative to overcome the loss due to the thermal stress. The present study was intended to develop Sequence Characterized Amplified Region (SCAR) markers using RAPD polymorphic fragments for the identification of thermo-tolerant line. Daba cocoons were exposed at the temperature at 46°C/4 h for three days. DNA was extracted and purified from five thermo-tolerant moth and five thermo-susceptible pupae and DNA polymorphism were analysed using 30 RAPD primers. OPK04, OPAJ15 and OPA17 generated the polymorphic fragments at the size of 1400, 700 and 900 bp respectively to distinguish the thermo-tolerant and susceptible lines. The polymorphic bands were cloned, sequenced and converted into stable SCAR markers. SCAR primers generated reproducible bands and appeared in thermo-tolerant line but not in thermo-susceptible line. High specificity in the detection of thermo-tolerant genotypes showed that SCAR marker is simple and reliable tool in assisting selection of thermo-tolerant tropical tasar Silkworm.

Keywords: *Antheraea mylitta*, thermo-tolerant, Random amplified polymorphic DNA, Molecular cloning, Sequence-characterized amplified region marker

NM O 04: Identification and Molecular characterization of a novel member of iflaviruses, infecting tropical tasar silkworms *Antheraea mylitta* and *Antheraea proylei*

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Abstract

The tropical tasar silkworms- *Antheraea mylitta* and *Antheraea proylei* frequently affected with gastrointestinal disease and the causative agent is suspected to be a virus. EST database developed by various investigators of *A. mylitta* included a transcript that was found to have strong similarity with that of Iflaviruses, a genus of positive sense single-stranded RNA viruses belonging to the order Picornavirales - primarily infecting insects. In this study the full length genome sequencing of this novel virus was attempted. The genome organization, amino acid sequence and phylogenetic analyses all indicate that the virus is a new member of the genus Iflavirus - closely related to *Antheraea pernyi* Iflavirus (91% amino acid similarity), with the proposed name of *Antheraea mylitta* Iflavirus (AmIV). The genome sequencing revealed 9837 nucleotides of contiguous sequence excluding the natural poly-A tail, encompassing the full length of the single, large open reading frame, flanked by untranslated regions at 5' and 3' ends. As per the available literature, open reading frame is predicted to encode a 2967 amino acid polyprotein possessing four viral structural proteins (VP1-VP4) located at the N-terminal end and the non-structural proteins, including a helicase, RNA-dependent RNA polymerase and 3C-protease, located at the C-terminal end of the polyprotein. The putative 3C-protease and autolytic cleavage sites were identified in this study, which are required for processing polyproteins into functional units, similarly found in other iflaviruses. The virus was maintained in *A. mylitta* populations and upon injection into *A. mylitta* larvae, AmIV spread through systemic infection to silkworm epidermis, midgut, fat body, ovary and eggs. The AmIV infected gravid female moths of *A. mylitta* and *A. proylei* produced AmIV-infected offspring, demonstrating vertical transmission route for AmIV. The study has successfully demonstrated key findings such as discovery of novel member of Iflavirus through genome sequencing molecular characterisation of open reading frames and vertical transmission route for AmIV infecting tasar silkworms, *A. mylitta* and *A. proylei*.

NM O 05: STRATEGIC PLAN FOR INCREASING *ANTHERAEA MYLITTA* RAW SILK PRODUCTION

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The tropical tasar silkworm, *Antherea mylitta* Drury (Lepidoptera: Saturniidae) is a polyphagous insect, having 44 eco-races distributed in majority of the agro-ecological conditions in India (12-31°N latitude and 72-96°E longitude) with varied phenotypic, physiological and behavioral characters. Since, tasar silkworm is a means of life for many forest dwellers and rural populace in tropical part in India, this sector has great potential in India. The present communication highlights the achievements made for tasar silkworm seed sector involving the technological intervention, private seed rearers and private graineurs. Due to technological intervention during 2010-11 to 2018-19 the recovery of cocoon dfl ratio increased to 3.64 from 4.22 across seed production centers. With the interventions of various programmes, nearly 35,48,427 commercial dfls were produced during 2018-19, which is lead to production of 152 MT raw silk production. Whereas, during 2004-05 only 1,52,993 dfls were generated through various schemes. Under the adoption programme for seed cocoon generation through registered seed rearers (AR) indicated an increased in coverage from 475 farmers during 2005 to 1857 during 2017. A positive trend was recorded between dfls brushed ($R^2= 0.977$) and seed cocoon produced ($R^2= 0.782$) over the years. The average cocoons produced per dfl ranged from 41.03 to 53.24 with an average of 46.98. Positive correlation with an increasing trend was also observed between seed cocoons processed and dfls produced ($R^2 = 0.803$) during 2005 to 2017. The Basic and nucleus seed production capacity was only 12.17 lakh during 1998-99 and it was 38.46 lakh during 2017-18. The impact assessment of various technological programme implemented on of tasar sericulture farmers resulted in increased employment through wage (7.24%), self employment (59.87 %), increase in DFL intake (19.74 %), improvement in production & productivity (23.46 %), change in income level (61.40 %), lifestyle changes (3.29 %), increased confidence level - due to enhanced awareness & skill level (100 %) and other Social Impacts like promoting tasar sericulture activities with the fellow farmers.

Concurrently, harnessing natural resources of tasar silkworm is another dimension for future self-sufficiency in tasar silk. One such programme *i.e.*, Raily ecorace of Bastar, Chhattisgarh region. The trend of raily cocoon production has reached to more than 2000 lakhs from 21.50 lakh since inception of conservation programme. Similar programmes have been for the *i.e.* Sarihan and Wild DABA in Jharkhand. During 4th FYP (1980-85) the tasar raw silk production in India was 444 MT and it has increased several folds to 2989 MT in 2017-18. These programme has wide scope in achieving the targeted tasar raw silk production. The orderly involvement of forest, Central and State sericulture departments can augment in transformation of their semi-domesticated relatives, seri-biodiversity and integrated bio-resource management of endemic eco-zones.

NM O 06: Utility of transposon *piggyBac* for transgenesis in eri silkworm *Samia ricini*

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Abstract

Transposon *piggyBac* is a versatile vector for generating transgenic insects. We designed the *piggyBac* vector to examine the extrachromosomal interplasmid transposition in eri. The reliable promoter is needed to express the *piggyBac* transposase, which is essential for the extrachromosomal interplasmid transposition. However, no reliable promoter in the eri has been reported yet. Using the luciferase reporter gene, we first examined the activity of transcription of the mulberry silkworm cytoplasmic actin 3 gene (*BmA3*) promoter in eri embryo. The *BmA3* promoter is a constitutive strong promoter. The *BmA3* promoter showed high activity of luciferase in eri embryo. Then, we constructed the helper plasmid which expresses the *piggyBac* transposase under the control of the *BmA3* promoter. We tested whether the *piggyBac* element on the donor plasmid transferred to the target plasmid in eri embryo. The interplasmid transposition occurred in the TTAA sequence on the target plasmid. We concluded from the results that the transposon *piggyBac* serves as a versatile vector for transgenesis in eri silkworm.

NM P 01: Estimation of General and Specific combining ability of six inbreed lines of eri silkworm, *Samia ricini* Donovan

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ABSTRACT

Six breeds of the eri silkworm, *Samia ricini* Donovan viz., Yellow Plain(YP), Greenish Blue Plain (GBP), Yellow Zebra (YZ), Greenish Blue Zebra (GBZ), Yellow spotted (YS) and Greenish Blue Spotted (GBS) were subjected to estimate their general combining ability in breeds and specific combining ability in the hybrids crossed in a 6 x 6 diallel fashion. Combining ability analysis was carried out for ten important economic characters, viz., fecundity, hatching, larval weight, cocoon weight male & female, shell weight male & female, shell percent (male & female), and absolute silk yield following full diallel cross analysis given by Griffing (1965a and b). The analysis of variance for combining ability of nine yield contributing traits manifested significant GCA variances in all the traits except absolute silk yield, while significant SCA variances were observed in seven parameters. Significant reciprocal variances were observed in nine parameters which were the indication of maternal effect in these traits in eri silkworm. Among the six breeds, Yellow Zebra was found to be the best general combiner who exhibited significant effects in seven traits followed by Yellow Plain for six traits. Among the hybrids, YP x GBZ and YZ x GBZ showed significant SCA effects for six traits. Observations on reciprocal crosses revealed significant effects by GBZ x GBP in seven traits. The hybrids YP x GBZ and GBZ x GBP have been identified for further trial rearing for higher production of eri silk.

Key words: combining ability, eri silkworm, diallel cross, reciprocal effects.

NM P 02: ANTERAEA FRITHI MOORE, A LATENT WILD SILKWORM OF INDIA

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Abstract

Antheraea is the largest genus among the wild silk moth of the family Saturniidae used for silk production. Of these, only few species viz., *Antheraea proylei*, *A. mylitta*, *A. assamensis* and *A. yamamai* have been commercially used successfully for production of silk in specific pocket of region. *A. frithi*, oak tasar silkworm is one of the important wild sericigenous insect mainly distributed in North-eastern region of India, particularly Manipur state. Keeping the facts in mind, the present study aims to study the bio-ecology, seasonal abundance, abiotic factors in relationship to the study site, Senapati district in Manipur. Study on bio-ecology depicts that the species is bivoltine in nature in Manipur existing during May-July and September-November. In natural condition, more than three lakhs numbers of seed cocoons are recorded during its peak season. This region could be recognised as an area of unique ecological niche for *A. frithi*. The co-relation between the density population of *A. frithi* with temperature, rainfall and relative humidity showed positive relation. Analysis of the cocoon character observed average cocoon weight 5.46 ± 0.3513 g, shell ratio 13.37 ± 0.43 % and 621 ± 21.73 m filament length more than the commercially exploited *A. proylei*. The cocoon is compact, hard and reelability percentage was 55.00 ± 4.27 %. The moth exhibit colour polymorphism showing yellow, brown, orange, grey indicating great genetic diversity in the natural population. *A. frithi* is a latent silk bioresource of India due to its better bio ecological adaptability in their natural habitat. Hence, the need of the hour is conservation and multiplication of the species so that it can be exploited for production of silk.

Key words: *Antheraea frithi*, natural condition, bivoltine, latent, conservation.

NM P 03: Analysing the Impact of Climatic Changes on Rearing Performance of *Antheraea assamensis* (Muga Silk Worm): Study of a Decade

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Muga silkworm, *Antheraea assamensis* (Helper) belonging to Saturniidae family which is geographically endemic only to NE region of India. The State of Assam has patented muga silk as Geographical Indication Registry in 2014. Muga silk worm rearing is suitable in temperate climate with high humidity and quality of host plants. The rearing is performed outdoor by brushing the infant worms on tender leaves of Som (*Persea bombycina*) and Soalu (*Litsaea polyantha*) trees. Muga Silkworm Seed Organization, Central Silk Board is mandated to produce muga basic and commercial quality seeds/disease free layings (dfls) under its nested sister units. Due to outdoor rearing conditions, the abiotic factors like temperature and humidity play an important role on effective rearing of muga silkworm. In this study meteorological data of 10 years was collected from rearing performed under nested units at different geographical locations. In detailed analysis it has been found that constant fluctuation in temperature and humidity was positively correlated to crop loss. The increase in temperature gradient due to climatic change has affected rearing of muga silkworm, similarly drastic fluctuation in relative humidity above 86% and temperature exceeding 32-37°C had always resulted in crop loss specifically from month of June to September which is vital for basic seed production ($t=13.74$, $P<0.00001$). The increase in temperature gradient over cooler months of the year (Oct-Feb) has negatively affected rearing of muga silkworm. Decrease in relative humidity below 68% and temperature rise above 27-32°C had always resulted in crop loss due shortening of winter span from the month of October to February which is vital for commercial seed production ($t=4.75$, $P<0.0001$). Both summer and winter season rearing analysis over 10 years have established the fact that temperature and relative humidity fluctuation specifically resulted in crop loss along with other secondary factors like diseases (flacherie, muscardine), pest (uzi), natural calamity and predators.

Keywords: *Antheraea assamensis*, temperature, humidity, rearing performance, crop loss.

NM P 04: Studies on Erratic emergence in Indian Tasar silkworm (*Antheraea mylitta*, D) and Seed preservation through single step refrigeration method

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ABSTRACT

In the Indian tropical Tasar silkworm (*Antheraea mylitta* Drury), control of erratic emergence in seed cocoon preservation and timely supply of seed in desired quantity to the farmers for commercial crop is one of the most challenging tasks. Studies at this laboratory revealed that by preservation of seed cocoons in different temperatures and altering photoperiod has given some hope. The Bivoltine (BV) and Trivoltine (TV) brood seed cocoons are preserved at 10°C, 15°C, 20°C, 25°C and 30°C, (RH60-70%) after one month of spinning i.e February, 2019 to till May, 2019 for 4 months. In BV negligible (<1%) erratic emergence was observed and natural emergence started in 20°C. In case of 25°C and 30°C preserved cocoons erratic emergence was recorded 10.66% in May and continued normal emergence in the month of June and continued for 15 days, laid eggs naturally. Pupal mortality ranged from 1-4%. But the seed cocoons preserved in 10°C and 15°C emergence prolonged for one more month and all emerged moths are crippled and unable to mate and pupal mortality ranged from 80-90%. In TV, 21% erratic emergence was observed in 25°C and 30°C during the month of May and natural emergence continued from June and pupal mortality ranged from 2-5%. The seed cocoons preserved at 20°C has shown only 4% erratic emergence and pupal mortality observed was 3% and laid normal eggs. But seed cocoons preserved at 10°C and 15°C emergence prolonged for one more month and all pupae became cold harder and died. The average fecundity in BV observed 242 with incubation period of 9 days and hatching was 96.66% in single day. The average fecundity in TV observed 212 with incubation period of 9 days and hatching was 96.18% in single day (under 25°C, 80% RH & 16h L:8h D).

In case of BV, seed preservation at lower temperature of 5°C is detrimental and recorded less hatching (46%) irrespective of number of days embryo. When temperature increased to 10°C with 5 days duration at 55 hours preservation recorded 85% hatching. In 15°C with 10 days duration at 55 hours recorded 95.20% with an incubation period of 5 days (total 20 days). At 20°C, 55-60 hours embryo preserved for 20 days recorded 84% hatching with incubation period of 3 days (total 23 days). In TV seed preserved at 5°C with 5 days at 48 hours egg, hatching was recorded 74.50%. At 10°C with 5 days preservation at 48 h embryo, hatching was recorded 75.38 with five days intermediate care at 15°C and incubation period 5 days (total 15 days). The seed of 48h preserved at 15°C for 10 days recorded 72.20% hatching with incubation period for 3 days (total 18 days). The seed of 48h preserved at 20°C for 20 days recorded only 36.00% hatching. Since this institute has developed a unique technique for preservation of Multi x bi eggs (where there is no Diapause factor) could be preserved up to 40 days through Double step refrigeration method, same principle is being applied here and studies are under progress. This indicates that there is a possibility of evolving a package for avoiding erratic emergence and finding out suitable sensitive stage for longer preservation of eggs.

Key words: Tasar silkworm, *Antheraea mylitta*, erratic emergence, egg preservation

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NM P 05: Wild Silks. Globalized materials in the longue durée.

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Abstract:

Archaeological findings show the long-lasting uses in Human industries of various species belonging primarily to the Saturniidae family, qualified as ‘wild’ by Silk specialists. At least two wild silks species have been used since the 3rd millennium BCE in the Indus valley (contemporary Pakistan), and another species was present during the following millennium in the Aegean. These discoveries and others made in the area comprised between Central Asia and Europe show that wild silks have an enduring globalized past which deserves attention in order to understand the history of silk/silks as well as the importance/significance of these materials in today’s world. These species and the substances they produce are nowadays the focus of emerging interests in the domains of economic development, natural resources management, and cultural heritage. In this presentation, we aim to examine some ‘wild silk’ textiles, cocoons and specimens identified in French collections and to question ways by which social sciences may contribute to the knowledge of wild silks in the past as well as today.

NM P 06: CONSERVATION OF WILD TASAR ECORACE MODAL (*Antheraea paphia* Linn) IN SIMILIPAL BIOSPHERE OF ODISHA, INDIA :AN INSECT CONSERVATION INITIATIVE

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Abstract

The State of Odisha (State Province of India) is the abode of wild tropical Tasar eco-races such as Modal and Nalia. These eco-races belong to the species *Antheraea paphia* Linn. are maintained in nature itself. In Odisha wild Tasar species are scattered throughout the hilly terrains. The wild Tasar eco-race *Modal* is mainly found in Similipal Bio-sphere of Mayurbhanj district in Odisha, India .It feeds primarily on the leaves of *Shorea robusta*. The cocoons are considered to be of highest silk content among any *sericigenous fauna* known in the world. The shell weight and Shell ratio are as much as 3.64gm and 25.68% respectively.

Similipal is situated between $20^{\circ} 17'$ to $22^{\circ} 22'$ N Latitude and $86^{\circ} 03'$ E to $86^{\circ} 37'$ E Longitude in Mayurbhanj district of Odisha. Forest area of Similipal Bio-sphere is 2750 km² of which core forest area is 845.70 km² and buffer area is 1904.30 km². It has a rugged hilly terrain. The maximum temperature touches around 42° C during summer and minimum 3° C during winter. Average annual rainfall is around 2000 mm.

A total of 1076 species of plants including 87 Orchids have been identified, a list of 42 species of mammals, 231 species of birds and 29 species of reptiles have been found.

During 1965 the wild Tasar cocoons population was 18.98 million and it gradually declined to 1.49 lakhs in 1995. The *Modal* eco-race was believed to have reached the state of extinction. The scientific insect conservation approach for conservation and proliferation of *Modal* population experimented through Modal Eco race Conservation Project (MECP) initiated from the year 2000 and population recharge is continuously going on in Similipal Biosphere and the precious wild Tasar fauna is saved from extinction.

Key words- Similipal Biosphere, Modal Eco race, Insect Conservation
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**NM P 07: TROPICAL TASAR FORESTRY AND TRANFORMATION OF
TASAR SERICULTURE TO A ZERO WASTE LIVELIHOOD ACTIVITY
THROUGH TASAR SILK PARK CONCEPT IN ODISHA**

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Abstract

The provincial state of Odisha lies between the latitudes 17.780 N and 22.730N, and between longitudes 81.53E to 87.53E in the eastern coast of India. The state has an area of 15.5 Million HA with forest area spreading over 5.8 million HA . The forest cover constitutes 37% of the State's Geographic area and per capita forest is 0.18 HA. There are two National Parks, one Biosphere reserve and 18 wildlife sanctuaries sustaining vast category of wild life fauna including the wild Tasar Silk Moth *Antheraea myllitta* Drury. and *Antheraea paphia* Linn. Tropical Tasar farming is considered as a natural gift to the tribal habitants living in and around the forests across the state as a source of livelihood. With stringent Forest Protection Acts coming into force ,there was gradual shrinkage of habitat for Tasar Silk Worm rearing leading to loss of livelihood of the tribal communities.

This lead to the initiation of Tropical Tasar Forestry programme in Odisha to regain the host habitat for wild Tasar Silk Moth *Antheraea myllitta* Drury. The concept of Tasar Silk Park evolved in the process to transform Tasar farming from a mere Cocoon crop to a Zero Waste livelihood activity with emphasis on development of Tasar Forestry, Tasar cocoon production, Tasar yarn production, fabric making, Tasar yarn dyeing, Tasar silk weaving , Garment stitching , Embroidering, Digital printing etc at Bhgamunda Tasar Silk Park in Keonjhar district of Odisha leading to habitat revival of Tasar Silk Moth *Antheraea myllitta* Drury.and women empowerment .

Key words- Tasar Silk Park, Tasar Forestry,Zero Waste Livelihood.

(The authors: 1-Joint Director of Sericulture, 2-Technical Inspector, 3.Director of Textiles & 4- Commissioner cum Secretary to Govt. H.T &H Dept. Odisha,India)

NM P 08: Potential of parthenogenesis in Eri silkworm (*Samia cynthia ricini*)

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The silk thread of Eri silkworm (*Samia cynthia ricini*), which belongs to the family Saturniinae, is rich in porosity, and its silk is light, warm and comfortable to touch, and has been reconsidered as a new silk material. In Japan, all-age breeding with artificial feed has already developed and genetic information are partially decoded. In addition, we are aiming the development of silk modification and useful substance production system by genetic recombination technology using Eri silkworm. Although Eri silkworm has to continue rearing for the maintenance because it is a non-diapause insect, it has recently become possible to regenerate frozen ovaries and testis-derived individuals. In the ovary transplantation of *Bombyx mori*, when the oviduct of the transplanted ovary is not connected to the external genital organ, the unfertilized eggs are taken out of the female adults and subjected to hot water treatment to induce parthenogenesis and regenerate the individuals. In this study, we investigated whether Eri silkworm's unfertilized eggs can have parthenogenesis. The condition of hot water treatment was investigated by changing the temperature and time around the condition of 46 ° C for 18 minutes, the best result in silkworm, *B. mori*. As a result, embryonic development was observed in part, although it did not reach hatching.

NM P 09: Performance of eri-silkworm (*Samia cynthia ricini* Boisduval) (Lepidoptera: Saturniidae) fed on different silkworm food plants for efficacy trials in Kenya.

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Abstract

It is important to understand the life cycle of silkworms and their preferred food plants in order to utilize them. To determine the life cycle and the preferred food plant for eri silk, *Samia cynthia ricini*, the larvae were fed on castor *Ricinus communis*, and cassava *Manihot esculenta* leaves, mostly preferred by eri silkworms and Mulberry *Morus alba* leaves, which is the foodplant for *Bombyx mori*. This was based on their complete life cycle, survival rate, and other few parameters including larval and cocoon weight. Castor leaves fed Eri-silkworm survived to adult moths with five larval instars. The second instar larval fed on cassava and mulberry leaves survived only to the 4th instar and could not complete their life cycle. The survival rate was 96% in castor fed eri silkworms compared to those fed on mulberry and cassava which did not survive to the 5th instar. Castor fed eri silkworms had an average weight of 7.6g before spinning with average cocoon weight of 2.7g. Castor leaves were concluded as the preferred food plant for the eri silkworms in this study.

Key words: Eri silkworm (*Samia Cynthia ricini*), Life cycle, Food plants

Section 4

Bacology of the silkworms

BA-LP: Lead Paper

Application of cloned transgenic silkworms using parthenogenetic strains for pharmaceutical production

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Construction of a platform adapted for pharmaceutical products is an urgent matter for further enhancement of transgenic silkworm technology. To utilize the protein produced by transgenic silkworms as a medicine, it is necessary that the system complies with Good Manufacturing Practices guidelines (GMP). It involves construction of a master bank that preserved the germplasm for long term and working bank for the production of proteins. In the master bank, the germplasm must be preserved for long term using cryopreservation technology. In the working bank the silkworm with the same genetic composition must be used and guarantee the supply from the master bank. Production of transgenic silkworms using parthenogenetic stains is one of clue to solve the problem; the utilization of parthenogenetic strain enables to proliferate and maintain the transgenic silkworms with the same genetic composition. In addition, the germplasms easily adapt for long-term cryopreservation technology. However, realization of the problem was not easy because existing parthenogenetic strains which are univoltine and lay only diapausing eggs. Such diapausing eggs cannot be used for the experiment because the process of making transgenic silkworm contains an injection of DNA into nondiapausing eggs. To solve the problem, we first attempted to create parthenogenetic transgenic silkworms using nondiapausing eggs obtained from ovaries implanted into male larvae. Although we successfully generated transgenic silkworms, its efficiency was very low. Therefore, we second tried to construct bivoltine parthenogenetic strains that give non-diapausing eggs only when the parent eggs are incubated at low temperature. We made F1 and F2 between existing univoltine parthenogenetic line and multivoltine or bivoltine strains, selected the silkworms whose eggs become nondiapausing only when parent embryos were developed at low temperature. We established several candidate strains and showed that transgenic silkworms can be created in relatively high efficiency by using their eggs. The eggs of the constructed strains become nondiapausing eggs when their parent eggs were incubated at room temperature and can be maintained for one year. In addition, we showed that the ovaries of the transgenic strains had an ability to be preserved in liquid nitrogen and the living silkworms could be recovered from the frozen ovaries implanted to the larvae of ordinal strains.

BA O 01: Molecular characterization, tissue distribution and transmission of nucleopolyhedrovirus in oak tasar silkworm, *Antheraea proylei*

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Abstract

The oak tasar silkworm, *Antheraea proylei* is a semi-domesticated sericigenous insect which is commercially exploited for the production of silk in North east & Northwest India. However its production is hampered by tiger band disease with a crop loss of 60-80 %. Hence, it is imperative not only to understand and investigate this disease but also to develop highly sensitive and efficient diagnostic tools for the early detection in order to formulate appropriate control measures. In this regard, full length genome of the causative virus, *Antheraea proylei* nucleopolyhedrovirus (AnprNPV) has been sequenced and found to belong to the group I alphabaculovirus, which showed clustering under one clade of NPV infecting saturniid silkworms upon phylogenetic analysis. The mode and source of infection of these viral pathogens were found to be from the surfaces of *A. proylei* eggs as the virus particles were detected on silkworm egg surfaces. The PCR technique was successfully used to detect and quantify the virus at different development stages in silkworm such as egg, larval and moth stages. One of the prominent observations that were made during PCR analysis was the co-infection of baculovirus (AnprNPV) and Iflavirus (ApIV) on oak tasar silkworm detected using gene specific primers for both the viruses, p94 being specific to AnprNPV and RdRp being specific to ApIV. Further analysis also revealed that the viruses were detected in all the tissues under investigation such as midgut, fat body, trachea, malpighian tubule, ovary, pupa, moth and eggs. The AnprNPV as well as ApIV multiplication was observed in the different development stages, however, AnprNPV did not actively multiply in pupa, moth and eggs. Vertical transmission was also observed in the case of ApIV infection, where eggs laid by female infected moth carried ApIV particles in turn infecting the newly hatched larvae. The viral load of AnprNPV and ApIV in different tissues of larvae and adults were found to be almost on similar levels in all the stages except at pupa, moth and egg stages. Finally, a Loop-mediated isothermal Amplification (LAMP) technique was developed and standardized for easy, simple application for efficient identification of the disease in silkworms. An appropriate egg disinfection method was also devised and formulated which was found very effective in decontamination of infected eggs.

BA O 02: *BmNPV* Resistant Transgenic Silkworm – An Emerging Technology for sustainable Cocoon production in India

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ABSTRACT

The baculovirus, *Bombyx mori* nucleopolyhedrovirus (*BmNPV*) causes major loss to the silk industry hampering cocoon production. Effective treatment against this virus has been elusive due to its sturdy nature and the lack of proper measures. Since the biology of the virus is well understood, multiple essential viral genes (*ie1*, *lef1*, *lef3* and *p74*) have been used in the construction of the vector. Transgenic silkworms resistant to baculovirus infection have been generated using the technique of *piggyBac* mediated germline transgenesis by the Scientists of CDD, Hyderabad. The *BmNPV* virus resistant property in the Nistari genetic background has been successfully transferred to a commercial high yielding, diapausing, baculovirus susceptible, CSR2 silkworm strain through marker assisted repeated backcross strategy at APSSRDI, Hindupur. Three transgenic hybrids were generated by crossing transgenic lines with various commercial breeds of India.

Upon regulatory approval, the contained trials under Phase I have been conducted at APSSRDI, Hindupur and three Research Institutions of Central Silk Board, CSRTI located at Mysore, Berhampore and Pampore to establish the efficacy of the identified transgenic Silkworm hybrids such as PM x CSR2 (Tg), CSR2 (Tg) x CSR4 and Nistari (Tg) x (SK6 x SK7) across several test centres. The results of the trials were consolidated based on the regulatory compliance for several of the pre cocoon and post cocoon parameters including Bio-safety issues. Extensive evaluation of the data has been conducted by the Expert group of the Review Committee for Genetic Manipulation (RCGM) for recommending to Genetic Engineering Appraisal Committee (GEAC) for their approval to conduct second phase of the trial among the selected farmers. The results of the first phase trials have been discussed.

BA O 03: Polyhedrin (*Polh*) gene sequence and phylogenetic analysis of a multi-nucleocapsid nucleopolyhedrovirus isolated from *Antheraea proylei* (Lepidoptera: Saturniidae): Morphological and ultrastructural characterization

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Abstract

Recently, a multi-nucleocapsid nucleopolyhedrovirus infecting the economically important oak tasar silkworm, *Antheraea proylei* causing severe cocoon crop loss in addition to the reported virus causing tiger band disease has been identified. Unlike the virus causing tiger band disease, the virus infected larvae exhibited the general symptom of found hanging head downwards, attached to the host twigs with its caudal legs. Phase contrast, scanning and transmission electron microscopic studies showed that the virus is tetrahedral in shape measuring from 2.45 to 4.10 μm in diameter and occlusion bodies (OBs) showed several virions from 3 to 21 and each virion had 3 to 12 multiple nucleocapsids packaged within a single viral envelop. The virus is infecting various vital tissues with soaring pathogenicity. The virus showed the non-existence of vertical transmission mechanism. This baculovirus was thus named *Antheraea proylei* nucleopolyhedrovirus-Palampur Himachal Pradesh (AnprNPV-PalampurHP). The genome size was found to be approximately 98.85 kbp. Phylogenetic analysis of the *Polh* gene showed that the AnprNPV-PalampurHP polyhedrin belongs to Group I NPVs and having the closer homology with the other NPVs polyhedrin identified from the different saturniid silkworms namely, *Antheraea proylei*, *Antheraea pernyi*, *Samia cynthia*, *Antheraea yamamai* from, India, China and Japan.

Key words: *Antheraea proylei*, oak tasar silkworm, virions, baculovirus, nucleopolyhedrovirus, polyhedrin gene.

BA O 04: An attractive bioresource in Kyushu University supported by NBRP

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Silkworm (*Bombyx mori*) is important for silk production as well as genetic and biological studies of lepidopteran insects. At Kyushu University, *B. mori* has been maintained since the early 1900s and *B. mori* strains, particularly strains with mutations, have been collected from all over the world. In 2002, the National Bioresource Project (NBRP) was established with support from the government of Japan. The NBRP aims to construct an efficacious system to collect, maintain, and distribute bioresources necessary for life science development. From the beginning of the project, Kyushu University was selected as the core facility center for *B. mori* strains. With the aid of the NBRP, 800 strains are maintained and distributed from Kyushu University. Here we introduce some of our representative strains.

Mutant strains of *B. mori* are useful to identify genes controlling the phenotypes of insects. In 2008, the genome assembly of *B. mori* became available, which accelerated the genetic studies of mutants. To date, about 50 loci of mutants have been cloned, including genes governing egg color, larval markings, larval color, molting, cocoon color, wing development, and courtship behaviors. In our repository, there are additional mutations that are yet to be studied. We believe that genetic studies using *B. mori* mutants will help to identify the function of unknown genes in lepidopteran insects.

We have established chromosome substitution strains using *B. mori* and *B. mandarina*. A standard *B. mori* strain, p50, and a *B. mandarina* strain, Sakado, collected in the Saitama Prefecture, were used. The substitution strains have been constructed by repeated backcrosses of p50 males. Each strain has one of the 26 autosomes derived from *B. mandarina*. These strains are useful to search for genes responsible for the domestication process of *B. mori* because *B. mandarina* and *B. mori* are thought to share a common ancestor. Moreover, these strains are useful for mapping of phenotypic mutants because polymorphisms are abundant in the two genomes. Moreover, the genome data of the Sakado strain is available and PCR-based polymorphic markers are easy to be constructed in arbitrary locations throughout the genome.

Genome editing experiments are essential for genetic research. Microinjection of sgRNA/Cas9 complex into non-diapausing eggs is required to conduct genomic editing in lepidopteran insects. We provide the non-diapausing p55 strain, which is suitable for genome editing experiments because the eggs of this strain tolerate damage from microinjection. The genome data of the p55 strain is available, making it easy to prepare sgRNA specific to the target sequence of the p55 strain. Moreover, females of the p55 strain injected with ouabain produces diapausing eggs. This trait enables us to obtain diapausing eggs from knockout strains.

Our strains are also useful in recombinant protein production using baculoviruses. Previous research has reported that the efficiency of recombinant protein production using baculovirus differs dramatically in different host strains. For example, the d17 strain is highly permissive to *Bombyx mori* nucleopolyhedrovirus and *Autographa californica* nucleopolyhedrovirus and is the most likely candidate for a bioreactor. In 2019, a private company, Kaiko Ltd., was established to use silkworm strains at Kyushu University for recombinant protein production.

BA O 05: TAL-PITCh mediated knock-in into the *l-fibroin* locus of the silkworm

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Genome editing is a gene engineering technique that enables target gene modification in an efficient and specific manner. In the silkworm *Bombyx mori* TALENs are most effective among the available genome editing tools. TALEN-mediated knockout has been done for the functional analysis of various silkworm genes and in addition to this we succeeded in the integration of a donor plasmid into the targeted genomic locus (knock-in) using TALEN-mediated PITCh system, termed TAL-PITCh. Here, we investigated whether the TAL-PITCh system can mediate the knock-in into *l-fibroin* (*l-fib*), a gene encoding major silk protein showing abundant expression in the posterior region of the silk gland. The initiation codon site of *l-fib* was targeted and we succeeded in the establishment of knock-in strain in which a donor vector harboring *hsp90* promoter and *GFP* was inserted. In this strain *GFP* was expressed strongly in the posterior region of the silk gland, suggesting that the plasmid was certainly inserted into the *l-fib* locus. A donor vector having 3xP3 promoter and *DsRed* sequence was also inserted and in this knock-in strain the stemmata-specific *DsRed* expression was observed. Thus, the 3xP3 promoter is supposed to be functional also in the *l-fib* locus. We next attempted the knock-in into the termination codon site and could successfully generate knock-in strain having *hsp90* promoter and *GFP* sequence inserted into the target site. All of these results suggest that the knock-in into *l-fib* locus is a promising approach for the efficient production of the recombinant protein as well as for the silk engineering.

BA O 06: Involvement of DMRT genes on sexual differentiation of the domesticated silkworm, *Bombyx mori*.

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Abstract

DMRT (Doublesex and Mab-3 Related Transcription factors) genes are extremely conserved factors in sexual differentiation pathway in animal kingdom. Among these, *doublesex (dsx)* gene is known to regulate various sexual traits of insect species in both male and female by its sex specific isoforms. Go-somatic mutant analysis and forced expression analysis suggest that *dsx* ortholog in *Bombyx mori* (*Bmdsx*) acts as a sexual differentiation factor likewise. However, analysis using mutant lines homozygous for *Bmdsx* mutation is still needed to fully understand the function of *Bmdsx*. In addition to the *Bmdsx*, there are three other DMRTs, *Bmdmrt11E*, *93B*, *99B* in silkworm genome, whose functions remain completely unknown. Thus, we created several mutant lines for the above four genes and investigated their phenotypes.

RT-PCR analysis revealed *Bmdsx* as a ubiquitously expressing gene, and *Bmdmrt11E* and *99B* as ovary-expressing and *Bmdmrt93B* as testis-expressing gene. We then established mutant lines for each gene. Mutants for *Bmdmrt11E* and *99B* produced partially abnormal transparent eggs due to the excessive accumulation of lipids. Females of the one line with *Bmdmrt11E* mutation were completely sterile. In addition, mutants of *Bmdmrt99B* showed abnormal behaviors, which was similar to the baculovirus infected-like scattering behavior.

Either female- or male- specific *Bmdsx* mutants showed tissue level-sex reversal in the genitalia, number of the body segments and germ cells, while several internal genital organs displayed normal sexual phenotype in these mutants irrespectively of their genetic sex. Interestingly, these genital organs together with the testis were abnormally developed in the *Bmdmrt93B* mutant males.

We believe that our results would lead to provide a novel reproduction controlling method. Since all these genes are transcription factors, identifying downstream factors might help to find targets of chemicals which will be useful for pest controls.

BA O 07: KAIKObase, the silkworm genome database – 2019 update

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As launched in 2009, KAIKObase serves as a genome database of the domesticated silkworm *Bombyx mori*. It provides genetic and physical maps as well as genome annotation obtained from the sequencing project of the International Silkworm Genome Consortium. Since then, KAIKObase has been a widely used knowledge base for silkworm and insect studies, although there are still some erroneous predicted genes due to misassembly and gaps in the genome. After a decade passed, thanks to the development of third-generation sequencing technology, a new genome assembly, which was derived from long (PacBio) and short (Illumina) reads, covers more transcribed regions than previous silkworm genome and shows improvements in gap closure and gene prediction. Since the new genome assembly and gene prediction are available, we updated KAIKObase with the latest genome information. In the new KAIKObase, we integrate new genome sequence, predicted genes, and transcriptomic data generated from RNA-seq and provide a genome browser for viewing structure, annotation, and expression level of each gene. We assign functional annotation to each gene by the description of the most homologous gene in NCBI nr database and accessions of InterPro and Gene Ontology. We also provide orthologous sequences of each gene in important insects including several lepidopteran species (especially lepidopteran pests) as silkworm is a model organism for the study of lepidopteran. For the users of previous KAIKObase, we provide URL links to the corresponding genes in the previous KAIKObase for each gene in the updated one so that users can easily find the information they have used. The updated KAIKObase will be publicly available within this year.

BA O 08: Ubiquitin related transcript expression in the silkgland of *B. mori* correlating to silk protein synthesis

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Ubiquitination is one of the important processes that regulate proteins expression for basic cellular processes like cell cycle regulation, control of signal transduction pathways, development and differentiation. Ubiquitin is a small regulatory protein found in most tissues of eukaryotic organisms. The ubiquitin-proteasome pathway plays important role in the programmed cell death of the silk gland. Ubiquitinated proteins participate in the posterior silk gland degeneration and also regulation of several different DNA repair pathways. Whether the process of ubiquitination holds the key in regulating the silk protein synthesis was analyzed. RNA was isolated from silkglands using TRIZOL method from the 3rd day of fifth instar larval from contrasting silkworm breeds for silk quality parameters, Bivoltine: CSR2, CSR27 and multivoltine: Pure Mysore, Nistari. *Lexogen SENSE mRNA-Seq Library Prep Kit V2* was used for library preparation and were sequenced using Illumina HiSeq2500. Among the several transcripts, there was enrichment of ubiquitinated and RNA biogenesis transcripts. Abundances of merged transcripts were estimated using StringTie. Differential expression of Genes (DEG) analysis was carried out, which indicated a total of 28 ubiquitin related transcripts among the 225 genes that showed differential expression for CSR2 and Pure Mysore and 254 genes for CSR27 and Nistari. Further, a total of 258 ubiquitin-related novel isoforms/transcripts were identified. Among the breeds analyzed, two ubiquitin-related genes were exclusively expressed in CSR2, followed by 2 in CSR27, 3 in Pure Mysore and 1 in Nistari. The gene/transcript E3 ubiquitin ligase RNF126 was identified in both bivoltine breeds that exhibit superior silk quality in comparison with multivoltines. The transcript UbiA prenyltransferase domain containing protein 1 homolog was found exclusively expressed in Nistari but interestingly it was upregulated 2.84 times in DEG comparison for CSR2 vs PureMysore. The results thus, indicate that these ubiquitin homologs function as molecular chaperons that lead to the activation of processes like proteasome synthesis and autophagy thereby promoting degradation of abnormal proteins synthesized in silk gland, however the functional complexity of this needs to be further studied.

BA O 09: A testis-specific uncharacterized gene unique to silkworm is necessary for cell progression and survival

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Owing to development of NGS technology and bioinformatics, we can access genome and transcriptome information, identify orthologous genes from many species, and predict their function. There are still, however, many genes whose functions are difficult to predict, and hundreds of lineage specific genes that are limited to a particular clade. In order to understand molecular basic mechanisms of life, it is necessary to clarify the functions of those uncharacterized and orphan genes.

We have been interested in function-unknown genes which are also unique to lepidopteran insects. In our previous studies, the 272 genes were identified (named kaonashi genes) under the following three criteria: (1) no homology to any known fly, mouse, and human genes (2) conserved only in the lepidopteran species (3) no known pfam domain.

In this study, we focused on the silkworm testis, which has interesting features, such as two types of sperm, nucleate eupyrene and anucleate apyrene, and huge single niche cells, and tried to identify kaonashi genes, which are involved in the silkworm testis development. At first, we performed transcriptome analysis using the three silkworm tissues (testis, hemolymph, and midgut), and identified 580 genes, which were significant highly expressed in testis. Among these genes, eight genes were included in the kaonashi gene list. Then, we performed quantitative RT-PCR using eight tissues including those not used in transcriptome analysis, and finally confirmed that five genes are the testis-specific kaonashi genes. Subsequently, in order to determine whether these genes are necessary for normal physiology, we performed RNA interference against the five genes in cultured cells. We found that knockdown of one of the five kaonashi genes caused G2/M cell cycle arrest with accumulation of polyploid cells. We are now analyzing the intracellular localization to gain insight into the gene functions.

In summary, we successfully identified five kaonashi genes restrictedly expressed in the silkworm testis, and found that one of the five genes is crucial for normal cell cycle progression.

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BA P 01: Functional analysis of a BmTetraspanin, which is increased in the gene expression in response to *Bombyx mori* nucleopolyhedrovirus (BmNPV) infection.

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BmNPV is a disease that causes serious damage to silkworms, but much has yet to be clarified regarding the antiviral mechanism of the host. In our previous study, we analyzed the expression of host genes by microarrays when BmNPV was infected into cultured silkworm cells. As a result, we identified several genes that could be considered infection response genes. In this study, we focused on BmTetraspanin, which is a transmembrane protein that has been reported to be involved in the cytoplasmic invasion of pathogens and examined whether it is involved in the host antiviral mechanism. Initially, we established a system to knock down the gene expression of endogenous BmTetraspanin by adding BmTetraspanin dsRNA to cultured cells. Subsequently, we used a recombinant virus to determine virus infection efficiency, which is the firefly luciferase gene was ligated downstream of the promoter of the p10 gene, a late-expressed gene of BmNPV. NPV-derived luciferase activity was measured after infection, providing an easily quantifiable method to estimate the relative viral load of silkworm cells. At the same time, cultured cells were collected, and the amount of viral DNA in the cultured cells were quantified by real-time PCR. Comparing the two methods, there was a correlation between the luciferase activity of cell lysates and the amount of viral DNA in cultured cells. And it was shown that the virus infection efficiency was significantly increased by knockdown of BmTetraspanin. In order to clarify whether BmTetraspanin is actually involved in BmNPV infection *in vivo*, we are generating BmTetraspanin-knockout silkworm line using transcription activator-like effector nuclease-mediated gene targeting (TALEN).

This study was supported by a grant from Science and Technology Research Partnership for Sustainable Development (SATREPS).

BA P 02: Insight into the molecules and processes involved in the formation of lepidopteran scales

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Abstract

Scales are symbolic of Lepidoptera. “What and how to make scales?” and “How to use scales?” are common interests in biology, biomimetics and material science. Scales from adult Lepidoptera have been extremely difficult to solubilize in any solvent, which has hindered molecular studies on them. Here we succeeded in solubilizing developing wing scales in a urea-containing buffer, allowing analysis of the protein composition of scales from *Bombyx mori*. We identified 58 and 61 cuticular proteins (CPs) from late pupal and pharate pupal wing scales with proteomic analysis and found that almost half of them were histidine (His)-rich CPs. Functional studies using RNAi revealed that His-rich CPs with different His-contents play different and critical roles in constructing the microstructure of the scale surface. In addition, films were successfully synthesized by crosslinking 45% and 15% His-rich CPs with laccase 2 (Bmlac2) and a sclerotization precursor (NADA or NBAD). This molecular study of the scale provides fundamental information to understand how such a fine microstructure is constructed and new insights into the potential-application of CPs as new biomaterials.

BA P 03: Rapid identification of silkworm microsporidia by matrix-assisted laser desorption/ionization time-of-flight mass spectrometry

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Microsporidia cause the disease pébrine in silkworm (*Bombyx mori*) and are known to be detrimental to sericulture. Pébrine is one of the most serious insect disease. More than 1,300 species are found. Recently, colonies grown in a medium can be directly differentiated on a matrix-assisted laser desorption/ionization time-of-flight mass spectrometry (MALDI-TOF MS), named MALDI biotyping. The microsporidian species *Nosema bombycis* was rapidly identified in silkworm using MALDI-TOF MS. Spores were extracted in 70% formic acid, then re-extracted after the addition of acetonitrile. Extracts (0.5 □L) were spotted on the target plate. The Autoflex III instrument was used in the linear positive ion mode. Mass spectra were generated in the range of m/z 1,000-20,000. Several types of microsporidian spores purified from infected silkworm could be distinguished based on the differences in their mass fingerprints. Microsporidia growing in a silkworm larva were also identified based on their mass spectra after rapid separation using filtration and centrifugation for 30 min. Moreover, solvents used in this MALDI biotyping analysis were low in costs and required in low volume. Therefore, MALDI biotyping should be the first choice for insect disease diagnosis because of cost-effective rapid identification.



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BA P 04: Analysis of biologic and economic parameters to evaluate the antiviral activity of Bm5 drug on *Bombyx mori* larvae infected by BmNPV

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Background: *Bombyx mori* nucleopolyhedrovirus, BmNPV, is the pathogen that causes the highest mortality in *Bombyx mori* L caterpillars, and this viral disease is not effectively controlled in the field yet. The compound identified as Bm5 (Zinc12888007) molecule is considered as a promising substance that inhibits the viral cathepsin enzyme (V-CATH), which is responsible for liquefaction of larvae and horizontal transmission of the virus. **Aims:** the objective of this investigation is to evaluate the action of the antiviral drug Bm5 in a preventive manner on biological and economic traits from larvae infected with BmNPV. **Methods:** hybrid caterpillars in the third larval stage of *B. mori*, were donated by the company BRATAC S/A (Paraná, Brazil). The infection was performed on the first day of the fifth instar by the ingestion of BmNPV wild-inoculated mulberry leaves at 8×10^8 COPS/mL (COPS=polyhedral viral occlusion bodies/milliliter). After infection, the silkworms were treated with 10 µL of the 10 mg/mL of antiviral drug Bm5 (InterBioscreen, Russia) diluted with 0.02% Pluronic-F127. Two pilot experiments were carried out with 20 caterpillars in the fifth larval stage in each group. There were three control groups without virus infection and two control groups with virus infection, being Bm5 drug administered in the same way as described for the virus administration. The test was carried out with one dose after the infection procedure. The parameters analyzed were: larval and pupa mortality; milky liquid trailing and tegument rupture; quantity, quality and weight of cocoons; silk percentage. **Results:** The survival rate of virus infection was 45-50%, and on Bm5 treatment was 85-90%. The drug and the diluent reagent did not interfere with the analyzed parameters. **Conclusion:** the Bm5 drug considerably decreases the mortality of BmNPV infected caterpillars when is administrated just after BmNPV infection. So, these results could contribute to future applications to control the BmNPV infection in the field of sericulture.

Keywords: *Nucleopolyhedrovirus*, silkworms, infection control, Bm5 drug

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BA P 05: Differential expression of the *BmsbRNA* gene in larval tissues and their relationship to BmNPV infection

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Background: The stem-bulge RNAs (sbRNAs) are non-coding molecules homologous to mammals Y RNAs, which are stem-loop structured ncRNAs, essential for the licensing of DNA replication initiation. From invertebrates, sbRNAs with the same function were described for *Caenorhabditis elegans*. In insect genomes, ncRNAs genes with sbRNA sequence motifs and structures were first detected by our research group, the *BmsbRNA* in *Bombyx mori* and, more recently, the Dm1 gene in *Drosophila melanogaster*. Regarding the *B. mori* cocoon production, the BmNPV is one of the major pathogens for this insect, resulting in massive larvae death and being extremely harmful to world sericulture. **Aims:** The analysis of the *BmsbRNA* gene expression on larval tissues is essential data for the gene functional analysis and their relationship to BmNPV infection. **Methods:** The hybrid silkworms at the end of the 3rd instar were gently supplied by BRATAC S.A. (Paraná, Brazil). Caterpillars were reared with fresh mulberry leaves until the 5th day of the 5th instar, at a temperature of $25 \pm 1^\circ\text{C}$ with 12 hours light/dark photoperiod. The experiments were carried out with tissues extracted from healthy larvae: male and female gonads, silk gland, Malpighian tubules, and fat body. Regarding BmNPV infected larvae, only the fat body was analyzed. For RNA extraction, tissues were processed with TRIzol-LS and DNase I (Invitrogen), and cDNA synthesis was carried out with iScript™ cDNA Synthesis Kit (Bio-Rad). The RT-qPCR was performed with Fast SYBR Green Master Mix, in triplicates and three independent experiments. The relative expression analyses were based on the $2^{-\Delta\Delta CT}$ method, using as control a segment from rRNA 5S gene. **Results:** On the 5th day of the 5th instar we detected overexpression of the *BmsbRNA* gene in a mix of gonads sample, in an order of 1000 fold more than silk glands and Malpighian tubules. Testis and ovary samples presented an increasing level of expression from the beginning of the 4th instar until the 1st day of the 5th instar, but the gene expression in the testis was higher than ovary in all the periods verified. On the 5th day of the 5th instar, both samples decreased the expression rate, but testis was still 42 fold higher. The results of healthy and BmNPV infected fat bodies shown that *BmsbRNA* expression is reduced by 32 fold in the 3rd day and undetected on the 5th day of the 5th instar. **Conclusion:** The results showed that the *BmsbRNA* gene expression is tissue/larval stage-dependent, and could be related to the testis proliferation state. Additionally, the expressive inhibition of this gene expression in BmNPV infected larva fat body shows a new metabolic data in that viral disease.

Keywords: Stem-bulge RNAs, non-coding RNAs, *Bombyx mori*, larval tissues, BmNPV

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BA P 06: Improvement of the injection method for the genome editing

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Recently, the genome editing technologies, such as the TALEN and CRISPR-cas9 system, have also been developed in the silkworm, *Bombyx mori*. These technologies are powerful tools for identifying various phenotypes that may lead to agricultural benefits. However, it is required the precise technique under the microscope to perform these approaches; in particular, when injecting the genome editing constructs into each egg immediately after oviposition. In this study, we aimed to establish a simple injection method in the CRISPR-cas9 system. For beginners, the most difficult technique is to insert a glass capillary into a hole on egg drilled with a tungsten needle. Therefore, after making a hole in the egg, we just put the solution including the genome editing constructs on the hole instead of inserting a glass capillary. We synthesized sgRNA designed with the sequence of the oily mutation (*BmBLOS2* gene), and performed the CRISPR-cas9 system by the new method. As a result of this approach, we succeeded to obtain the larvae which showed the oily mosaics, and their percentage was 40% (17 oily mosaics/42 hatched eggs). Therefore, we decided that this approach allows easy performing the genome editing techniques.

BA P 07: QTL analysis of high cocoon yielding ability of the silkworm using ddRAD-seq

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In order to develop genetic markers related to high cocoon yielding ability of the silkworm, *Bombyx mori*, we have conducted quantitative trait locus (QTL) analysis on three traits (weight of cocoon, cocoon shell weight, and cocoon shell ratio) related to the high cocoon ability in the silkworm using double-digest restriction site-associated DNA sequencing (ddRAD-seq). First, we generated F₁ progeny derived from the cross of the silkworm strain ‘Nichi01’ showing high cocoon yielding ability and the strain ‘Daizo’ showing normal cocoon yielding ability. We then generated 143 F₂ progeny derived from a pair of the F₁ progeny. The weight of cocoon, cocoon shell weight and cocoon shell ratio were evaluated for each F₂ progeny. Genomic DNA of the parent of the F₁ progeny, the parent of the F₂ progeny, and the 143 F₂ progeny were extracted and a library for the ddRAD-seq was generated using the genomic DNA digested with a pair of restriction enzymes, PstI and MspI. ddRAD-seq was performed using Illumina HiSeq sequencer and over 2 million RAD tags were generated in average per individual. A linkage map consists of 28 linkage groups, which is equal to the number of chromosomes in the silkworm, were then constructed using 1119 SNP markers commonly genotyped between the F₂ progeny using the RAD tags. QTL analysis on the three traits were conducted using the linkage map and quantitative data of the three traits by R/QTL package. We identified one statistically significant QTL ($p < 0.05$) for each trait, respectively.

BA P 08: Responses of susceptible silkworm strain to *Bombyx mori* nuclear polyhedrosis virus by inoculation with *Beauveria bassiana*, *Metarhizium anisopliae* and *Nosema bombycis*

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The grasserie disease is the most important disease in sericulture because outbreak of the disease causes great economic loss for the industries. The pathogen of the disease is *Bombyx mori* nuclear polyhedrosis virus (BmNPV). Therefore, responses of 30 silkworm (*Bombyx mori*) strains had been examined against inoculation with BmNPV, and the Kanko strain had been the most susceptible in the tested 30 strains (Murakami and Miyamoto, 2013). On the other hand, silkworms are also susceptible to white muscardine disease, green muscardine disease and pebrine disease, and pathogens of these diseases are *Beauveria bassiana*, *Metarhizium anisopliae* and *Nosema bombycis*, respectively. Outbreaks of these diseases cause also great loss in sericulture. Here, we present the results from inoculation of Kanko strain and of other strains with these pathogens. Second stage larvae were coated with spores of *B. bassiana* or *M. anisopliae* and were fed on diets contained with spores of *N. bombycis* and were reared at room temperature. Then died larvae were counted and mortalities of the tested strains were compared. As results, there were not clear differences among mortalities of tested strains inoculated with *B. bassiana* or *M. anisopliae*. Moreover, mortality of Kanko strain was the lowest among strains inoculated with *N. bombycis*. This revealed that Kanko strain might be the most susceptible to infection of BmNPV but might not be for infection of *B. bassiana*, *M. anisopliae* and *N. bombycis*. This study was supported by a grant from Science and Technology Research Partnership for Sustainable Development (SATREPS) project.

BA P 09: Development of Method for Long-term Preservation of Silkworm Strains using Frozen Germ Cells

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Many kinds of strains or races have been established for the domesticated silkworm, *Bombyx mori*, due to its importance for sericulture and use as an experimental animal. It is estimated that there are more than 2000 strains of the silkworm in Japan. To maintain such a large bio-resources, each strain usually has to be reared at least annually, because the diapausing eggs (early embryos) can only be preserved for up to a year. Silkworm rearing, however, requires several kinds of labor intensive activities such as management of a mulberry field, preparing a rearing room, daily care for animals, and so on. There is also some concern about the loss of unique strains due to environmental hazards, genetic contamination and changes in genotype during the passage of generations. To alleviate these shortcomings and risks, studies for long-term preservation using frozen germ cells have been carried out. Those studies are mainly classified into two categories: one using frozen ovaries and the other using frozen sperm.

Development of Method for Freezing and Transplanting Ovaries. The ovaries were removed from larvae at either 3rd, 4th, or 5th instar, and cryopreserved in liquid nitrogen (-196 °C). Thawed ovaries were transplanted to be surgically castrated female larvae at the same or a different developmental stage. Freezing tolerance of ovaries becomes stronger with older instar larvae and binding rate of oviduct (thread body) becomes higher with younger instar larvae. Heat shock to larvae is effective for Freezing and transplanting ovaries

Development of Method for Freezing Sperm and Artificial Insemination. We developed an instrument for artificial insemination consisting of a capillary tube, an N2 gas cylinder, two pressure regulators, a three-way electromagnetic valve and a foot-switch. The sperm collected from male moths was frozen in a deep freezer at -80°C, and then sperm was put in liquid nitrogen (-196 °C). Trypsin acts the same as glandula prostatica for sperm activation. Female moths were artificially inseminated with cryopreserved semen. The fertility of inseminated females differed by the strain (0% to 100%). But addition of sperm from triploid males is improved the fertility. The eupyrene sperm of low fertilization strain confirmed to be alive by observation under a fluorescence microscope.

Development of Method for Obtaining Offspring using both Cryopreserved Ovaries and Sperm. To long-term cryopreservation of silkworm genetic resources, we investigated an application of the cryopreserved germ cells of both sexes in combination with the transplantation of frozen ovaries and artificial insemination with frozen sperm. We confirmed that the recipient females yielded fertilized eggs and, in the next generation, the larvae hatched from the fertilized eggs possessed apparent genetic characters of the donors and completed post-embryonic development. The germ cells of both sexes survived after freezing for more than 4 years. Then the germ cells are kept frozen for more than 15 years.

Section 5

Post-cocoon technology

PC-LP: Lead Paper

**Technological interventions for supporting cottage basin reeling units
for quality improvement in Tropics.**

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ABSTRACT

India is the second largest producer of raw silk in the world and major share of the yarn produced is from Karnataka in India. In Karnataka 50 percent of yarn is produced in cottage basin reeling units using both bivoltine and multi bivoltine cocoons. Cottage basin is a traditional yarn reeling device for reeling silk yarn from cocoons and quality of silk produced mainly depends on the raw material, machine used , process method adopted, quality of water, and skill of reelers. Reelers still follow the traditional processing method as technologies have made very little impact on them. In order to upgrade the machinery and process parameters for producing quality raw silk various technological interventions and machines has been developed and combined them into suitable package and tested in the field and proven to be beneficial . This paper emphasizes the need for technological interventions necessary and the effect of different technologies in improving the quality and productivity of micro enterprises. Reelers in the sericulture developing nations can be benefitted with these low cost technologies for up gradation and adoption for increasing the yield to produce quality silk economically.

Key Words: Technological Interventions: Quality improvement.

PC O 01: DEVELOPMENT OF NOVEL FABRICS USING VOID RAW SILK AND ITS LOW STRESS MECHANICAL AND THERMAL COMFORT PROPERTIES

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ABSTRACT:

CSTRI, CSB has developed new technology for the production of void raw silk in reeling process. During the process of reeling of cocoons, PVA yarns are introduced and reeled together with the raw silk, with standard processing conditions. These yarns were utilized for the production of fabrics in power looms with bivoltine silk as warp and void silk produced with 10, 20, 30 cocoons per end along with PVA yarn as weft. After weaving the fabrics, the fabric samples were degummed and dyed using reactive dyes in HTHP dyeing machine, wherein, the PVA component was dissolved so as to create void in the raw silk fabrics and hence improve the fabric comfort properties. The Indian PVA yarn having 50 denier was used in the study. For comparison purpose raw silk was also reeled with 10, 20, 30 cocoons per end and used for the production of fabrics. The dyed fabric samples were then measured for low stress mechanical properties using Kawabata Evaluation System (KES). The tensile properties viz., tensile linearity (LT) did not show significant difference between the raw silk and void silk fabrics whereas void silk fabrics shown significantly more tensile strength compared to raw silk fabrics, which may be attributed the structure of the fabric. Further, as the number of cocoons increased the tensile resilience increased for both raw and void silk fabrics. However, the raw silk fabrics have shown better tensile resilience compared to void silk fabrics. The fabric extensibility EMT at maximum applied force i.e., elongation property of void silk fabrics have shown significantly more compared to raw silk fabrics. Based on shear properties, the void silk fabrics are soft and having better drape compared to raw silk fabrics. The compression properties viz., Linearity of compression (LC), Compressional resilience (RC) did not show significant difference between raw silk and void silk fabrics, whereas compressional energy (WC) has significantly increased in case of void silk fabrics thus indicating that void silk fabrics are more fluffy fabrics. The void silk fabrics have shown higher coefficient of friction (MIU), lower mean deviation of coefficient of friction (MMD) compared to raw silk fabrics, which indicate that void silk fabrics possess greater friction and uniform fabric surface, whereas the higher values of geometrical roughness (SMD) indicate surface roughness effect of the void silk fabric. The hand values are evaluated from the low stress mechanical properties viz., Koshi i.e., stiffness of void silk fabrics are much less compared to raw silk fabrics, thus indicating that void silk fabrics are user friendly, Numeri i.e., smoothness, Fukurami i.e., fullness & softness of void silk fabrics are found to be significantly on the higher side compared to raw silk fabrics. The Total hand values (THV) of void silk fabrics are found to be in the range of 4.0 ~ 5.0, which are significantly better values than that of raw silk fabrics in case of winter wear applications. The thermal comfort properties of these fabrics viz., Q max values of raw and void raw silk fabrics did not show significant difference whereas the 30 cocoons reeled fabrics have shown slightly higher Q-max value, indicating that there is more rapid movement of heat from the body to the fabric surface resulting in a cooler feeling fabric. The clothing insulation values (CLO) and Thermal insulation value (TIV) of the void raw silk fabrics are slightly higher than raw silk fabrics. The void silk fabrics produced from 30 cocoons have shown maximum TIV of 44.41%. Thus the novel void raw silk fabrics could be useful for variety of applications for the development silk industry.

PC O 02: Development and standardization of silkworm cocoon quality testing and grading protocol for multi-bivoltine (Kolar Gold) crossbred cocoons in Karnataka, India

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Abstract

Sericulture industry in Karnataka, India is characterized by small cocoon producers and small converters. To determine the fare sale price for the cocoons, quality assessment needs to be carried out before the commencement of bidding process in the cocoon markets. To improve the cocoon and silk marketing system in the state, the Government constituted ‘Technical Committee’ which recommended cocoon quality grading. In this context, development and standardization of silkworm cocoon quality testing protocol for the popular crossbred silkworm, ‘Kolar Gold’ (CSR2 x PM) was taken up by KSSRDI. More than 50,000 cocoon lots were screened at three government cocoon markets. The protocol involved three steps testing viz., preliminary screening (step-1) where percentage of defective cocoons, presence of non-pupated cocoon and number of cocoons per Kg are tested. The cocoon lots which pass the preliminary test are subjected to step-2 testing where cocoon weight, shell weight and cocoon shell ratio are assessed and estimated renditta is determined. In the final step-3 cocoon shell moisture level is determined and cocoon grade is assigned. The silkworm cocoon quality testing protocol for ‘Kolar Gold’ has been approved by the Government of Karnataka and cocoon testing laboratories are established at seven major government cocoon markets where the developed protocol is installed and functional.

Key Words: *Cocoon quality Testing; CQT Protocol; Cocoon Grading*

PC O 03: A study on Muga silk twist optimization and weaving of Muga silk Crepe and Muga Chiffon fabrics by retaining natural Golden colour for product diversification

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Abstracts:

The Golden Yellow Muga Silk is produced only in Assam and North Eastern states of India by Muga silk Worm (*Antheraea assamensis*). It is the most costly natural textile fiber in the world Muga Raw Silk yarn had been sold at about US\$ 300.00 – 325.00 per kilogram. Presently 1 square meter of plain Muga fabric costs about 30.00 – 45.00 US\$. However Muga silk products are confined to plain weave and limited traditional loom finished fabrics like Mekhala, Chaddar and Sarees. This study has been objected to study the improvement of Muga yarn quality by optimization of twists and develop new Muga silk fabric product in form of Muga Crepe and Muga Chiffon for its wider application in Muga silk garment making.

Muga reeled yarn of 60/70 (Average 65 denier) has been used for this study. Pre twist soaking of yarn was done in water with 2% soap oil and 1% coconut oil. The twist optimization study was conducted on Up-twister type twisting machine in twist range from 1250 – 2000 TPM (twist per meter). Twist study was done for both Z-Twist (clockwise) and S-Twist (counter clock wise). It has been found that even at 2000 TPM twist level it retains tenacity of 3.30 -3.40 gram per denier and elongation of 33.00 -36.00 percent.

Weaving study for Muga Crepe and Chiffon in natural Golden colour was conducted in 2x2 power-looms. In Muga Crepe fabric weaving reeled untwisted Muga yarn 60 /70 denier with 0-Twist was used as warp thread. Weft yarn used in Muga Crepe weaving was 1 pick S twisted + 1 pick Z twisted, each of 60/70 denier with 2000 TPM twist. The woven Muga Crepe was having 82 picks per inches in warp and 54 picks per inch in weft. Muga chiffon fabrics of 36 inches width were woven by using 60 / 70 denier Muga yarn. In warp 2S + 2Z yarns of 2000 TPM was used and weft with S –Twist of 2000 TPM was used. The woven Muga fabric has a resultant weave of 84 ends per inches and 58 picks per inches.

With the object of getting Crepe and Chiffon effect in Muga fabric by retaining its natural Golden colour, first fabric was soaked in water with trace of soaking agent for 3 hours and the boiled in 10% soap solution for 30 minutes. In the fabric thus produced natural coloured Golden Muga fabric Crepe and Chiffon effect was obtained with 18 % crimp in width in case of golden Muga Crepe and in case of Chiffon crimp of about 18 % was found in length, while crimp in Chiffon width was about 15 % . The fabric so produced has been found suitable for stitching garments.

Key Words:

Muga Silk, Golden colour, Twisting, Natural Colour, Crepe, Chiffon, Crimp, tenacity, Elongation.

PC O 04: Studies on Dimensional, Comfort and Hand Properties of Eri Silk Single knit fabrics for next-to-skin garments

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Abstract

Eri silk is a highly valuable wild fibre available widely in northeastern parts of India, which has good physical and thermal comfort properties. To make a better use of this natural material like next-to-skin knitted garments, it is necessary to investigate the dimensional, moisture transmission and hand properties of the single jersey knitted fabrics. Through this work, an attempt was made to develop eri silk single knit fabrics structures such as single jersey (SJ), single pique (SP) and honeycomb (HC) with three different yarn counts such as 25.00Tex (2/80sNm), 16.68Tex (2/120s Nm) and 14.26Tex (2/140s Nm) and two different loop length levels of tight, and slack. The developed samples were conditioned in the standard testing atmospheric condition of $20^{\circ}\pm2^{\circ}\text{C}$ and $65\pm2\%$ RH for 24 hours before to the testing of samples. Dimensional, moisture and thermal comfort properties of the fabric samples were evaluated according to the international textile testing standards. All the sixteen low stress mechanical parameters were determined with the four modules of Kawabata instrument. The study showed that the eri silk yarn count, fabric structures, and their corresponding loop length has a significant influence on the dimensional parameters, moisture absorbency, drying rate, thermal insulation of eri silk knit fabrics. With the increased loop length, tensile, bending and compression properties of eri silk knit fabrics improved significantly. Eri silk single jersey fabric showed better performance for winter next-to-skin garments (inner wear), whereas honeycomb fabric showed better performance for the winter outer wear applications.

Key Words: eri silk, dimensional, comfort, hand properties, single knit structures, yarn count, loop length

PC O 05: DEVELOPMENT OF STRATEGIES FOR SAFE AND PROFITABLE DISPOSAL OF SERICULTURE BY-PRODUCT FOR VALUE ADDITION IN KARNATAKA-INDIA

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ABSTRACT

Sericulture industry is an agro based industry involving different stages of operations from soil to fabrics. In every operation, wastes & by-products are generated and these cellulosic and proteinous materials are natural and eco- friendly and have good demand in the cosmetic, medical, pharmaceutical, agriculture, horticulture and textile sectors as raw materials for various product development. Reduce, Reuse and Recycle is the slogan of the profitable industries, hence Government of Karnataka (GOK) has asked to draw strategies for effective utilisation of sericulture by products for value addition on industry scale. Silk fibre waste, sericin, litter, pupae and mulberry shoots are the chief by- products of sericulture industry and are available in huge volume. About 50-60% cottage/filature basin reeling sector do not use completely dried cocoons for reeling, & such pupae well soaked in hot water for long period resulting in infection and produces green house gases such as carbon dioxides and methane and untreated sewage water from reeling units contain large amount of nitrates, phosphorus and ammonia which increase BOD level that affects seriously the ecology and aquatic life, which directly or indirectly influence civilized society. Other seri-bio waste may not cause serious ecological impact but underutilized. KSSRDI has made head way in developing and, standardising the process of utilization of by-products and supporting to establish start up industries in support with GOK. The paper discusses the sericulture bio wastes & its impact on environment, production of value added products, and preparation of road map for start up industries and its impact on growth of sericulture income.

Key words: Sericulture, By-products, Sericin , Cottage basin, Start-ups

Section 6

Economy

EC-LP: Lead Paper

Role of ISC for the development of Sericulture & Silk Industry in the world

By Dileep Kumar .R. Programme Coordinator, International Sericultural Commission

1. Introduction

Sericulture and Silk Industry has emerged as an ideal rural avocation for poverty alleviation and employment generation in many developing countries. Its activities are aligning with the Sustainable Development Goals (SDG) set by United Nations. The industry that has been successfully developed as a commercially viable economic model for rural development can be developed/introduced in many countries in the world as an ideal occupation for poverty alleviation. The International Sericultural Commission (ISC) has initiated many innovative programmes for the development and popularisation of silk industry across the globe. The ISC has been focussing mainly to converge programmes and assistance available from different agencies like; Government Departments, International Organizations, private entrepreneurs, etc., for bringing the much needed global synergy for transforming the silk industry as an effective tool for inclusive development and poverty alleviation. Specific strategic plans have been devised for the sustained development of the industry in potential countries of the world.

2. About ISC

International Sericultural Commission (ISC) is a UN registered inter-governmental organization engaged in the development of sericulture and silk industry across the globe. The ISC, which was institutionalised on 8th August, 1960 was functioning from Lyon, France till 2012. The Head Quarters of ISC started functioning from India with effect from 1st January 2013, consequent upon the election of an Indian nominee as the Secretary General. The shifting of ISC HQs has heralded with a number of innovative activities, which are now immensely benefiting the ISC member countries.

2.1. Structure of ISC

The ISC is governed by an international treaty signed by the participating Countries which was later adopted as its statute. At present, there are 20 Member Countries and 35 Associate Members in ISC. The 17 Member Countries are Afghanistan, Bangladesh, Brazil, DPR Korea, Egypt, France, Ghana, Greece, Indonesia, India, Iran, Japan, Kenya, Madagascar, Nepal, Romania, Syria, Thailand, Tunisia and Uzbekistan. The Governing Council bodies are “the Conference” and “the Executive Committee”. The Aims and Objectives enshrined in ISC Statutes are being implemented through a Secretariat headed by the Secretary General. The Secretary General is the Chief Executive Officer of ISC, who is elected by the Member Countries on a three year term.

2.2. Aim and Objectives

The chief aim of ISC is to encourage and promote the development of sericulture and silk industry across the globe. To achieve this, the following Objectives are laid out:-

- a) To act as the Global Agency on all matters related to sericulture and silk industry,
- b) Facilitate carrying-out enduring research and investigations on sericulture science,
- c) Collaboration with other international organizations,
- d) Undertaking frontier areas of research using silkworm or other sericigenous insects as “biological model” and silk as a material,
- e) Exchange of knowledge and genetic materials,
- f) Capacity building,
- g) Exchange of scientific information through sericultural documentation centre,
- h) Publication of the scientific journal “Sericologia”, and specialized publications, etc., and
- i) Organization of international scientific and technical meetings.

2.3. The activities

Ever since the HQs of ISC shifted to India, many innovative activities were conceived with the aim of introducing / developing sericulture as an effective tool for poverty alleviation and employment generation among the rural population. The major activities being undertaken by ISC are briefly narrated below:-

2.3.1. Global leadership on silk industry

Being the only inter-governmental organization on silk industry, ISC has been protecting the interest of sericulture and silk industry at global forum. ISC is acting as a referral agency for vetting sericulture developmental projects which are being funded from international donor agencies. ISC has also been extending technical support to countries for the preparation of sericulture developmental projects, its implementation and later sourcing financial assistance from multilateral agencies. The mandate also includes global review of silk and silk products on a regular basis aiding various stakeholders to frame policy options for the sustained growth of the industry.

2.3.2. Promoting research and investigations on sericulture science

The ISC is proud to carry forward the rich legacy of advanced research on sericulture science initiated by Sir Louis Pasteur during 1860s. These efforts of many renowned scientists, including Sir Louis Pasteur, culminated in convening the 1st International Congress on Sericulture Science at Italy during 1870. Decisions taken in one of these Global meetings held during 1948 led to the formulation of a permanent inter-governmental body christened as “International Sericultural Commission”. Subsequently, the ISC was officially institutionalised on 8th August, 1960.

It has been acknowledged worldwide that since the publication of the text instituting the ISC Convention, fundamental research work using silkworm as a biological model multiplied the world over. Due to the collaboration and cooperation through these works, significant and useful outputs were generated in different parts of the world thereby benefitted the industrial, pharmaceutical and cosmetic sectors. There are numerous possibilities still exist for the usage of silkworm in the areas of molecular biology, genetics and biotechnology which are being now explored. The genome

sequence of *Bombyxmori* was completed in 2004 by Japanese and Chinese teams with the active association of ISC. Thus the ISC has been facilitating promotion of R&D activities among the countries and institutions to enhance the productivity and quality of silk. This type of collaboration is currently underway among Japan, India, Uzbekistan, Bulgaria, Australia, China, Romania, Bangladesh, etc.

ISC is also recognizing reputed R&D institutions as “Global Centres of Excellence” facilitating the countries to availing services on critical areas of research and development. Recently a R&D institution from Romania; Research Centre for Advanced Research in Sericulture and Promotion of Silk Production (RCARS-PSP) has been recognized as a “Global Centre of Excellence for Advanced Research in Sericulture and Promotion of Silk Production” (GCEARS-PSP).

2.3.3. Collaboration with international organizations

ISC has established collaboration with leading international organizations like FAO, IFAD, World Bank, UNDP, JICA, UNICEF, ITC, ESCAP, etc. on issues related to development of sericulture and silk industry. These collaborations have culminated in implementing various sericulture development programmes, enhanced the quality of research and technical manpower on sericulture science and silk industry, improved income generation in sericulture by enhancing the productivity and quality of silk, extensive infrastructure investments in sericulture industry and transforming sericulture practice as an economically viable occupation for employment generation and poverty alleviation.

While the above organizations have reiterated their intent for collaborating with ISC to support the countries under the Technical Cooperation Programme (TCP), recently ISC has also established tie-up with African Asian Rural Development Organization (AARDO) and South Asian Association of Regional Cooperation (SAARC). The developmental assistance from all these international organizations are providing the much needed synergy for accelerating the growth of sericulture across the nations.

2.3.4. Volunteer Expert Programme (VEP)

Sericulture is now being introduced in many developing countries where the expertise on implementing sericulture programme is very limited. The financial resources available under the project/programme may also be not sufficient to hire expert services from sericulturally advanced countries. In order to extend a helping hand to such countries, ISC has introduced a new programme called “Volunteer Expert Programme” wherein the countries may avail the services of about 55 sericulture experts from a list of Volunteers pooled by the ISC. The terms and conditions of the programme are given below:

1. The recipient country may avail the services of the expert without paying any consultancy charges,
2. The travelling, boarding, lodging and other expenses shall be met by the recipient country, and
3. The expert shall, after completion of the consultancy period, submit a report to recipient country, in the areas where the expert service has been sourced.

2.3.5. Exchange of knowledge and genetic materials

The last two decades witnessed significant progress in developing innovations and practices on sericulture and silk industry. Since the silk industry provides gainful employment to large sections of marginalized people across the continents, many countries are ready to share their knowledge for the orderly development of the industry. For example, the Indian Government has committed to support the countries for replicating the successful model of commercial sericulture practise developed in the country. Thus, ISC is making all out efforts to facilitate free flow of information, technologies and practices among the countries.

Large quantity of genetic materials on silkworm and mulberry are dispersed around the world un-utilized, under-utilized, untapped or untouched. It is extremely important for the countries concerned to share these materials for research purpose thereby facilitating aggregation of potential traits for enhancing production, productivity and quality. All the years of hard work would be wasted if sericulture researchers do not utilize these genetic materials for the benefit of the poor farmers.

Keeping these facts into consideration, ISC has been encouraging Member Countries to share permissible varieties of genetic resources through the ISC platform for research purpose. The R&D institutes or agencies located in other countries can also exchange genetic materials through ISC on reciprocal basis. Many countries have already initiated steps for sharing of genetic materials.

2.3.6. Capacity Building

Under the Capacity Building Programme, different types of activities are organised by ISC either through its own funds or sourcing support from international and regional agencies and the Governments of the Member Countries. The details are given below:

a) Training Programmes of ISC

The ISC organizes training to the persons nominated by the Government of the Member Countries. Such nominated candidates should be associated in the sericulture developmental programmes implemented in their respective countries and should have adequate qualification and knowledge of English to undergo training in a foreign country. The training shall be arranged in sericulturally developing countries like India, Japan, or Thailand. While the host country will arrange for the training facilities, accommodation and other expenses, the recipient country would meet the international travel expenses of the trainees.

b) Training programmes under Indian Technical Economic Cooperation (ITEC) of Ministry of External Affairs, Govt. of India

ISC organises a special training on sericulture and silk industry for the candidates nominated from its Member Countries at Central Sericultural Research & Training Institute, Mysore. This programme is sponsored by the Ministry of External Affairs, Govt.

of India under the Indian Technical Economic Cooperation (ITEC).

Under the programme, the sponsored candidate shall be provided with return air journey in economy/excursion class, living allowance, accommodation in the place of training in Hotel/Hostel, project allowance, study tour, etc. The cost of organizing the training shall also be met under the programme. The training programme proposed for the year April 2019 to March 2020 are given below:

Sl.No.	Name of the course	Period	No. of trainees
1	Training on Sericulture and Silk Industry at Central Sericulture Research and Training Institute, Mysore, India	2 nd to 29 th September 2019	30
2	Training on Post Cocoon Technology at Central Silk Technological Research Institute, Bangalore, India	6 th January to 2 nd February 2020	20
3	Training on Mulberry Silkworm Seed Production Technology	7 th to 20 th October 2019	20

c) Scholarship Programme

This programme aims to inspire the youngsters in sericulturally developing ISC Member Countries to take up research on sericulture and related fields or specialised studies/assignments by providing them opportunity to further their interest on sericulture science. The programme details are:

- ☞ The countries hosting the scholarship study shall be Japan and India,
- ☞ The host countries meet the maintenance expenditure covering facilities like guide support, laboratory, accommodation, etc.,
- ☞ ISC shall provide the international travel expenses and appropriate living allowance for the stay of the candidates,
- ☞ The duration of scholarship shall be a maximum of one month.
- ☞ The candidates deputed by the Government of the Member Countries shall possess adequate qualification and knowledge of English to live in a foreign country.

2.3.7. Organizing international scientific and technical meetings

One of the main activities of ISC has been to organize Global Meetings on sericulture and silk industry. These Meetings offers an exclusive opportunity for policy planners, technocrats, international scientists, universities, faculty & students of Institutions of research, including those in silk and silk related businesses to interact, share and exchange the most recent advancements in their fields. The recommendations evolved in these meetings have paved the way for adopting technologies and innovations, taking up developmental programmes, policy changes for the organized development of silk industry, furthering research and technical activities, etc. The following are the different types of Meetings organized by ISC:

- a) International Congresses on Sericulture and Silk Industry. The 1st Congress was held at Italy during 1870 and the recent one at Bangalore during November 2014.
- b) Regional Consultative Meetings based on the specific needs of Regional international agencies like SAARC, ESCAP, etc.
- c) International Workshops to enlighten the country delegates on various advantages on sericulture and silk industry.
- d) Technical Meetings and exposure visits as per specific needs of countries, agencies and institutions.

2.3.8. Publication of “Sericologia”, and specialized publications

SERICOLOGIA is a reputed quarterly journal dedicated to the science of sericulture published by International Sericultural Commission. The journal started publication in the year 1948 from France with the title ‘Journal of Silkworms’ which later renamed as “Sericologia”. The journal serves as the most effective medium to disseminate technical and scientific knowledge even to the farthest corners of sericultural areas across the globe.

ISC has also been involved in the publication of many books and magazines on sericulture and silk industry like; Proceedings of ISC Congress, Regional Consultative Meetings, International Workshops and other Technical Meetings.

2.3.9. Louis Pasteur Award

ISC instituted the only International Award on Sericulture and Silk Industry, known as “Louis Pasteur Award”, which is considered as the Nobel Prize in Sericulture and Silk Industry. Persons who have contributed outstandingly for the development of sericulture and silk industry are selected for the Louis Pasteur Award. The award consists of a Citation, Medal and a Certificate. The award is given away during the ISC Congress held once in three years. The award is given to a maximum of three persons during the occasion. The awardees are elected by an Expert Committee constituted for the purpose and later approved by the Executive Committee of the ISC. So far 35 renowned scientists from different parts of the world have been awarded with this prestigious prize.

2.3.10. Award on Excellence on Sericulture Science

ISC has instituted four new awards in four categories of sericulture and silk industry namely: Silkworm Host Plant Development , Silkworm Development, Post cocoon and Post yarn Technology , and Silkworm and Silk in Non-Textile Industry. The award shall be given to scientists, professionals and other stakeholders associated with activities related to silkworm host plant and all silkworms and all silks including mulberry, non-mulberry, spiders, bees, hornets, and the other silk insects. Only individual persons shall be considered for the award. Any specific invention, research, action or any other efforts of the persons/group resulted/which can result significant impact to the specified areas of silk and related industries shall be considered for the award. The contribution shall have field applicability and contribute to the welfare of the silk industry in any manner.

3. Global Eco-system for silk

Sericulture and silk industry can be introduced as an ideal avocation for rural development which eventually leads to inclusive development in many developing countries of Africa and Asia. The present global eco-system is favourable to adopt silk industry as an economically viable occupation for poverty alleviation. Some of these favourable conditions are listed below:

3.1. Increasing Global demand for silk

The global silk consumption for the last five years witnessed a robust growth of 12%. The major consumers are India, USA, Europe and Japan. It is expected that this trend may continue in the coming years also subject to any economic recessions witnessed around the world. This situation provide greater demand for silk in the market to full-fulfil the increased requirement.

On the other hand, the reports emanating from different sources indicates that there may be sharp decline in Chinese silk production due to high labour cost, rapid industrialization and urbanization. As mandated in WTO rules and regulations, China may have to phase farm based subsidies by the end of 2019, which includes sericulture also. This effectively increase the cost of production and resultantly the silk production may come down significantly. With this hovering demand pull, the sericulture would become more remunerative thereby enhance the income generation of the primary cocoon producers.

3.2. Domestic demand for silk in potential countries

A recent study undertaken by ISC found that sericulture can be developed as a major employment generator in many developing countries of the world. The Balance of Trade (BoT) on silk in all these countries are on the negative trajectory. This means that these countries are increasingly depending on imported silk for their domestic requirement. So there is a stable domestic demand for silk in these countries. Many countries are traditional silk producers, albeit on a very limited scale. So there is a great potential to develop sericulture industry, which not only save foreign exchange but also generate gainful employment among the rural population.

3.3. Favourable socio-economic and climatic conditions

The Labour Force Participation Rate (LFPR) in sericulture is highest in comparison to other rural avocations. It provides employment to a massive 8.5 million persons alone in India. It is a family oriented enterprise where the women participation is about 60%. In short, 1 Hectare of mulberry plantation can provide employment to about 15 persons throughout the year from plantation to final product. The industry also require special skill in each phases of its production process that could be sourced among the families and rural artisans. These features of the industry readily align with the socio-economic conditions prevailing in many developing countries of the world.

The tropical climatic conditions of Asia, Africa and Latin American region are best suited to sericulture. The favourable conditions are; plenty of sunlight to yield

maximum leaf production, fertile land, opportunity for regular crop cycles to earn stable income, reduced susceptibility to diseases and pests, the incredible inclination of the rural people to adopt skilled work in the field of animal husbandry and artisanry jobs, availability of local materials for equipments and tool, etc.

3.4. Indian Sericulture Industry; a “Successful Enterprise Model” for replication

Sericulture and silk industry in India has emerged as an economically viable commercial enterprise model for providing employment to about 8.2 million persons. Although the grassroots level stakeholders are distributed on a highly fragmented production base, the programmes of the government could federate them thereby synchronize the production process resulting better production. This effort not only facilitated in disseminating technologies and innovation in an orderly manner but also enhanced the production, productivity and quality of silk matching international standards. The government has also played a major part in developing innovations and technologies and later effectively disseminating the same among the farmers by incentivizing additional investments required for the purpose.

This model developed in India can be easily replicated in many countries as the socio-economic and climatic conditions in all these countries are similar. This apart, the Indian Government is ready to help the developing countries to replicate the model by sharing the technologies and innovations. The government can also extend facilities like capacity building, sharing experts and resources, supply of materials, establish research collaborations, etc.

3.5. Enabling convergence of assistance

The above paragraphs gave a brief description about the support services available for the development of silk industry through various agencies and the prevailing favourable situations for developing the industry in different countries. Now the onus is lying with International Sericultural Commission, respective Countries and other agencies to converge these facilities and conditions on a single platform to provide the much needed impetus for the developmental agenda. As a prelude to these efforts, the ISC is ready to collaborate with countries and agencies with the following objectives:

- a) To facilitate exchange of information, experiences, views, and experts on sericulture and silk industry.
- b) To take up studies as well as action research projects, generate information and documentation in related fields.
- c) To organise exposure visits and training programmes in the field of sericulture and other areas of mutual interests.
- d) To take up projects jointly.
- e) To conduct joint international seminars, symposia and workshops on the themes relevant to both the Parties.

4. The Path Ahead – Strategic Plan

The International Sericultural Commission is glad to inform the representatives of various countries that we have conceived a strategic Plan of Action for the introduction/development of sericulture and silk industry in potential areas of the world. The following are the perspective plans proposed by ISC:

- 1) ISC would collaborate with Countries to undertake an evaluation study on sericulture and silk industry in potential areas of the world. Experts can be sourced from ISC for undertaking the study under the “Volunteer Expert Programme”.
- 2) Based on the evaluation study, comprehensive Silk Developmental Projects either for individual Countries or as Joint Projects for a Group of Countries can be conceived. International Sericultural Commission can provide technical support to the countries for the preparation of Projects by providing expert services.
- 3) ISC would support the countries to source financial support from multilateral agencies for taking up sericulture developmental Projects,
- 4) The Projects shall be implemented under the framework of an “Apex Advisory Committee” constituted by ISC and representatives of the concerned countries.
- 5) ISC would facilitate the support of Government of India for extending technical support, capacity building, sharing of knowledge and materials, supply of seed, equipments and machineries during the initial period or till such facilities are established in the respective countries.
- 6) Simultaneously, the Countries may avail the various facilities available in ISC for strengthening the manpower and expertise in the respective countries.
- 7) The countries may enroll as Members of ISC to participate in the above programme.

EC O 01: Farmers Producers Organizations- a vital tool for doubling the Sericulture farmers income in India

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Abstract

Indian agriculture is characterized by small holder farmers. More than 85 percent farmers are small and marginal who own 40% of land and contribute 56% of the total production. Aggregation has an important role to play. However, they suffer from many constraints and losing interest in farming and other farm based activities. The major constraints being faced are lack of capital; monsoon vagaries; raising input cost; non-adoption of cutting edge technologies and above all uncertain market situation. To help the farmers to overcome the above difficulties several policy options are being considered. Different tools of aggregation like Cooperatives, FPC, 1SHG, CIG, FIG, etc. FPC has been introduced recently to bring in professionalism in agribusiness. Among all the options, Farmers Producer's Organization (FPO) also referred as Farmers producers' Company (FPC) has become more effective to address the above challenges being faced by the farmers in general and small and marginal farmers in particular. The important advantages of FPOs are aggregation of produce; enhance scales of economy; procure inputs at a lower price ; enable post-harvest value addition; derive more holding capacity; improved bargaining and selling power; access to timely and adequate finance; access to technology and market linkages.

Sericulture, a land based activity of high returns is a main stay of small and marginal farmers especially in Asian and south East Asian region. Farmers are suffering from low capital investment constraints and poor bargaining power with small produce. The concept of FPO has been implemented in five selected clusters where large number of farmers are located in a nearby areas. Because of initial success, FPO concept as tool is being popularized in India and has been well accepted by the sericulture farmers. FPO is found more suitable for resource poor sericulture farmers and the concept has helped to double the farmers income with better resource management. Farmers of new clusters are enthused and have come forward to organize themselves in to FPOs. Initial success, issues to be addressed; mid-term corrections and policy ambience required to make it more pro farmer tool are discussed in this paper.

Key words: FPOs, Market vagaries; Bargaining power; Aggregation

EC O 02: Silk Value Chain Development Technologies for Achieving Sustainable Development Goals in South Asian Countries through Regional Collaboration

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Abstract

As a follow up to the Millennium Development Goals (MDGs), in 2015, the international community adopted a set of 17 goals as a part of new global agenda and UN's blueprint for more sustainable future for all. These Sustainable Development Goals (SDGs) are interrelated and the 2030 agenda to achieve them all is in nature and universally applicable, taking into account different national realities, levels of development and respecting national policies and priorities. Achieving the SDGs requires the partnership of governments, private sector, civil society and citizens alike, concentrating on value chain interventions. The Labour Force Participation Rate (LFPR) in sericulture is far ahead in comparison to similar rural avocations. Women participation in sericulture is about 60%, which not only enables women empowerment in family earnings but also ensures utilization of the earnings effectively. Since, the activities of sericulture are primarily focused for the upliftment of rural and marginal farmers, it significantly contributes to poverty alleviation thereby fulfils many objectives of the SDGs set by the United Nations. Silk textile industry activities align with 6 SDGs.

There is a greater opportunity to develop sericulture in South Asian countries as the production in traditional areas of the world has started declining due to rapid industrialisation and urbanisation. Demand for silk is increasing across the globe and South Asian countries have a huge domestic demand and market potentialities, but they do not produce adequate quantity of quality raw silk to meet their domestic demand and are import dependant. South Asia possesses congenial agro-climatic and socio economic conditions suitable for practicing sericulture. Besides, the region is endowed with rich culture and tradition in textile manufacturing and produces textiles that are unique to the region. Silk for ages has been inseparable part of the lives of the population. The successful strategies of tropical sericulture technology developed and adopted by India could easily be replicated in other Asian countries, for augmenting the production of silk and simultaneously addressing the SDGs. Regional cooperation and integration can fruitfully complement the national actions for achieving SDGs. Regionally coordinated industrial strategy focusing on harnessing the potential of silk industry while banking on the traditional knowledge and available skill, strong tradition of silk weaving, take us nearer to accomplishing the set goals in South Asian countries in several ways. International Sericulture Commission (ISC) had recently deputed its three Volunteer Experts who are specialised in major sectoral areas of silk industry, to Bangladesh, Nepal and Uttarkhand (India) to take up 'Reconnaissance Study on Sericulture Research and Development'. The study team which performed the Value Chain Analysis identified the constraints and opportunities for the development of silk industry through regional collaboration. Cumulatively, within a span of five years covering around 8000 silkworm rearers it is possible to produce 244 MT of international grade bivoltine raw silk valued at 12.73 million \$ and generate 21,740 man years of direct employment. This paper discusses the various silk value chain technologies for achieving SDGs in South Asian Countries through regional collaboration.

(Key words: SDGs, Silk Value Chain, South Asian Countries)

EC O 03: Revitalisation of sericulture sub sector for improved livelihoods and rural economic growth in Kenya

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Abstract

Sericulture in Kenya dates back to 1970s when it was introduced through Technical Cooperation between the Governments of Kenya and Japan. However, over years it faced various challenges that reduced the speed at which the industry grew. It is only after 2014 when the Government of Kenya renewed interest in revitalising the sub sector based on expert opinion that sericulture has greater potential to improve livelihoods of many Kenyans. The required system change is two folds: (1) develop firm sericultural research system that will (a) provide locally adaptable mulberry varieties and silkworm races suitable for the Kenyan conditions; (b) package best silk farming practices by farmers; (c) open up utilization of silk biomaterials; (2) improve training and extension services to support silk farming and increased investment in sericulture sub sector. Thus in 2016, the government of Kenya joined the International Sericultural Commission (ISC) as part of building the country capacity. Further, the government secured technical cooperation project with the government of Japan (2016-2021) to support development of firm basis for sericultural research in Kenya focused on developing strong mulberry and silkworm research systems. This includes staff capacity building to ensure the country sustainability of sericulture research. Apart from *Bombyx mori*, Eri silkworm is reared at farm level in the country. Further, there are various wild silkworms in the country with unique silk values that the country is expected to exploit. The current silkworm production at farm level is negligible owing to suppressed extension activities awaiting development of suitable varieties and best local farming practices to ensure quality production. However, Kenyan farmers are eager to start silk farming considering the high number of request by potential farmers to get support. The domestic and external market is also available based on the various interests by traders but Kenya has no silk processing factory apart from the current construction of a silk processing laboratory at our Centre, which will provide important case for development of the sericulture industry in the country.

Key words: sericulture, silk farming, wild silks

EC O 04: A STUDY ON IMPACT ASSESSMENT USING SIX SIGMA METHODOLOGIES FOR QUALITY IMPROVEMENT IN IDENTIFIED COTTAGE BASIN / DOMESTIC BASIN / MULTIEND REELING UNITS IN KARNATAKA STATE, INDIA

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ABSTRACT

India is the 2nd largest producer of raw silk as well as the largest consumer of raw silk in the world. Though India has achieved significant progress in Silk production and productivity, the quality of the raw silk produced in bulk is below the international standards and cannot be used in high-speed looms. The power loom weavers prefer imported raw silk because of more uniformity, less winding breaks and low degumming losses compared to domestic raw silk. Hence, there is a need to import raw silk from China by incurring huge foreign exchange. To address this issue, the Govt of India has taken a decision to minimize the import of silk to bare minimum by 2022 and become self-sufficient by 2024-25 by producing international grade raw silk indigenously. Keeping these in view, studies have been conducted on impact assessment using six sigma methodologies in selected cottage basin, domestic basin and multiend reeling units. As a first step, base line survey was undertaken to identify the reelers those who were producing silk below 2A grade and getting low price for the raw silk they produced due to poor quality of raw silk. To improve the quality of the raw silk and increase their income, the reelers were educated about the cause for the defects in raw silk produced by them through cause and effect diagram (Ishikawa diagram) and also identify the failure mode and its effect on the final product (Failure Mode Effect Analysis – FMEA). The reelers understood that the cause for the defects are due to man, method, material, machine or environment and they avoided human error while reeling and procedural lapses, selected good quality of cocoons, maintained proper reeling machine speed, maintained optimum temperature and humidity while reeling. The reelers also understood the failure modes while reeling and its effects on the final products. After adopting the six sigma methodologies in reeling units the quality of the raw silk was tested and the results revealed that the grade of the silk was improved to 2A grade and above from the present level of A-grade in the identified silk reeling units and the profit margin of the reelers increased compared to the profit margin made before application of six sigma methodologies. This study suggest for a large scale application of six sigma methodology for overall quality improvement in silk reeling units.

Key Words : Degumming, Cause and Effect Diagram, Failure Mode Effect Analysis

**EC O 05: Country report of
Islamic Republic of IRAN
25th ISC Congress, 19-22 November 2019, Japan**

History

Sericulture is one of the complementary and eco-friendly side-jobs alongside other agricultural and rural jobs rooted in ancient Persia. Iran is also among the silk-producing countries located on the way of famous Silk Road and many of its major cities have been connected through this road. Sericulture has a relatively long history in Iran and it has flourished in two periods: Sassanid period (224-651 AD) and Safavid period (1501-1722 AD) when the annual production of Iranian raw silk has been reported 3000 tons

But over the years, sericulture production has been decreased in IRAN. because many farmers switched to other crops. By establishing the Sericulture Development Center of IRAN as the custodian of sericulture to perform the governmental, developmental and supervisory duties, since (2014 AD) the Iranian Ministry of Agriculture is determined to maintain the present condition, revive and develop sericulture in the country by creating and developing the required infrastructures.

Current Condition

Today, annually producing around 225 tons of silk yarn, Iran has the eighth rank in the world. There are 25000 farmers of sericulture in 31 provinces of Iran have selected sericulture as one of their jobs. Guilan, Khorasan Razavi, Golestan, North Khorasan and Mazandaran are the most important provinces where the most sericulture is done. Relative advantages of sericulture in terms of climate, geography, human resources and other factors in Iran has caused the Iranian farmers in different parts of the country to produce silk cocoons for at least one time each year (spring and summer). In addition, in case of providing the required inputs such as mulberry leaves and silkworm eggs, there will be the possibility of sericulture in autumn too. In this year , second time rearing has been initiated in 5 provinces In a small scale.

Currently, there are approximately 15000 Hectare of mulberry farms in Iran often planted in form of a single tree on the edge of farms, on the border of farms or together with the other farm trees and only in some areas of Guilan province there are mulberry trees in form of dense farms used in sericulture, producing mulberry and green space.

Guilan province, with 35% of Iran's total share of sericulture, is considered the hub of this activity in the country. Guilan province, with 35% of Iran's total share of sericulture, is considered the hub of this activity in the country.

The most important challenges facing the sericulture development

- Inadequate lands for mulberry farms and low efficiency local farms.
- High dependence of the produced raw silk to carpet industry and lack of investment units in this area to produce new products from silk, especially pharmaceutical and sanitary products.
- Aging of the Farmers and reduction in their physical strength and the need to replace them.
- The low tendency of the young people, especially the ones educated in Agricultural Sciences to work due to the traditional silk-production process.
- Land use change of the agricultural fields considering the growing process of other agricultural and non-agricultural jobs.
- Limited use of mechanization, especially during the procedure of mulberry farms to

silkworm rearing and cocoon production.

The Main Advantages and Capacities of Sericulture

- Short production period and rapid return on investment compared to some other disciplines of agriculture field.
- Low capital required for sustainable employment and preventing migration of the rural Group maximum collaboration of the women and other family members
- As a side-job alongside other without disturbing the other agricultural jobs in form of an eco-friendly job
- The possibility of planting mulberry seedlings in most soils, sloping lands and margins of agricultural fields as the only food required by the silkworm.
- Possibility of exploiting the mulberry farms within 15 to 20 years after planting the seedlings.
- Foreign exchange savings through producing raw materials and silk thread required for carpet weaving and industries.
- Job-creation and improving the life condition of the rural societies

Supportive plans of Islamic Republic of Iran for farmers with new approaches

Determination of the annual guaranteed price for fresh silk cocoon as a minimum with the expected profit to estimate production and act upon production by the farmers

- Awarding bank facilities to buy equipment, rebuild the mulberry farms, construct and reconstruct the sericulture sites, construct and reconstruct silk industry units and factories and producing final silk products such as carpets, clothing and some other handcrafts.
- To expand the sericulture insurance among the farmers to reduce the risk by paying a large portion of the premium paid by the public sector.
- To develop educational and promotional programs for empowerment, informing with the aim of increasing production of silk cocoons per unit's area and producing high-quality cocoons with knowledge management approach in the country .
- Organizing and managing the farmers in form of non-governmental agricultural organizations .

The result of government actions in this year

- 1-Increase the number of sericultural households with 17500 families to 2500 families.
- 2- Increase the number of provinces active in the field of sericulture from 22 to 31
- 3-Increase the egg distribution by 55% compared to last year
- 4-Increase production of fresh cocoon from 980 tons to 1385 tons

International Cooperation

IRAN has become a member of International Sericultural Commission (ISC) since 1975 Cooperation of commission member countries especially in exchanging knowledge and experience and sharing the results of the carried out applied researches through holding educational and promotional workshops is considered as an effective effort in improving the added value of sericulture industry in the world which can provide more income and welfare for the individuals active in this agricultural sub-sector.

Future Plans

1. Applied researches for eugenics and to achieve high-production and high-quality lines of silk-worm and mulberry tree in order to produce robust and efficient varieties

- compatible with requirements of different regions.
- 2. Planning to produce different varieties of hybrid silkworm egg in proportion to relative advantages of different regions of Iran.
 - 3. Planning to prevent and control pests and diseases of mulberry tree and silkworm in collaborate with plant protection organization and Veterinary Organization
 - 4. Planning to develop mechanization in sericulture process with the aim of reducing work hardship and increasing productivity
 - 5. Planning to create structural changes in sericulture, cocoon and raw silk production methods in order to make the production chain economical
 - 6. Planning to obtain new products from silkworm in order to create added value and attract more investment.

EC O 06: COUNTRY REPORT – INDIA

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Introduction

Silk has a long history and tradition of production, consumption and trade by developing its own weave and texture in India. Thus silk carries an important place in the life and culture of Indians and no ritual is complete without silk in India. India is the second largest silk producing and the largest silk consuming country in the world.

Owing to its high employment potential, low capital requirement and remunerative nature of its production, the sericulture industry plays a major role in providing livelihood opportunities for millions of people and for socio-economic development of a largely agrarian economy of India. The sericulture related activities ensure the livelihood security for over 1.2 million families spread over in about 75,350 villages across the country.

India is the only country in the world to produce all the five known commercial varieties of silk namely, mulberry, tasar, oak tasar, eri and muga. The raw silk production in the country during 2018-19 was 35,468 MT.

Growth in Mulberry Silk Production

Mulberry is the major silk produced in the country, which accounted for about 71% of the total silk production in the country during 2018-19. Mulberry sericulture is practised throughout the country. However, the major production comes from southern region.

Table 1: Mulberry Area and Mulberry Production in India during 2011-12 to 2018-19

Year	Mulberry area (ha)	Raw silk production (MT)			Share in total production (%)	
		Bivoltine	Cross Breed	Total	Bivoltine	Cross Breed
2011-12	181089	1685	16587	18272	9.22	90.78
2012-13	186015	1984	16731	18715	10.60	89.40
2013-14	203023	2559	16917	19476	13.14	86.86
2014-15	219819	3870	17520	21390	18.09	81.91
2015-16	208947	4613	15865	20478	22.53	77.47
2016-17	216810	5266	16007	21273	24.76	75.24
2017-18	223926	5874	16192	22066	26.62	73.38
2018-19	235001	6987	18357	25344	27.57	72.43
CAGR* (%)	3.31	19.46	1.28	4.17		

Note: CAGR- Compound Annual Growth Rate

The mulberry area increased from 181,089 ha in 2011-12 to 235,001 ha in 2018-19 at a compound annual growth rate of 3.31% (Table 1). During the same period, the mulberry raw silk production increased from 18,272 MT to 24,344 MT at a growth rate

of 4.17% per annum. In India, with the prevalence of tropical climate, multivoltine mulberry silk has been produced traditionally. The cross breed silk, which is obtained from the hybrid of multivoltine and bivoltine silkworm breeds, is the major type of mulberry silk produced in the country. The cross breed silk production grew at a modest rate of 1.28% per annum during the period between 2011-12 and 2018-19.

Bivoltine silk, which is reeled from bivoltine hybrid cocoons, performs better than silk produced by the crossbreed or multivoltine hybrid silkworms in terms of quality and productivity. Therefore, the Government has been providing thrust for production of the bivoltine silk to improve the quality and productivity of the silk produced in the country. The new bivoltine silkworm hybrids and bivoltine silk rearing and reeling packages evolved by the research institutes and the Japan International Cooperation Agency (JICA) assisted projects have helped to accelerate the growth in bivoltine silk production in the country. The bivoltine silk production has been growing in the country at an incredible rate of 19.46% per annum during the period.

The fast pace of growth in bivoltine silk production compared to crossbreed silk production resulted in steep increase in the share of bivoltine silk production in total mulberry silk production in the country from mere 3.69% in 1995-96 to whopping 27.57% in 2018-19. The increase in the indigenous production of bivoltine silk has helped to reduce the raw silk imports drastically during the last decade.

Growth in *Vanya* Silk Production

In Sanskrit language, the term “*Vanya*” means untamed, wild or forest based. As tasar and muga silkworms are wild in nature and reared in open fields on trees in natural forests and perennial plantations, the non-mulberry silks namely, tasar, eri and muga silks are known as *Vanya* silks in India. *Vanya* silk production assumes a major significance in India due to involvement of tribals in a substantial number in different stages of production. The *Vanya* silk production has grown substantially in India owing to huge production potentialities arising out of wide congenial biodiversity for *Vanya* silkworms, eco-friendly nature of the production, steady and growing demand for *Vanya* silk products and processing activities and extensive promotion of *Vanya* silk products.

Table 2: *Vanya* Silk Production in India during 2011-12 to 2018-19

Year	Silk production (MT)			
	Tasar raw silk	Eri spun silk	Muga raw silk	Total Vanya
2011-12	1590	3072	126	4788
2012-13	1729	3116	119	4964
2013-14	2619	4237	148	7004
2014-15	2434	4726	158	7318
2015-16	2819	5060	166	8045
2016-17	3268	5637	170	9075
2017-18	2988	6661	192	9841
2018-19	2981	6910	233	10124
CAGR* (%)	8.17	10.66	7.99	9.81

Note: CAGR- Compound Annual Growth Rate

The forest based tasar silk is prominently produced in central and eastern India. The north-eastern states are known for the production of eri and muga silks. The tasar silk production increased from 1,590 MT in 2011-12 to 2,981 MT in 2018-19 registering a growth rate of 8.17% per annum (Table 2). Eri silk production recorded an annual growth of 10.66% to increase from 3,027 MT in 2011-12 to 6,910 MT in 2018-19. Muga silk grew at a rate of 7.99% during the period.

Growth in Overall Silk Production

The silk production in the country grew from 23,060 MT in 2011-12 to 35,468 MT in 2018-19 at an annual compound growth rate of 5.53% (Table 3). The mulberry silk production in the country grew at 4.17% per annum during the period. On the other hand, the non-mulberry silks registered higher growth rates of 8.17% by tasar, 10.66% by eri and 7.99% by muga. Among the four varieties of silks, mulberry silk accounted for 79% of the total silk production in the country during 2011-12. As the non-mulberry silk production grew at a comparatively higher rate than mulberry silk during the period, the share of mulberry silk in the total silk production reduced to 71% in 2018-19.

Table 3: Total Silk Production in India during 2011-12 to 2018-19

Year	Raw silk production (MT)			Share in total production (%)	
	Mulberry	Vanya	Total	Mulberry	Vanya
2011-12	18272	4788	23060	79.24	20.76
2012-13	18715	4964	23679	79.04	20.96
2013-14	19476	7004	26480	73.55	26.45
2014-15	21390	7318	28708	74.51	25.49
2015-16	20478	8045	28523	71.79	28.21
2016-17	21273	9075	30348	70.10	29.90
2017-18	22066	9841	31907	69.16	30.84
2018-19	25344	10124	35468	71.46	28.54
CAGR* (%)	4.17	9.81	5.53		

Growth in Silk Consumption

The raw silk requirement has been growing in the country at 3.64% per annum from 28,743 MT in 2011-12 to 38,253 MT in 2018-19 (Table 4). As the domestic production of silk in India is not able to meet the actual requirement of the silk industry, India imports raw silk to fill the demand-supply gap. Out of the total requirement of 28,743 MT of raw silk during 2011-12, 23,060 MT (80%) was domestically produced and the remaining 5,683 MT (20%) was imported primarily from China.

As there is declining trend in import of raw silk due to increase in domestic silk production especially import substitute bivoltine silk production, the demand-supply gap has been narrowing down over the years. The share of domestically produced silk in the total quantity of silk consumed during 2018-19 increased to 93% and the share of the imported silk fell down to 7%. It is expected that the country would become self-sufficient in raw silk production by 2022.

Table 4: Raw Silk Production, Import and Availability in India during 2011-12 to 2018-19

Year	Domestic production of raw silk (MT)	Raw silk imports (MT)	Total consumption of raw silk (MT)
2011-12	23060	5683	28743
2012-13	23679	4959	28638
2013-14	26480	3260	29740
2014-15	28708	3489	32197
2015-16	28523	3529	32052
2016-17	30348	3795	34143
2017-18	31907	3712	35619
2018-19	35468	2785	38253
CAGR* (%)	5.53	-8.53	3.64

Prospects of Sericulture Industry in India

Indian silk industry has registered an impressive growth, both horizontally and vertically. With the demand growing domestically, there is a scope to increase the silk production with the availability of a large seri-biodiversity. Besides, as discussed above, the Indian sericulture industry is poised to transform in its structure in many ways – a large producer of multivoltine silk into a bivoltine silk producer, from the largest raw silk importer into self-reliant in raw silk and the largest producer of *Vanya* or wild silks.

A largest portion of consumption of silk is in the form of saree which is a traditional product. With the purchasing power of the people increasing and the dressing habits changing, now new products are developed through fabric engineering, blending, designing new fabric structures and employing new processing techniques to meet the needs of domestic as well as international markets. Muga satin fabric, eri silk denim fabrics, eri and mulberry knits, eri silk blanket and carpet, eri silk thermal wear, silk life style products such as ladies purse, bags, socks, glouze, accessories etc., are some products developed in this direction.

Attention is also paid on exploring non-traditional uses of silk to add value to the by-products generated in the industry that catapults the industry into a more profitable and economically viable one. Products with high commercial value are explored from by-products of sericulture industry (sericin, pupae, moths, silkworm excreta, silk fiber waste and mulberry leaves, fruits and roots) for therapeutic use (anti diabetic, antiviral, hypoglycaemic, antibacterial and antivirus products), as cosmetics (skin and hair products), animal food (feed for cattle, poultry, fishes etc.,) and foodstuff for human consumption (oil, juice, marmalade, wine, fruit distillate, vinegar, dried fruit powder and natural colouring).

EC O 07: Country Report Sericulture in Thailand

**The Queen Sirikit Department of Sericulture
Ministry of Agriculture and Cooperatives, Bangkok, Thailand**

The 25th International Congress on Sericulture & Silk Industry on November 19th – 22nd, 2019 at Tsukuba, Japan.

History of Sericulture in Thailand

Sericulture in Thailand had a long history, found the scarp of silk fabric attaching to a prehistoric bronze bracelet dating back 2,400 – 3,000 years at Ban Chiang, Udonthani province indicating that sericulture of Thailand might be on going over 3,000 years. Historical evident in the period of Sukhothai and Ayutthaya showed that silk fabric had been used but it was imported from China. In 1902 when the actual development of the King Chulalongkorn (King Rama V) was undertaken towards the cocoon growing, weaving fabrics and so forth. At that time, the Thai government decided to hire Dr. Kametaro Toyama, an associate professor of Tokyo University, to give the advice about how to raise their cocoon at best quality. Soon, there were developing researches together with the establishment of Thai silk expert group, focusing on the development of this matter in particular. In 1903, the King Chulalongkorn commanded to establish a Thai Silk Technical Bureau, a part of the Ministry of Agriculture at that time. Besides, His majesty assigned the Prince of the First Class Pichai Mahindarodom (a Royal Prince Penpatthanaphong) as a Director of this bureau. Then he developed a school called “a Silk Technical School” as a replacement center of the Japanese professors for those Thai silk workers. From 1969 to 1988 Thailand received a backup from the Japanese government in accordance with the Colombo Plan. By sending 6 Thai silk experts to conduct a research towards the cocoon production, pesticide usage and right fabric pulling, Thailand has ultimately succeeded in producing weft yarns, as a substitution for those imported yarns. In 1976, the Queen Sirikit decided to establish the Foundation for the Promotion of Supplementary Occupations and Related Techniques in order to increase income for those poor in the remote areas. Thai silk is not only part of the jobs this foundation aims to perform, but also promoting Thai custom and tradition through our handicrafts. This foundation is located throughout the country, representing the generosity of Her Majesty Queen Sirikit, the Queen Mother to all Thais.

In 1999, Her Majesty Queen Sirikit, the Queen Mother said “Sericulture is not only the source of extra income for farmers but also the historical and fine culture of the Thai nation that has long been inherited. No matter how the country’s economy has changed, development of Sericulture must continue”. In 2009 until present, the Queen Sirikit Department of Sericulture (QSDS) was established under the Ministry of Agriculture and Cooperatives is responsible for a whole sericulture mission which consist of strategy and policy formulation, research and development, conservation and standard certification, development and technology transfer, and marketing development to help the farmer to improve their lives, and the community in general.

Type of Silk

In Thailand, mulberry silk is the most important of the country as much as 90 – 97 percent of country production, therefore, the term “silk” in general refers to the silk of

the mulberry silkworm. Mulberry silk comes from the silkworm (*Bombyx mori* L.) which solely feeds on the leaves of mulberry plant. These silkworms are completely domesticated and reared indoors. There are 3 types of Thai silkworm varieties (Fig.1).

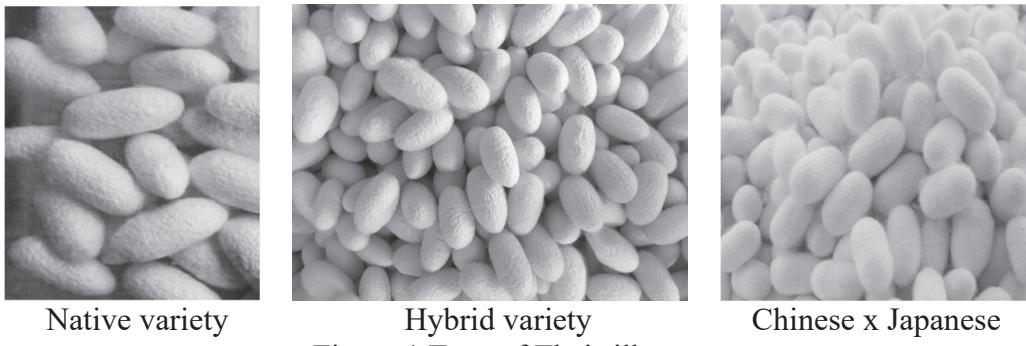


Figure 1 Type of Thai silkworm

1. Thai native silkworm variety

It is indigenous variety of the country including improved Thai native silkworm varieties. The dominant characteristics are yellow cocoons with shuttle shape, silk yarn length as 250 – 350 meters per cocoon.

2. Improved Thai silkworm variety

These varieties are developed and improved within the country by having all genes or some not taken from the Thai native silkworm variety. The improved Thai silkworm varieties are classified into 3 types as the following;

a) Improved Thai native silkworm variety

It is a Thai polyvoltine type which its agriculture characteristics are similar to Thai native silkworm variety with yellow cocoons such as NangLai, NangSew, Nognkhai 4(NK.4) and Pakchong 21 (P.C.21) etc.

b) Thai hybrids silkworm variety

It is a variety which was obtained between Thai native silkworm varieties or breeding Thai variety race and hybrid silkworms (polyvoltine into bivoltine, bivoltine into polyvoltine). This race has yellow cocoon with the silk yarn length as 600 – 800 meters per cocoon.

c) Hybrid variety

This race is one of Thai varieties as bivoltine race which was developed to produce white cocoon and the other color cocoons such as yellow cocoon. The cocoon is oval, peanut and round shape by having of 1,000 meters of silk yarn length per cocoon.

3. Silkworm variety imported from the other country

This variety was imported from the other countries in particular China. They are hybrid silkworms with white and oval shape cocoon.

The Queen Sirikit Department of Sericulture is responsible for conserving of silkworm variety and establishing silkworm breeds bank. The current number of silkworm variety for bivoltine 168 varieties and polyvoltine 95 varieties¹.

Silk production in Thailand can be divided into two categories depending on whether the yarn is reeled by hand or by machine. Hand-reeled yarn is produced on the farm using relatively simple equipment; farmer may sell their hand-reeled yarn to factories or weave it themselves to produce fabric in traditional styles. Production is based

¹ Source: Office of Sericulture Conservation and Standard Conformity Assessment data on September 4, 2019

on native ‘polyvoltine’ silkworm varieties that give low yields but are tolerant of local conditions and are therefore relatively easy to rear. Some new ‘Thai hybrid’ silkworm varieties have been developed which are more productive and which preserve the ‘lustrous’ character of traditional Thai silk. In the case of machine-reeled yarn, the farmers produce and sell cocoons and the yarn is reeled in factories. The silkworms are ‘bivoltine’ varieties which are highly productive but require higher levels of skill and care than polyvoltine or ‘Thai hybrid’ varieties. In general, farmers who produce cocoons for machine reeling have larger mulberry holdings and produce at a larger scale than the hand-reelers. However, there are no fixed barriers between the two sub-sectors; farmers may rear ‘Thai hybrid’ varieties for hand-reeling during some production cycles and switch to import ‘bivoltine hybrid’ varieties for sale to factories in other production cycles each year. The current number of silkworm variety in Thailand for bivoltine and polyvoltine are 168 and 95 varieties respectively.

Mulberry cultivation

Government sector has been researching on the improvement of mulberry variety by studying how to breeding the quality and quantity of mulberry leave yield which are suitable for silkworm feeding and the other products (Table 1). The mulberry leave yields are based on its variety. For example, the varieties of as per farmer practice, the given yields are about 2,000 – 2,500 kg/rai/year. Nevertheless, some farmer still uses the native varieties (such as Noi, Ta Dam, and Khun-Pai varieties provide 320 – 400 kg/hectare/year) which these capacities of producing the leave yield are 2,000 – 2,500 kg/rai/year. The Queen Sirikit Department of Sericulture introduced new varieties Buriram 60, Srisaket 84, Sakolnakhon, and Sakolnakhon 85 (Fig.2) to replace the farmer’s low yielding varieties. These 4 varieties could provide 688, 506, 560, and 545 kg/hectare/year, respectively. Additionally, the fruiting mulberry varieties are developed such as Chiangmai variety which use for modified products.

Table 1: The current number of mulberry varieties in Thailand

Mulberry variety	Number of variety
Native variety	35
Approved and Recommended variety	8
Mulberry for fruit variety	28
Mulberry variety imported	39
Hybrids variety	94
Wild mulberry	23
Total	227

Source: Office of Sericulture Conservation and Standard Conformity Assessment data on September 4, 2019

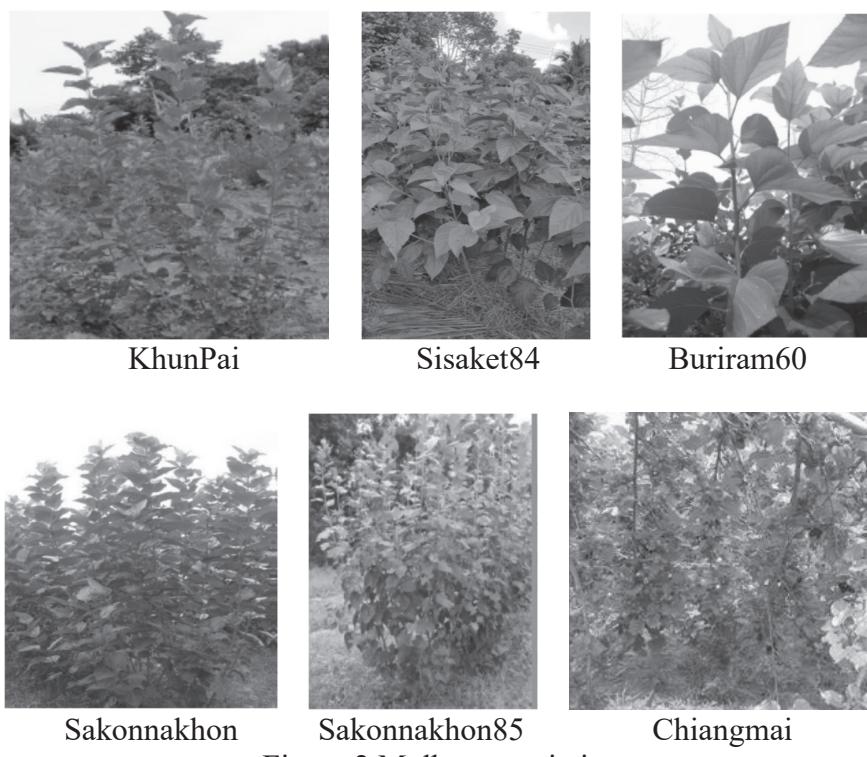


Figure 2 Mulberry varieties

Sericulture situation

Sericulture in Thailand, there are approximately 81,497 farmers of sericulture with area of mulberry field is about 6,723 hectares². The table 2 below indicates the sericulture farmer and mulberry plantation area for the last ten years found that the current mulberry area decreased because many farmers switched to other crops such as rice (major crops in Thailand) or started growing alternative crops and also the growth of the national economy and population.

Table 2: Sericulture famer and mulberry plantation area for the last ten years 2010 – 2019

Year	Sericulture farmer	Mulberry plantation (hectares)
2010	-	-
2011	98,558	17,298
2012	-	-
2013	107,435	10,000
2014	73,874	7,838
2015	82,071	7,553
2016	-	-
2017	85,578	7,234
2018	87,369	7,085
2019	81,497	6,723

Source: The Queen Sirikit Department of Sericulture, research and TAMIS data 2010 - 2019

² The Queen Sirikit Department of Sericulture, TAMIS data on August 31,2019

The farmer of sericulture, most of them are located in Northeastern part of Thailand. They are small scale farmers who work on sericulture as a secondary occupation apart of paddy field. There are three types of sericulture farmers in Thailand according to their varieties of silkworm rearing as follow polyvoltine group, Thai hybrid group (polyvoltine x bivoltine) and bivoltine group. Thai silk yarn production, there are two types that consumed in the market as hand reeled yarn and machine reeled yarn.

Raw silk production

Thailand has two kinds reeling of silk yarn by hand or by machine, silk yarn from hand reeling using for traditional weaving and in the country, for silk yarn from the machine reeling using in factories or some farmer using by hand weaving also. In 2018, raw silk yarn production in Thailand was decrease 403 tons compare with the year in 2016 (712 tons) (Table 3).

Table 3: Raw silk production for the last ten years 2010 – 2019

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Raw silk (Tons)	655	655	655	680	692	698	712	448	403	-

Situation of raw silk and spun silk

Table 4: Import and Export of raw silk and spun silk for the last ten years 2010 – 2019

Year	Import		Export	
	Qty (Tons)	Value (US\$)	Qty (Tons)	Value (US\$)
2010	-	-	-	-
2011	-	13,019,972	-	4,082,893
2012	-	8,714,363	-	3,565,082
2013	345	11,429,664	107	3,335,738
2014	368	7,112,299	115	3,906,113
2015	294	5,702,230	141	3,168,366
2016	371	7,728,650	94	3,892,239
2017	315	7,829,234	115	4,785,671
2018	468	10,668,428	262	9,510,270
2019	242	5,111,925	125	3,131,541

Source: Thai Customs Department and Office of Sericulture Development and Technology Transfer data 2010 – July, 2019



EC O 08: EGYPT COUNTRY REPORT ON SERICULTURE

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A female Egyptian mummy, 30-50 years old belong to the twenty-one dynasty was discovered with a piece of silk in her curls. As well as, a woolen tunic with decorative stripes with a weft of white silk is the earliest example that can be traced from The Ptolemaic era. A portion of a coloured silk fabric was found at Qustul, south of Abu Simbel, it is probably not older than the fourth century AD. From the fourth century AD onwards silk became more common in Egypt. It was suggested by Mummification scientists that silk was used in Egypt as long as 1,000 years BC.

Egyptian knows well and appreciates the value of natural silk, since the eighteenth century, the manufacture of silk products and textiles occupies a high position almost equal to that of cotton textiles and it is known to all that Egypt is famous with planting and manufacture of cotton. Silk was considered the third most popular raw material for textiles in Egypt after linen and wool. Economically, the unit price for raw silk is around twenty times that of raw cotton.

Sericulture Research Department was established since 1927 belonging to Ministry of Agriculture and Land Reclamation. Since then, the department has been responsible for the proliferation and re-activation of silk production in Egypt. Of course there are some periods of inactivity or fall for reasons out of our control, but there is always the determination to restore silk and the spread of silk products again in the Egyptian markets and rely on our local production to meet our needs. The current number of silk producers does not exceed 1,000 families.

In Egypt, Mulberry silkworm rearing is a simple project suitable for young investors, rural women and poor families, especially the costs are simple and labor is relatively cheap compared to the rest of the world. Recently, Mulberry farms have been distributed around Egypt in Delta regions and Upper Egypt.



Egypt began implementing the project of planting **One Million Mulberry Trees** following President Abdel Fattah El Sisi's vision to revive the Silk Road once again and link Egypt with the countries of Asia again. As well as, there were about 27 mulberry varieties around all Egypt.



Local Mulberry varieties can grow well in new reclaimed lands, and marginal lands with marginal irrigated water and treated or semi-treated Sewage. It can be safely estimated that 28,000 to 30,000 kg of leaves can be harvested per Hectare per Year under conditions of optimum agronomic practices.

Mulberry silkworm, *Bombyx mori* L. is the only silk producing insect in Egypt, and upon our breeding program, recently it has been found some silkworm hybrids that can withstand our hot climatic conditions.



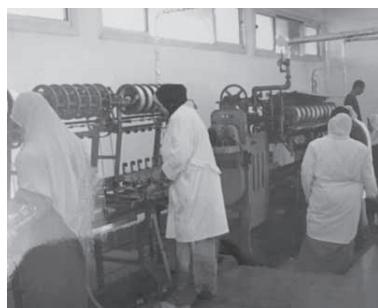
Recently a great project established in Upper Egypt depending on evaluating these hybrids and other imported hybrids. Egypt is currently overcoming the shortage of silkworm eggs by importing them from China, and The EU.

Currently, some large national applied projects have been established and supported by the Egyptian government in order to revive silk activity in some governorates such as Fayoum, Sohag and Qena. This is in addition to research projects with China and fellowships with India. A great Union of Silk producers, that link with

mulberry silkworm rears around all Egypt, which caring with planting mulberry trees and fruits, importing silkworm seeds, and extension activities to new farmers.



With developing techniques used by the Sericulture Research Department, investors and agencies started to carry out silk production projects. Silk production is efficiently carried out on a small scale basis best fits with rural women, young graduates and small investors, which in turn will significantly increase production quantity and quality and job opportunities, contributing considerably to the wellbeing of rural people. Silkworm reares are primarily located in Menoufia, Qalyubia, Fayoum, Dakahlia and Gharbia Governorates. They usually sell what they produce to two major factories in Egypt, Sericulture Research Department owns one of these factories and The Union of Silk Producers owns the other.

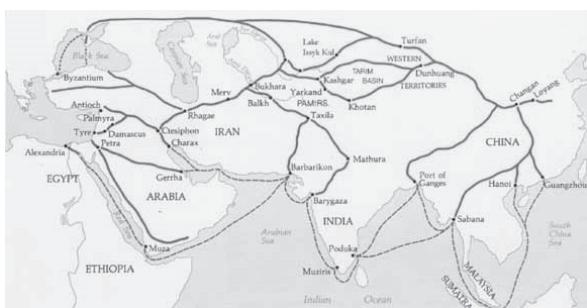


Carpet manufacturing is one of the main industries in need of raw natural silk. Manufacturers buy raw natural silk from the local union of the silk producers and from promoters on Facebook to produce natural silk carpets. Menoufia Governorate is the home to most of the silk-carpet looms in Egypt. The European Union is the destination of 90% of local, natural silk carpet exports. East Europe mainly relies on imports for its total supply of carpets, offering opportunities for Egyptian suppliers. In 2014, carpets from Egypt accounted only for 2.5% of total carpet imports. Eastern European imports of carpets from Egypt increased substantially from 2010 to 2014 by

27% annually. Beside to Egyptian silk carpets manufactures, the village of Akhmim in Upper Egypt (Suhage Governorate) established a good reputation as weavers of silk cloths.



"One Belt and One Road" strategy, inspired by the exchange of ideas and traditions along the historical Silk Road. China officially launched the initiative in September 2013 when President Xi used a speech at a university in Kazakhstan to call for the creation of a "Silk Road". The 'road' is not actually a road but rather a sea route linking China's southern coast to east Africa and the Mediterranean. The 'belt' is a series of overland corridors connecting China with Europe, via Central Asia and the Middle East. The Belt and Road initiative is an immensely ambitious development campaign through which China wants to boost trade and stimulate economic growth across Africa. It hopes to do so by building massive amounts of infrastructure connecting it to countries around the globe.



Scientific projects had been carried out between Egypt (Sericulture Research Department) and China (Jiangsu University) under this perspective for increasing increase natural silk and cocoons outputs.



Egypt Network for Integrated Development (ENID/ El Nidaa) team with a representative from IFPRI Egypt visited China in the last quarter of 2018 to learn from the Chinese experience in rural cluster development. The purpose of the trip was to acquaint the group on the success stories of some of the silk producers. Reviving silk production in Upper Egypt ; ENID/ EL Nidaa's silk project aims to revive this important industry in Upper Egypt via producing quality silk yarns and products to meet the growing needs in the local and foreign markets in addition to providing job opportunities for women in the household. The hand weaving of silk yarn will take place in the villages of Naqada in Qena governorate. On the economical level, the intervention is expected to promote Egyptian exports of highly demanded silk carpets, as well as natural silk apparel. On the environmental level, the project will use solar energy to extract ground water for the cultivation and that it uses organic compost. Also the project is using natural colors for dying the silk threads. The importance of reviving silk industry has become more necessary especially upon the devaluation of the Egyptian pound, which increases the export potential of all silk related products. That is why the government began to pay attention to the promotion of this industry as one of the means for achieving sustainable agricultural and rural development. The new strategy followed now in China opened new opportunities for developing countries like Egypt to introduce their products in the Chinese market for the middle class. Foreign direct investments (FDI) in the silk industry in Egypt can be beneficial for the two countries in terms of high-quality products and low labor cost of skilled workers in Egypt, especially in the South. In addition, Chinese FDI can potentially provide a sustainable source of income for rural communities working on the silk industry.



EC P 01: “Eri culture as fibre and human food -BTC economy model- case study in Bodoland Territorial Council (BTC) ASSAM, INDIA”.

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Abstract:

Eri culture is mainly confined to the Brahmaputra valley of Assam and in some tribal inhabitant districts of Bihar, Jharkhand, West Bengal, Orissa, Andhra Pradesh, etc. Eri silkworm (*Philosami aricini*) is polyphagous and feeds on wide range of host plants. Castor(*Ricinus communis*) and Kesseru (*Heteropanax fragrans*) are two primary food plants. Some of the important secondary food plants are Tapioca(*Manihot esculenta Crantz*); Payam (*Evodiaflax inifolia*); Barkesseru (*Alianthus excels*) and Papaya (*Carica papaya*). The BTC area is endowed with numerous flora and fauna, which include varieties of sericigenous insects and their food plants. The climatic condition of these Districts is suitable for commercial exploitation of Muga and Eri silks. At present in BTC total 44250 nos. of families are engaged in Sericulture in 1658 Sericulture villages. The art of rearing of silkworms, spinning & weaving is an integral part of the Bodo people. It is not only a traditional practice but also plays a dominant role in socio-economic development by stabilizing the economic condition of the families. Eri culture is practiced not only for silk but also for the protein rich pupae for consumption of people as a delicacy food. The Eri silk has special thermal properties, which supplement the requirements of warm clothing to some extent.

By-product utilization is another area that has been addressed to some extent in recent past. It is well known fact that eri silkworm pupae for ages has been the main product in eri in the northeast, the silk being just a byproduct. The pupae that are rich in protein (53.30 %), fats(25.60%) and a calorific value of 460 kcal/100 g dry wt. which is higher than that of cows milk, eggs, chicken, white sugar etc., offers a great opportunity for designing recipes for human consumption. At present BTC produces 1200 MT eri cut cocoon and 6250 MT of pupae per year. Eri Cut cocoons are used as fibre and pupae are used as food in BTC areas. On average one eri rearer produces 20 to 30 kgs. Cut cocoons and 100 to 150 kgs pupae in a year. Out of production 50% both incase cut cocoons and pupae farmers are consumed themselves and rest quantity sale in the market at the rate of Rs. 850/- kg in case of cut cocoons and Rs.300 to 400/- kg in case of pupae. .

Key words :Eri culture, rearing, cut cocoons, silk, pupae, fibre and food.

EC P 02: STUDIES ON THE ECONOMIC IMPORTANCE OF BIVOLTINE SERICULTURE IN RURAL AREAS OF INDIA

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Prosperity of Indian rural populace largely depends on the development of agriculture and allied sector activities. Sericulture is a cottage based agro industry and nature of the industry gains importance not only for its economic and employment potential in rural areas but also for its export prospective. Sericulture in India, offers agro based, ecologically and economically sustainable activity for the rural poor, small and marginal farmers which also include women. The objective of the present study was to find out the cost and return of sericulture in traditional sericulture practicing areas of Tamil Nadu, India, with special reference to bivoltine sericulture. The data were collected from randomly selected 200 farmers. The parameters on Mulberry garden establishment cost, fixed and operational cost on mulberry cultivation, cocoon production cost and cost and return from cocoon production have been considered for the analysis. The results indicated that the farmers are able to realize an average net income of Rs.33874.50 per acre per year for practicing bivoltine sericulture, including the cost of family labour. The estimated benefit, cost ratio worked out to 1.23. Analysis on the economic importance of sericulture enterprise and returns for the investment on cost and labour revealed that Mulberry crop ranks high with a net income of Rs.33,874.50 per acre per annum when compared to net income of Rs.4245.50, Rs.10208.90, 7884.09 and Rs.12142.49 with crops of Cow Pea, Paddy, Ragi and Beans respectively. The study further revealed that bivoltine sericulture ensures stable and enhanced income, besides gainful employment and livelihood opportunities to small farmers even with land holding size of one acre.

Key words: Mulberry, Bivoltine & Income.

EC P 03: Impact of Japan International Cooperation Agency (JICA) in producing Bivoltine cocoons and Silk in Karnataka, India

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ABSTRACT

In order to produce superior grade of 3A to 4A raw silk of warp quality, good quality bivoltine hybrid cocoons and suitable reeling technology are essential. In view of this JICA and Central Silk Board has developed the new bivoltine sericulture technologies like Improved mulberry variety (V-1), Disinfection Technology, Scientific Chawki Rearing, CSR Silkworm Breeds and Use of rotary mountages and required reeling technology which are suitable to tropical conditions under Bivoltine Sericulture Technology Development Project (1991-97). Later, these technologies were demonstrated and verified by CSB and JICA in association with the Department of Sericulture in 10 Technical Service Centres. Out of which 8 in Karnataka, each 1 in Andhra Pradesh and Tamil Nadu respectively. Karnataka farmers proved that, they able to produce quality bivoltine cocoons to meet the demand of international gradable silk. The efforts of JICA and CPP implementation has yielded significantly progressive growth of bivoltine cocoon production in Karnataka State, which ranges from 1885 MT (1997-98), 4198 MT (2001-02) and 13870 MT (2019). The impact has also promoted in fetching the better cocoon price with good income to the farmers. The tremendous achievement of bivoltine cocoon and silk production in Karnataka is due to the successful implementation of JICA II, III phase and other bivoltine extension programmes. Using these bivoltine hybrid cocoons, India is producing superior grade of raw silk.

EC P 04: Perception of Farm Youth about Seri-based Integrated Farming System in Eastern Dry Zone of Karnataka

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ABSTRACT

The study was conducted in purposively selected three districts of Eastern Dry Zone of Karnataka. One taluk from each district, one Grama Panchayath from each taluk and two villages from each Grama Panchayath were selected based on the maximum number of beneficiary sericulture farm youth covered under Integrated Farming System (IFS) project. Further, from each village, 20 respondents were selected by using simple random technique thus making a total sample of 120. The data were collected by using structured interview schedule. The perception about seri-based IFS was recorded on three point continuum viz. ‘Agree’ ‘Uncertain’ and ‘Disagree’ with a score of 3,2 and 1 respectively. The data was analysed by using appropriate statistical tests. The results revealed that majority of respondents (51.67 %) belonged to high category of perception about Seri-based IFS. With respect to the different statements such as seri-based IFS provides enough scope to employ family members round the year and seri-based IFS helps to increase income were recorded maximum mean scores (3.00 and 2.95) with the respondents. But, the statements namely the management of seri-based IFS farm is more difficult than conventional farm and marketing of products from seri-based IFS farm is difficult (1.21 and 1.25) with the respondents. The characteristics such as educational status, occupational status, land holding, extension participation, economic orientation and scientific orientation exhibited positive and significant relationship with perception of farm youth about seri-based IFS. Hence, the concerned development departments should organize the demonstrations, trainings, field days, exposure visits etc., to educate the farmers about all the benefits of Seri-based IFS. The positive and significantly related characteristics need to be considered while selecting the farmers for the extension educational programmes to enhance their perception level and promote the seri-based IFS as socially acceptable, economically viable and eco-friendly among farm youth.

Key words: Perception, farm youth, Seri-based Integrated Farming System, Resources

EC P 05: Space Technology inputs for Sericulture Development in India

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ABSTRACT

The paper discusses the research carried out over the last three decades in using space technology in sericulture development by Indian Space Research Organization (ISRO) and Central Silk Board (CSB), Ministry of Textiles in collaboration with many partner institutions. One of the early research findings on applications of remote sensing in sericulture development was reported by Nageswara Rao et al (1991). In the early part of 2000, ISRO and CSB have developed appropriate methodologies for identifying areas suitable for sericulture development in new areas and non-traditional districts of several Indian states. District-wise statistics of suitable areas for silk-worm food plants were generated and graded as A (excellent), B (very good), C (good), D (moderate) and E (less suitable). Subsequent research was focussed on assessment of leaf biomass and silkworm seed requirement taking advantage of the repeat observation capability of the satellite remote sensing. Having estimated the leaf yield potential in the preceding month (t1 say March month), further prediction of likely leaf yield was made based on the changes observed in the Normalized Difference Vegetation Index (NDVI) observed over time (t2 say April month) assuming a linear relationship between bio-mass and NDVI.

The above mentioned research and availability of various tools of spatial data analytics have motivated us towards developing a Sericulture Information Linkages & Knowledge Systems (SILKS). This geospatial portal can be visited at silks.csb.gov.in for more details. It is being developed for about 100 districts of India where sericulture is the main stay of rural activities. SILKS database has not only the conventional non-spatial data but also the latest, scientific spatial data on suitable areas of sericulture development, existing areas under silkworm food plants, etc. All the information and planning tools from SILKS can be run as an enterprise starting with a shoe-string budget. They can be built around personal computers, palm-tops, I-pads etc. Information and planning advice can be sold as a commodity. A quick estimate of employment opportunities shows that nearly 500,000 graduates per year can get livelihood on running as many SILKS- like information kiosks as required in the rural India. The Subscribers Trunk Dialing (STD)/PCOs that existed once can be revived into information kiosks and village panchayat office buildings, cooperative milk societies and libraries in the villages can be locations for starting such enterprises.

Section 7

Sericulture in non-textile industries and new silk applications

NT-LP: Lead Paper

Spatial Control of Cell Adhesion on Silk Fibroin Matrices by Click Modification

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In this study, we altered cell adhesion property of *Bombyx mori* silk fibroin matrices by click chemistry modification with polyethylene glycol (PEG), which is known to repel proteins and cells. The click modification reactions were targeted to azido groups incorporated into silk fibroin by a newly-developed genetic code expansion technique. The PEG-modified silk matrices showed decreased cell adhesion and partial photolysis of azido groups by UV irradiation before PEG modification enabled spatial control of cell adhesion. This achievement will lead to the production of self-standing, biocompatible, and spatially arrangeable cell substrates for tissue engineering applications.

Silk matrices (film and porous sponge) were prepared from silk fibroin incorporated with an azido-bearing synthetic amino acid, 4-azido-L-phenylalanine, produced by the H06 transgenic *B. mori* line expressing the F432V mutant of *B. mori* phenylalanyl-tRNA synthetase α -subunit (*ACS Synth. Biol.* 7, 801-806, 2018). Initial adhesion of mouse fibroblasts NIH3T3 on the surface of silk films was investigated when they were modified with DBCO-mPEG of different PEG chain lengths (5, 10, 20, and 30 kDa). Non-treated silk films showed good attachment of fibroblasts whereas the PEG-modified silk films showed decreased adhesion depending on the length of PEG chains. The decrease was more significant for longer PEG chains of 20 and 30 kDa. For spatial patterning of fibroblasts, silk films were first irradiated by UV light through a photomask and then modified with DBCO-mPEG of 20 kDa. Fibroblasts were cultured on the modified silk films for three days. A clear pattern was formed by selective adhesion of cells onto the irradiated areas where PEG did not attach (Fig. 1). The result demonstrated that cells can be spatially patterned on silk film by PEG modification after controlled photolysis of azido groups. Similar spatial patterning of fibroblasts was tried with 3D porous silk sponges. The results will be shown in the presentation.



Fig. 1. Pattern of “SILK” written by cells on silk fibroin film.

NT O 01: Selective enrichment of α -linolenic acid from silkworm, *Bombyx mori* pupae oil by fungal lipases

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Abstract:

Omega-3 fatty acid particularly α -linolenic acid is a precursor for other essential omega 3-fatty acids in human body and maintains normal physiological functions. As α -linolenic acid cannot be synthesized by human body; it must be exclusively obtained from the diet. Silkworm, *Bombyx mori* pupae oil is known to be rich source of α -linolenic acid. Hence, process was developed for concentration of α -linolenic acid from silkworm pupae oil by eco-friendly enzymatic approach. Lipase enzymes were screened from different species of *Cordyceps* spp. belongs to Ascomycetis fungi and produced by solid state fermentation process using silkworm pupae based media. The selective enzymatic hydrolysis of silkworm pupae oil for recovery of α -linolenic acid was performed using crude lipases extracted from *Cordyceps* spp. The quantification of α -linolenic acid was determined by gas–liquid chromatography and high-performance liquid chromatography. Results have indicated that pupae oil selectively hydrolyzed with fungal lipases yielded higher levels of α -linolenic acid (58.2%) than chemical hydrolysis process (32%). The enzymatically hydrolyzed fatty acid mixture was further concentrated for α -linolenic acid by urea inclusion complexation followed by fractional crystallization and improved to 92%. The resultant α -linolenic acid was further purified with silica column chromatography and achieved up to 97 % of purity. Therefore combination of selective enzymatic hydrolysis with urea inclusion complexation followed by fractional crystallization and silica column chromatography is an effective way to obtain higher purity of α -linolenic acid from silkworm pupae oil.

NT O 02: Sericin Based Nano-Micro Systems for Application in Drug Delivery and Food Preservation

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Abstract

Sericin is a fibrous amphiphilic protein with 63% hydrophilic and 37% hydrophobic amino acids, whose sol-gel property can be attributed to its secondary structure and high amounts of serine, aspartic acid and glycine. Curcumin is a polyphenol extracted from *Curcuma longa* that is generally used as a food colorant and preservative with broad spectrum antimicrobial activity and potent antioxidant activity. However, its applicative potential is restricted due to its hydrophobicity, photolability, poor bioavailability and low absorption. Sericin possesses inherent emulsifying, moisture retaining, antibacterial, UV protectant, amphiphilic and antioxidant properties. These properties make sericin a strong candidate for application as edible coating for food preservation. Based on the conformation of the β -sheets and random coils, sericin based composites exhibit varying morphological and rheological behaviour. The present study attempted to synthesize curcumin integrated sericin composites using different solvent systems with three distinct methods of preparation. A one step desolvation method was carried out to synthesize curcumin loaded sericin nanoparticles that showed high encapsulation efficiency (84.75%) and loading capacity (1.066%). Simultaneously, to check the film-forming ability of sericin, water-based curcumin conjugated sericin films were prepared with diethyl ether and studied for its film forming characteristics. The adhesion of the thin film to a hydrophobic surface was studied by instrumental analyses *viz.* quartz crystal microbalance (QCM), atomic force microscopy (AFM), nuclear magnetic resonance (NMR) and optical polarimetry (OP). To improve the oral bioavailability of curcumin without compromising on edibility and biocompatibility, a third oil-in-water (O/W) sericin-curcumin emulsion was synthesized in the presence of ethyl oleate under high energy physical agitation method. Preliminary results of the three types of sericin based materials have shown encouraging results and detailed investigation on their potential applications are currently underway.

Keywords: Sericin; Curcumin; Desolvation; Emulsion; Films; Amphiphilic

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NT O 03: Studies on Mechanical Properties and appearance of Indian Tasar Silk

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ABSTRACT

Tasar cocoons and tasar raw silk filaments have been evaluated for physical and mechanical properties such as cocoon shape, size, filament denier, fibre surface texture and filament's tensile behaviour. Tasar silk (Daba and Raily verities) have been subjected to reeling process and the characteristics of silk yarn reeled from outer, middle and inner layers of the cocoon have been studied in this article.

Cocoon and filament characters are found to be dependent on the variety and size of the cocoon. The denier variations in the tasar silk filaments from outer to inner layers of the cocoon, yarn cohesiveness and tensile properties of the tasar silk yarn of these three cocoon layers have also been evaluated. Outer layer filaments are observed to be coarser, followed by the filaments of the middle layer and the inner layer filaments are comparatively finer. Although the denier gradually reduces, there is no significant change in tenacity of the tasar silk filaments of outer, middle and inner layers of cocoon. Surface appearance of the tasar silk fibre has been observed through SEM imaging and the images show presence of fibrillations and longitudinal striations on the fibre surface.

X-X-X-X-X-X-X-X-X-X

NT O 04: SILK BASED MATERIALS IN THE DESIGN OF ADVANCED MEDICINES

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The use of silk cocoon proteins, fibroin and sericin in medicine and pharmaceuticals production is one of promising and high-tech ways of their application. These proteins were originally used as raw materials for the production of protein hydrolysates that possess a wide range of physiological, prophylactic, and therapeutic effects [1]. But these proteins will find a more effective application not in the depolymerized form but in their natural polymeric form characterized by high mechanical, shaperon and sanitary properties, biocompatibility, biodegradability and self-assembly which are much-needed in the 3D printing, designing and modulation of dosage drugs and their properties [2].

The fibroin property of interconversion from the soluble to the gel and crystalline state allows to create on its basis and, especially, with the participation of sericin, a large variety of drugs with modified properties. This is important in the creation of low-toxic pharmaceuticals and in the treatment of metabolic and neurodegenerative diseases, especially, in personalized therapy [3].

The research and development strategy in this area is focused on the selection of suitable raw materials and wastes of the silk industry, on their inexpensive processing into universal initial semi-products for bio- and nanotechnology, on the development and selection of attainable methods for conversion the initial semi-products into bio-sorbents and composites with targeted properties as well as on the methods of incorporating the samples of effective local and foreign medicines, both soluble and insoluble, and also possessing some other specific properties into the silk matrices.

The use of these methods allowed us to obtain samples for testing dosage forms with the inclusion of polyphenolics: quercetin, curcumin, gossypol and its derivatives, proteins (insulin, lysozyme, lipases, phospholipase A₂, phospholipase D), protein hydrolysates (different peptides and amino acids), allapinin and other drugs.

We have examined EM-structure and FTIR spectra of the obtained samples, there solubility, cumulative releasing of drugs and model substances included in the silk matrices, antioxidant, antimicrobial, enzymatic and other studied activities and properties. The rate of ligands release varied in accordance with its concentration, temperature, pH, content of extragent and the ratio of fibroin and the bio (polymer) additionally introduced into the silk matrices. As shown obtained results silk proteins can be used in creation of large variety of drugs with modified properties.

Key words: silk proteins, matrix material, drug delivery.

NT O 05: Synthesis and characterization of antimicrobial chitosan and silk fibroin nanofibers (CS-SF Nanofibers)

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Abstract

Chitosan (CS), a naturally occurring polysaccharide isolated from the silkworm (pupal exuviae) possesses inimitable biocompatibility, excellent biodegradability and exceptional antibacterial properties whereas silk fibroin (SF) has viscous nature which increases mechanical property. In the present work, CS-SF nanofibres were successfully fabricated by electrospinning using CS (20%) and SF (80%) to evaluate its antibacterial character/potential. The morphology of electrospun blend nanofibers was observed by scanning electron microscopy (SEM). Further, the vibrational properties of amino acids, co-factors and the resulting minute structural changes observed in chitosan and silk fibroin nanofibers were studied using FTIR. The presence of primary amine at 948 cm⁻¹, amide II at 1,164 cm⁻¹, CH ring at 1254 cm⁻¹ and amide I at 1,632 cm⁻¹ transmittance peaks were noticed in CS-SF nanofibers which could be attributed to the random coil protein conformation. X-Ray Diffraction (XRD) analysis of CS-SF nanofibre showed distinct peaks indicating the presence of chitosan and fibroin. The antibacterial activities against *Shigella flexneri*, *Escherichia coli*, *Staphylococcus aureus* and *Bacillus thuringensis* (silkworm pathogen) were evaluated by the disc diffusion and spectrophotometric methods. The growth inhibition was noticed against all the test pathogens but maximum inhibition was noticed against *B. thuringensis* and *S. flexneri*. Hence, the nanofibers synthesized can be exploited as an antibiotic (in sericulture industry for management of bacterial disease), as well as potential therapeutic product that can be used for different biomedical applications.

Keywords: Chitosan, Fibroin, Electrospinning, Nanofibers, Antibacterial activity.

NT O 06: INFLUENCE OF APPLICATION OF SERI-WASTE BIO-DIGESTER LIQUID TO MULBERRY ON COCOON PARAMETERS OF SILKWORM, *Bombyx mori* L.

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ABSTRACT

An experiment was conducted during 2017-18 to study the effect of seri-waste bio-digester application to mulberry on cocoon parameters of silkworm. Mulberry grown with the application of 50 per cent seri-bio-digester effluent + 25 per cent bio-digester effluent + 25 per cent Recommended Dose of Fertilizers (RDF) significantly enhanced the Effective Rate of Rearing (ERR) (98.28 per cent), maximum larval weight (38.63g/10) and cocoon parameters viz., single cocoon weight (1.86g), pupal weight (1.53g), shell weight (0.30g), shell ratio (16.60 per cent) and single cocoon filament length (915.10g) followed by 25 per cent seri-bio-digester effluent + 25 per cent bio-digester effluent + 25 per cent vermi compost + 25 percent compost with larval weight (1.86g), pupal weight (1.53g), shell weight (1.53g), shell ratio (16.34 per cent) and single filament length (911.68m). The study revealed that, application of seri-waste bio-digester effluent to mulberry along with other organic manures increased the rearing and cocoon parameters providing all the essential nutrients for mulberry growth compared to application of sole inorganic fertilizers and inturn it contributed for quality cocoon production. Utilization of sericulture waste generated during mulberry cultivation and silkworm rearing leads to generate additional income, entrepreneurship development in sericulture and value addition inturn contributing to achieve sustainability in sericulture.

Keywords: Mulberry, Seri waste biodigester, Silkworm, Rearing performance.

NT O 07: Pressure- and water-induced crystallization of silk fibroin

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Silkworms and spiders convert silk fibroin solution into fibers by adjusting water contents and shear forces in their gland. Previous study demonstrated that water molecules played a role in the formation of β -sheet structure of silkworm silk fibroin.¹ However, little is known about the effect of pressure on the crystallization of silk fibroin. Moreover, the difference in reactivity to pressure and water molecules between silkworm and spider silk remains to be solved.

In this study, we investigated the effect of pressure and water on the crystallization of silkworm and spider silk films. The amorphous silk films were prepared by casting a silk fibroin solution. The silk films were incubated at different pressure and relative humidity. We found that effect of pressure was different between silkworm and spider silk. Pressure did not induce crystallization of spider silk but induced β -sheet formation of silkworm silk at above 100 MPa (Fig.1). On the other hand, water molecules induced crystallization of both silkworm and spider silk (Fig.2).

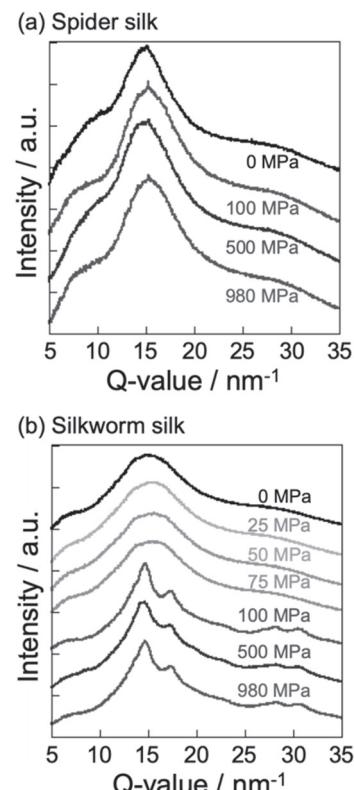


Fig.1. Wide-angle X-ray scattering of (a) spider and (b) silkworm silk film incubated under different pressure.

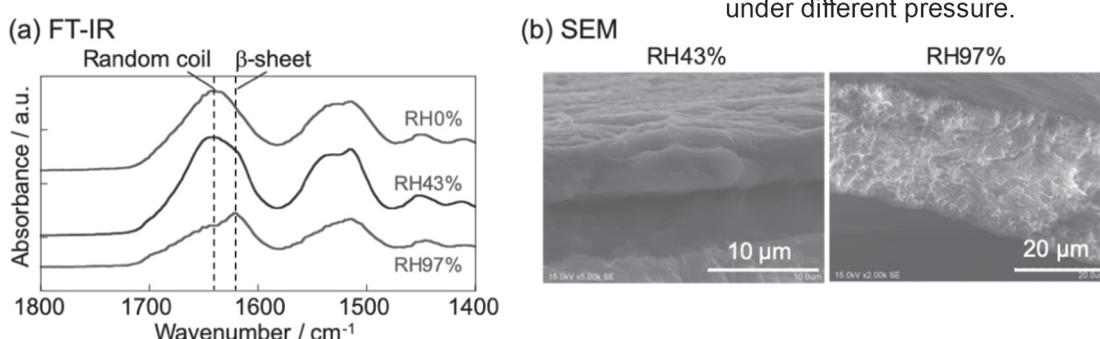


Fig.2. Humidity-dependent conformational transition of spider silk film analyzed by (a) Fourier transform infrared spectroscopy (FT-IR) and (b) scanning electron microscopy (SEM).

[Reference]

- Yazawa, K. et al. *Biomacromolecules*, **17**, 1057-1066 (2016).

NT O 08: Cellulose-Silk Composites for Bone Tissue Engineering

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Abstract

The applicability of silk fibroin for biomedical uses has been confirmed already, leading to its use as surgical aid for instance. Research is also progressing on the use of silk fibroin for tissue engineering applications, comprising dermal and cartilage tissue among others. It has been confirmed, how silk fibroin improves cell adhesion and proliferation when used as a scaffold material.

Cellulose also is a widely researched material, due to its great availability. Various approaches have been taken to establish cellulose as a biomedical material, which is how its usability as a wound dressing material could be confirmed. Cellulose has also been tried for tissue engineering applications, such as bone tissue engineering, with promising results.

Though both materials already have beneficial features for bone tissue engineering, they also lack certain properties: Whereas silk fibroin greatly aids cell viability it is not able to contend with actual bone matrix in terms of mechanical stability. Cellulose is beneficial for mechanical stability and biocompatible, but does not support cell viability.

By combining both materials in a composite, we aim to let both complement each other to make a durable and cell growth promoting scaffold.

This is achieved by dissolving cellulose in Dimethylacetamide with 9% LiCl (DMAc/LiCl), and subsequent dissolving of silk fibroin in the same solution. Afterwards sodium chloride is added as a porogen and the solution is solidified into a gel. Then the porogen and the organic solvent are removed via extensive solvent exchange against water, yielding a stable and porous scaffold material.

We will present the structures, mechanical properties, and cell compatibility of the cellulose-silk composites, and discuss the possibility for use as a bone tissue engineering material.

NT O 09: Mulberry, *Morus alba L.* a potential medicinal plant in Ayurveda - A Review

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ABSTRACT:

For the eternal health, longevity and remedy, to remove pain and discomfort, fragrance, flavour and food, mankind all over the world dependent upon the plant kingdom to meet their all needs. Medicinal plants still play important role in emerging and developing countries and are the major components of all indigenous or alternative systems of medicine. Ayurveda is a scientific ancient health science which originated in India 5000 years ago. The medicines in Vedic period of India was practiced based on the principles of Ayurveda. Therefore, Ayurveda is considered to be the fifth Veda or Upaanga of Atharvaveda. The systematic description of Ayurveda and its Siddhantas has been elaborately, systematically and descriptively written in the form of verses and they are individualistic to the three Bruhatrayis (Charaka Samhitha, Sushrutha Samhitha and Ashtanga Hrudaya) which forms the foundation for approach towards various diseases management through medicinal plants. About 700 medicinal plants are described in Charaka Samhitha and Sushrutha Samhitha as a treatment for multiple diseases.

The present paper reviews the medicinal value of *Morus sp* (Tooda in Ayurveda) since Samhitha period (1500 BC to 4 th AD) till date. The Mulberry tree is known for its various medicinal properties and has gained importance since samhitha period and has been extensively described pharmacologically in Nighantus of Ayurveda (4th AD – 18th AD). It has been indicated in various diseases depending upon its pharmacodynamic properties mentioned through Rasa, Guna, Veerya, Vipaka and Karma. All the parts of the mulberry tree viz., leaves, bark, fruit and roots have medicinal value and treated to cure various ailments such as asthma, cough, bronchitis, oedema, insomnia, wound healing, diabetes, influenza, eye infections and nosebleeds. Currently, development of mulberry based Ayurvedic drugs in combination with other medicinal plants to treat diabetes, hypertension and as nutritional supplement are under progress. The chronological reference of *M. alba*, morphology, phytochemistry, pharmacological, ethnomedicinal review with reference to Ayurveda and the current trends in drug development is discussed.

NT O 10: Prospects of breeding wild species of silkworm of the Giant Peacock Moth (lat. *Saturnia pyri*, Denis & Schiffermüller, 1775), as one of the branches of sericulture in Azerbaijan

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Abstract. The presence of large areas of diverse forests and favorable conditions in Azerbaijan give great opportunities for breeding the wild silkworms of family *Saturniidae*. So, in China, in Japan, in India, in Argentina and in many other countries, they have long been engaged in the cultivation of non-traditional breeds of silkworms. In modern sericulture, not only durable fabrics and threads are obtained from them, but also high-tech biomaterials. In this regard, there is a need for a detailed study of the production capacity of the breed that actually lives in the green areas of our country, i.e., to explore its biological and technological indicators in the laboratory. The article describes the cultivation of the Giant Peacock Moth (lat. *Saturnia Pyri*) in the laboratory. It evaluates the efficiency and possibilities for future expanded cultivation and production of specific silk which will be the first in Azerbaijan and in the entire Transcaucasian region.

Keywords: *Saturniidae, Saturnia Pyri, the Great Peacock Moth, wild silkworm, caterpillar, cocoon, silkworm eggs, hatching, molting, sericulture, silk industry*

NT O 11: Silk sericin of different molecular weights and their properties.

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Abstract:

Sericin derived from silkworm cocoons, has long been considered a waste product from the production of silk textiles. However, sericin is gaining attention as a valuable protein for a range of potential applications in the fields of biomaterials, cosmetics and the food industry. The recovery of sericin from the silk processing industry for use in high value applications can lead to significant environmental as well as economic benefits. However, in order to realise these benefits, it is important to have control over sericin extraction since the process can significantly degrade it changing its properties. The aim of this study was to understand the extraction conditions required to obtain undegraded sericin from the domestic silk cocoon - *Bombyx mori*. Sericin was extracted using a number of extraction methods - high temperature, alkaline degumming, extraction with denaturing agents and using a novel mechanical method. SEM images of the degummed cocoon fibres revealed the sericin removal efficiency of the extraction conditions. The molecular weight distribution of the sericin extracted with the different methods was examined by SDS-PAGE. The results suggested sericin bands with a wide range of molecular weights. The extracted sericin were separated into low and high molecular weights and the gelling kinetics of the two fractions was studied. The results confirmed the effect of molecular weight in gelation and stability of sericin. The ability to control molecular weight and associated properties will aid in developing methods that will help tailor the properties of sericin depending on the desired application.

NT O 12: Evaluation of Hair Conditioning Efficiency of Silk Sericin – In Vitro Hair Combability Test

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Abstract

Context: Sericin is a water soluble and biodegradable protein containing 18 amino acids extracted from *Bombyx mori* silk cocoons. This protein has been widely used in skin-care products due to its various biological activities such as anti-oxidation, good moisture absorption and wound healing. However, the potential application of sericin in hair-care product has not yet been explored.

Objective: This research work evaluated the amino acid profile of silk sericin extract and its conditioning efficiency on virgin Asian hair locks by combability test.

Materials and methods: Silk sericin extract which demonstrated high amount of serine, was incorporated in water and serum-based formulations at 1% w/w (sericin solution and sericin serum). The obtained sericin solution and sericin serum were evaluated for hair conditioning efficiency compared to no treatment, serum placebo and commercial encapsulated sericin 0.5% w/w in serum. A total of 3 virgin Asian hair locks was applied with 1.0 g of each formulation. Combing force of hair surface was measured before and after 2, 4, 6 and 8 hours of single application of formulation by using Texture Analyzer with combing device.

Results: After 2 hours of application, sericin solution, sericin serum and commercial encapsulated sericin 0.5% w/w in serum gave higher improvement of combing force of the hair surface than that from no treatment. Moreover, sericin solution and commercial encapsulated sericin 0.5% w/w in serum showed greater efficacy than that from serum placebo, while sericin serum showed no superior to serum placebo. After 4 and 6 hours of application, sericin solution, sericin serum and commercial encapsulated sericin 0.5% w/w in serum exhibited higher improvement of combing force of the hair surface than those from no treatment and serum placebo. After 8 hours of application, all formulations showed higher improvement of combing force of the hair surface than that from no treatment, but no superior to serum placebo.

Discussion and conclusions: Silk sericin in both solution and serum formulations gave superior hair conditioning efficiency for up to 6 hours which was comparable to that of commercial encapsulated sericin containing in serum. Amino acids containing in silk sericin may contribute to the improvement of hair combing force. The present work suggests that silk sericin can serve as a new conditioning agent in hair-care products.

Keywords: silk sericin, combability, conditioning efficiency, Asian hair

Acknowledgement This work was supported by the Thailand Science Research and Innovation (TSRI), ITAP-National Science and Technology Development Agency (NSTDA), and SeriTech Company Limited, Thailand.

NT O 13: Tasar cocoon cooking water is a cheap source of sericin : its characterization

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Abstract:

Sericin was extracted from tasar cocoon cooking waste water. The chemical composition of sericin powder, including amino acid and CHNS analysis, and physical characterization such as FTIR, TGA, SEM was assayed in detail. The molecular weight distribution of sericin was investigated by SDS-PAGE. The results suggested that sericin represented a family of proteins with wide-ranging molecular weight distribution. The waste water sericin having higher amount of low molecular weight proteins (>35kDa) and lower amount of high molecular weight (<245kDa). Amino acid analysis revealed that contents of serine (22.62%), aspartic acid (19.36%) and glycine (12.65%) were greater than other amino acids, of the 17 kinds of amino acids, respectively in tasar cocoon cooking water, which indicated that aspartic acid and glycine were also important amino acids attributed to the functions of sericin. In addition, sericin was found to inhibit tyrosinase, elastase and glutathione-S-transferase activity, and had apparent radical scavenging impacts on 2,2 diphenyl 1 picryl hydrazil (DPPH), hydrogen peroxide and inhibition of lipid peroxidation. Result suggested that tasar waste water sericins might be a valuable ingredient for cosmeceutical products.

Keywords: *Antheraea mylitta* ; Tasar; cooking water; sericin; anti-tyrosinase

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NT O 14: Relationship between secondary structures of silk fibroin-based biomaterials and cell behaviors

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Silk fibroin has been expected as novel biomaterials due to their excellent biocompatibility, hygroscopic and mechanical strength. In addition, silk fibroin-based biomaterials are potentially useful for a range of clinical applications because various shaped silk fibroin materials such as films, gels, nanofibers can be processed from aqueous solution. In our previous study, silk fibroin-based biomaterials immobilized with functional molecules as wound dressings have been developed. β -sheet structures of silk fibroin were thought to be an important factor in the immobilization of functional molecules. Thus, this study has been focused on structural changes of silk fibroin molecules.

Silk fibroin aqueous solution was cast and dried at room temperature or 50°C to obtain silk fibroin films. After drying, films were treated with 80% alcohol aqueous solutions and dried at room temperature or 50°C. Secondary structures of silk fibroin in films were analyzed by ATR-FTIR spectroscopy. ATR-FTIR spectra showed that structural changes to β -sheet were induced by drying processes and treatments with 80% alcohol aqueous solutions. It was suggested that various properties of alcohol molecules in alcohol/water mixtures influenced on β -sheet contents in films. Fibroblasts were cultured on silk fibroin films, and cell behaviors on films were evaluated at each predetermined time point. Various proliferation patterns were observed on silk fibroin films. Films with higher β -sheet contents induced the enhanced cell proliferation. These results suggested that β -sheet contents of silk fibroin-based biomaterials would affect cell behaviors.

NT O 15: Assembly of MnO₂ into protein-based nano-platform for Tumor targeting accumulation and combination tumor therapy

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Abstract

Manganese dioxide (MnO₂) nanoparticles can act as a great candidate for photodynamic therapy and drug delivery. MnO₂ were discovered to be effective in improving the levels of reactive oxygen and controlling a drug release in acidic tumor microenvironment. However, its application in clinic treatment is hindered by its lack of tumor targeting and extremely tiny size (less than 5 nm). Here, for the first time, we overcomed these disadvantages by using *Bombyx mori* (*B. mori*) silk fibroin as a biotemplate to regulate the self-assembly of MnO₂ nanoparticles for designing a hybrid MnO₂-SF nanoparticles. The hybrid nanoparticle yield high stability, biocompatibility and programmable oxygen generation rate. We further enhanced its tumor targeting by decorating the hybrid MnO₂-SF nanoparticles (NP) with folic acid (FA). The hybrid MnO₂-SF nanoparticles exhibited a core-shell structure. Its distinctive raspberry-like surface morphology improved drug loading capability. In vitro studies showed that MnO₂-SF NPs generate high level of oxygen by reacting with H₂O₂ and release loaded drug selectively in acidic condition. The hybrid MnO₂-SF NPs are found to efficiently internalize in human breast cancer cells (MCF-7) in vitro, and quickly reach tumor in vivo. After loading antitumor drug, doxorubicin (DOX), and photosensitizer, chlorin e6 (Ce6), the hybrid MnO₂-SF NPs can more effectively kill tumor cells and inhibit the growth of tumor by chemotherapy and photodynamic therapy. These results suggest great potential of MnO₂-SF NPs for modulation of the tumor microenvironment and enhancement of tumor treatment.

Key words: manganese dioxide nanoparticles, *Bombyx mori* (*B. mori*) silk fibroin, self-assembly, tumor targeting, tumor therapy

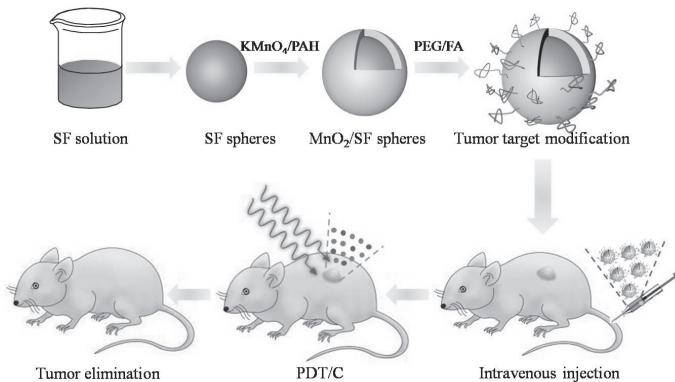
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Abstract Graphic



NT O 16: Aligned electrospun silk fibroin fibers for wound repair

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Abstract

Electrospun fibroin fibers have emerged as a promising class of biomaterials for tissue regeneration since they mimic the nanoscale properties of certain fibrous components of the native extracellular matrix in tissues. Silk-based materials have great potentials in medical applications because of the excellent biocompatibility, remarkable mechanical properties as well as tailorabile degradability. However, electrospun silk fibroin fibers' application in tissue regeneration is limited by its mechanical properties. In this work, we prepared the well-aligned silk nanofibers through the magnetic field collecting device which provided effect of magnetic field superimposed electric field by adding nano-Fe₃O₄ particles to spinning solution. The resulted aligned fibers construct the membranes with an orientation structure, improved mechanical properties and a certain magnetic responsiveness which have been demonstrated by scanning electron microscopy, tensile test and vibration sample magnetometer test. Biocompatibility analysis proves that the structure well guides the adhesion, proliferation and differentiation into blood vessels of mesenchymal stem cells along the aligned SF fibers. We further cultured the myoblast C2C12 on the aligned silk nanofiber and found that it could also induce cell to grow along with the direction of orientation. The results from the in vivo experiment also show an obvious repair effect in a rat model of skin defects. These features make the aligned electrospun silk fibroin fibers an excellent biomaterial having a great potential for wound repair in deep skin trauma muscle repair.

Key words: silk fibroin, aligned electrospun fibers, vascularization, skin defects repair

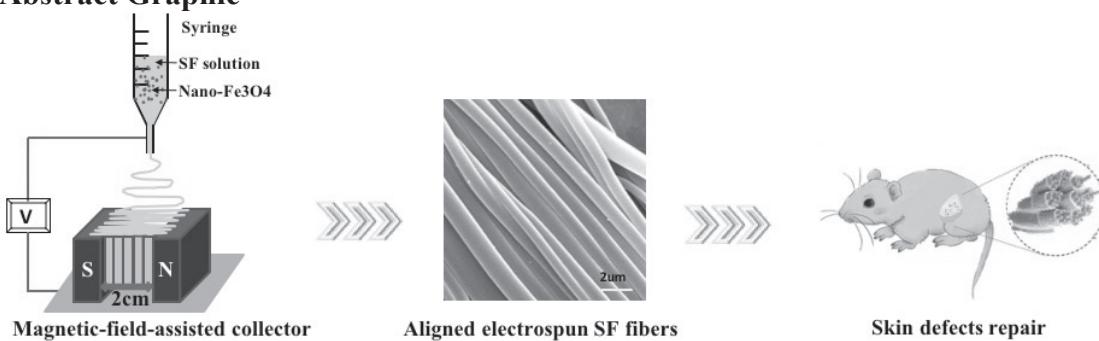
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Abstract Graphic



NT O 17: Structural origin of the water-resistance of films cast from *S. c. ricini* silk fibron solutions in 1,1,1,3,3,3-hexafluoro-2-propanol

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Abstract:

The utilization of silk fibroin from the wild-silkworm, *Samia cynthia ricini* (*S. c. ricini*) is limited, largely due to lack of appropriate processing strategies. For instance, films cast from liquid fibroin (LF) and regenerated cocoon silk fibroin (CSF) are water-soluble and require post-treatment to render them water-resistant. In this study, we report of a mild strategy for preparation of water-resistant films directly from silk gland fibroin (SGF) of *S. c. ricini* without the need of post-treatment. A solution of 40%-EtOH-solidified SGF in 1,1,1,3,3,3-hexafluoro-2-propanol (HFIP) gave a film from which transparent film was cast. Compared to a film cast from LF, this contains some β -sheet content which renders it water-resistant.

Experimental

Detailed characterization of the chemical composition, structure and physical properties of the HFIP-based film were performed by GPC, HPLC, FTIR, ^{13}C NMR, WAXD and thermal analyses and compared to that of a film cast from LF. Further structural clarifications were performed by analyzing LF- and HFIP-based films after heat-treatment at 220 °C for 1 min.

Results and Discussion

The molecular weight distribution and amino acid compositions of the LF-and HFIP-based films were essentially similar. On the other hand, unlike in the LF-based film, FTIR results revealed the HFIP-based film to have some β -sheet. These results were well supported by ^{13}C solid-state NMR data and is believed to be the origin of the water-resistance in the HFIP-based film. Further, WAXD results for the LF- and HFIP-based films were as shown in figure 1 a and b, respectively. The peak position of the strong and sharp peak detected at $2\theta = 11.6^\circ$ in the profile for the LF-based profile was broad and shifted to a slightly wide-angle ($2\theta = 12.8^\circ$) in the profile of the HFIP-based film. This shift may be attributed to a smaller or wide distribution of the hexagonal packing domain size. Based on these results, a plausible model of the mechanism leading to the water-resistance of the HFIP-based film is discussed.

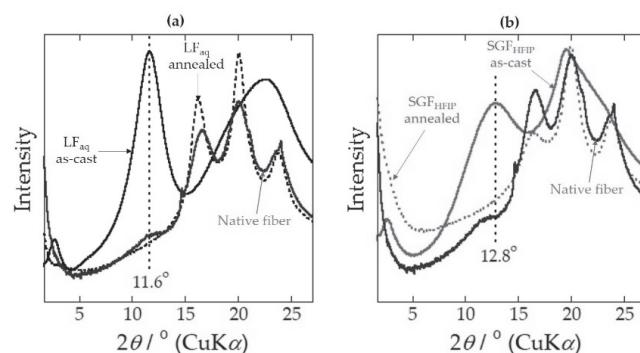


Figure 1. WAXD 2θ-profiles of *S. c. ricini* LF_{aq} (a; black) and SGF_{HFIP} (b; red) films, and native fiber (blue). The solid

NT P 01: An Arginine inducing *Bombyx mori* (*B.mori*) silk sericin assembling into nanofibers for promoting osteogenic differentiation of BMSCs

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Abstract

Nanofibrous scaffolds attracted great attention in bone tissue engineering, for their similarity with the architecture of bone extracellular matrix. *Bombyx mori* silk sericin (BS) is a global protein with features desirable as a biomaterial, such as excellent biocompatibility, hypoallergenic, hydrophilicity, and biodegradation. Here we study how Arginine (ARG) changed the nanostructure of sericin, and affect murine bone marrow-derived mesenchymal stem cells (BMSCs) differentiation. AFM images indicated that ARG induced sericin nanoparticle to form nanofibrous. Circular dichroism (CD) and FT-IR spectra showed that ARG increased the percent of β -sheet and thermal stability of BS added ARG (R-BS). The cell viability and differentiation assay declared that R-BS membranes with network-like nanofiber structure improved cell elongation and differentiation. This study suggested that sericin mediated by ARG could be potentially used in bone tissue engineering, which also significantly enhanced BS socioeconomic value.

Key Words: *Bombyx mori* (*B.mori*) silk sericin, arginine, nanoparticle, nanofibrous osteogenic differentiation,

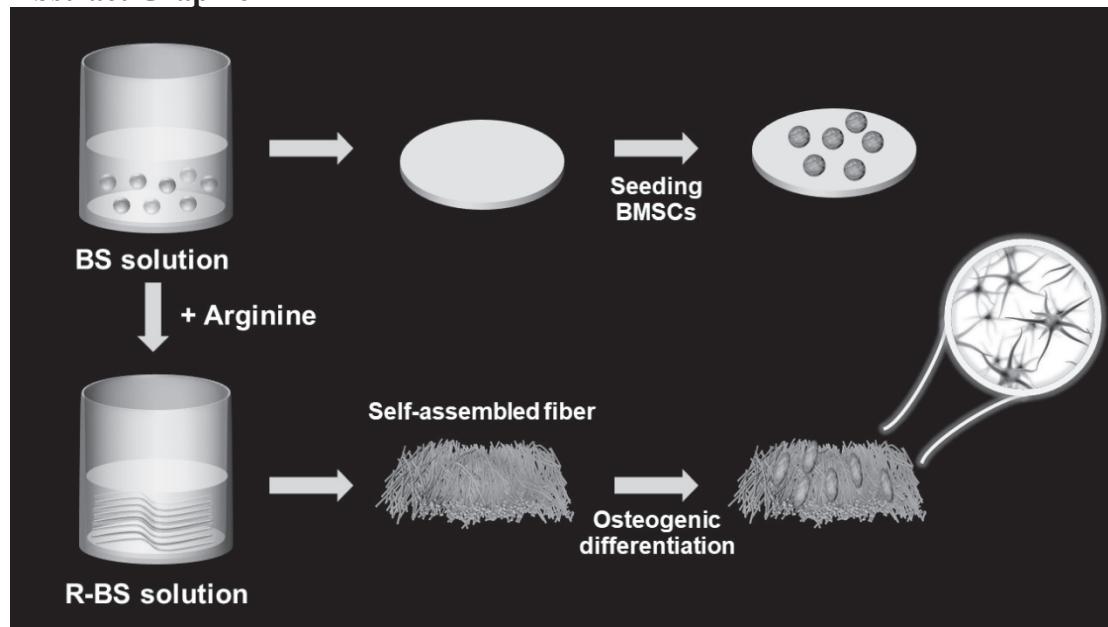
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Abstract Graphic



NT P 02: Preparation of Silk Fibroin / Graphene Oxide Composite Scaffold and Its Effect on Neural Stem Cells

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Abstract

As a kind of natural polymer, silk fibroin (SF) not only has good degradability, biocompatibility and mechanical properties, but also can be easily processed into various material formats. This allows it to be widely utilized in the field of biological materials. Graphene oxide (GO) shows good thermal conductivity, good light transmission and mechanical strength. However, the toxicity of GO limits its application as biomaterials in tissue engineering. As a common global health problem, nerve injury could seriously affect patients' quality of life and result in an enormous socioeconomic burden. Due to the limited regenerative capacity of the nervous system, neural stem cell (NSC)-based therapies have great promise for nerve injury and repair.

In this study, silk fibroin /graphene oxide composite scaffolds (SF/GO scaffolds) were prepared successfully by freeze-casting, using SF solution and GO solution as raw materials. The results showed that the addition of GO can significantly improve the mechanical properties of SF/GO scaffolds. Cell viability test showed that the SF/GO scaffolds have good biocompatibility. Compared with the SF scaffold, the addition of GO can promote the differentiation of NSCs into neurons. The more the GO is added, the more neurons differentiate. The above results show that the FSFGO scaffolds prepared in this study can indeed promote the differentiation of NSCs into neurons and are expected to be used as medical biomaterials in the field of nerve injury repair.

Key words: silk fibroin, graphene oxide, neural stem cell, freeze-casting, differentiation

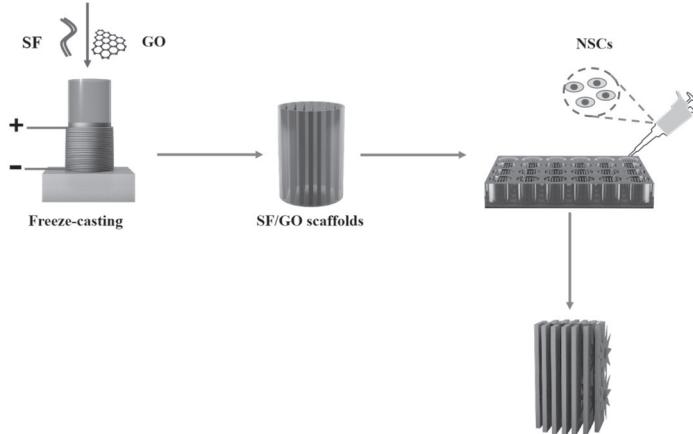
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Abstract Graphic



NT P 03: Fibroin nanofiber hydroxyapatite composites promote osteogenic differentiation of stem cells

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Abstract

Bone defect is one of the main medical problems in today's society. In order to construct a material that promotes osteogenic differentiation of stem cells, silk fibroin which contains good biocompatibility has been combined with the main ingredients of bone—Hydroxyapatite (HA). One of the major problems is how to make silk fibroin and hydroxyapatite combining better. Silk fibroin film appears in the form of Nano silk fibers by electrospinning and dense hydroxyapatite coating was deposited in fibers using electrochemical mineralization technique. By adjusting the electrochemical parameters, the hydroxyapatite layer is coated on the surface of the nano silk fibers, which allows for the best use of both. Based on its good biocompatibility, the composite material can make human bone marrow mesenchymal-derived stem cells(hMSCs) and human adipose-derived mesenchymal stem cells(hAMSCs) adhere to the surface and grow. Through the analysis of related proteins and genes, we found that the two kinds of cells underwent osteogenic differentiation on the surface of materials and via the ERK and P38 signaling pathways. From what has been discussed above, the composite material can effectively promote the osteogenic differentiation of the hMSCs and hAMSCs, which may have application prospect in the field of bone tissue engineering and provides a new method for the surface mineralization of nanofibers.

Key words: silk fibroin, hydroxyapatite, electrochemical mineralization, stem cells, osteoblast differentiation

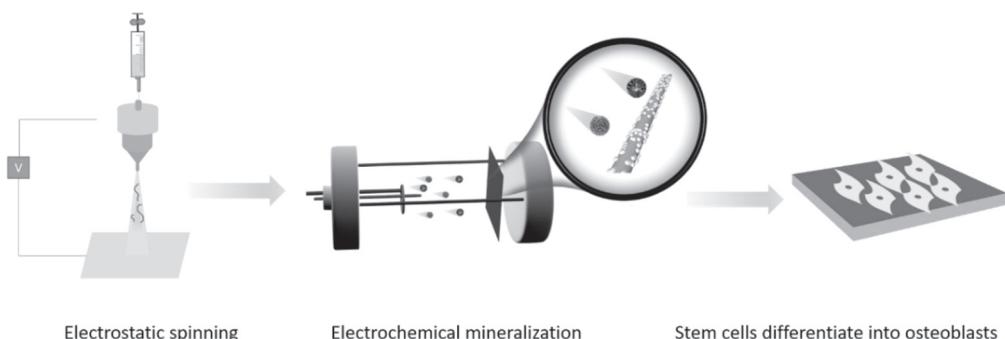
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Abstract Graphic



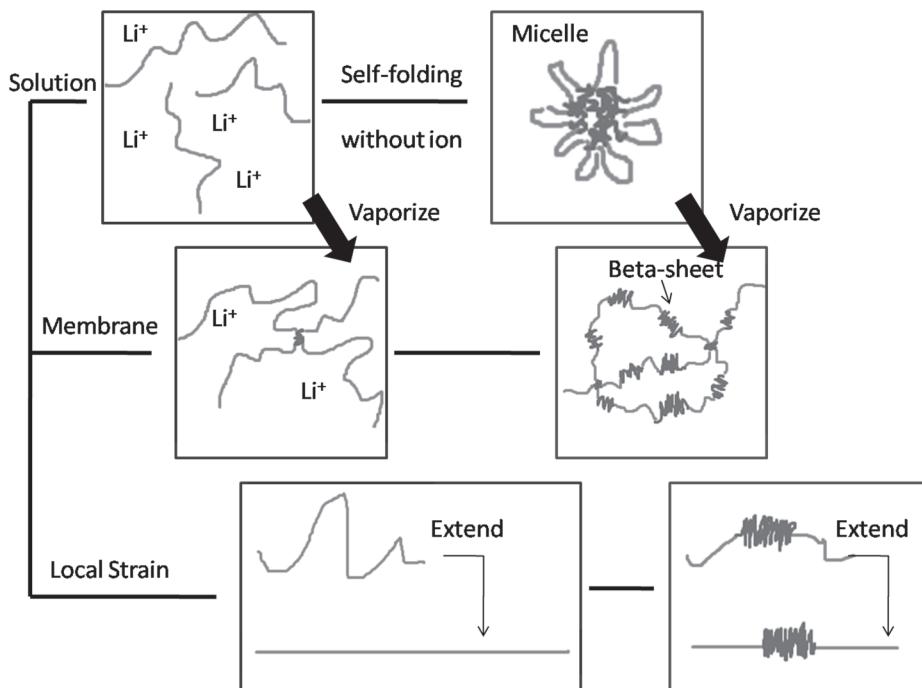
NT P 04: Tuning silk fibroin membrane stain-stress behavior with residue metal ion

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Abstract

Bio-compatibility and mechanical strength defined the application of silk fibroin materials. Although natural silk is known to endure high elongation stress while maintaining flexibility, the silk fibroin materials produced using regenerated fibroin tend to be more brittle. The maximum strain of a crosslinking system is defined by the capability of chain extension between cross-linking points. Thus for a silk fibroin system, intra-molecule beta-sheet folding could certainly limit possible extention of fibroin chains, which in turn lead to brittleness. Besides using high molecular mass fibroin, increasing the fraction of random coil structure would improve the extendibility of material system. Metal ion is a critical element in natural silk processing and is also known to promote random coil structure as well as water bounding in fibroin solution. Thus in this work we demonstrate the mechanical behavior of a regenerated fibroin membrane can be tuned by adjusting the residue Li^+ ion concentration. This lead to softer material and the maximum strain can be drastically increased as ion concentration increases.

Key words: silk fibroin, metal ion, mechanical property, membrane

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NT P 05: Polydopamine modification of silk fibroin membranes significantly promotes their wound healing effect

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Abstract

Natural polymer-based wounddressings have gained great attention in skin tissue engineering. Silk fibroin (SF) spun from Bombyx mori (B.mori) is a potential wound dressing material due to its outstanding biocompatibility and biodegradability, however, its wound healing effect is still limited. To maximize the wound healing effect of SF-based wound dressing, we first fabricated fibrous electrospun SF (ESF) membranes with large porosity and specific surface area, and then formed polydopamine (PDA) coating on the ESF fibers to form PESF membranes. We found that PDA coating enabled the PESF membranes to outperform the ESF membranes in enhancing the hydrophilicity and protein adsorption ability of the membranes as well as the attachment, spreading and proliferation of fibroblasts on the membranes in vitro. Our further in vivo histological analysis confirmed that the PESF membranes accelerated wound healing in a rat skin wound model more effectively within 2 weeks than both the ESF membrane and a commercial dressing (3M™ Tegaderm™). The enhanced wound healing effect of the PESF membranes was further proved by the increase in the content of hydroxyproline (a constituent in collagen) in the wound treated by the PESF membranes. Therefore, the PESF membranes could be used as a promising wounddressing for wound healing and skin regeneration.

Key words: electrospun silk fibroin membranes, poly-dopamine, wound dressing, wound healing

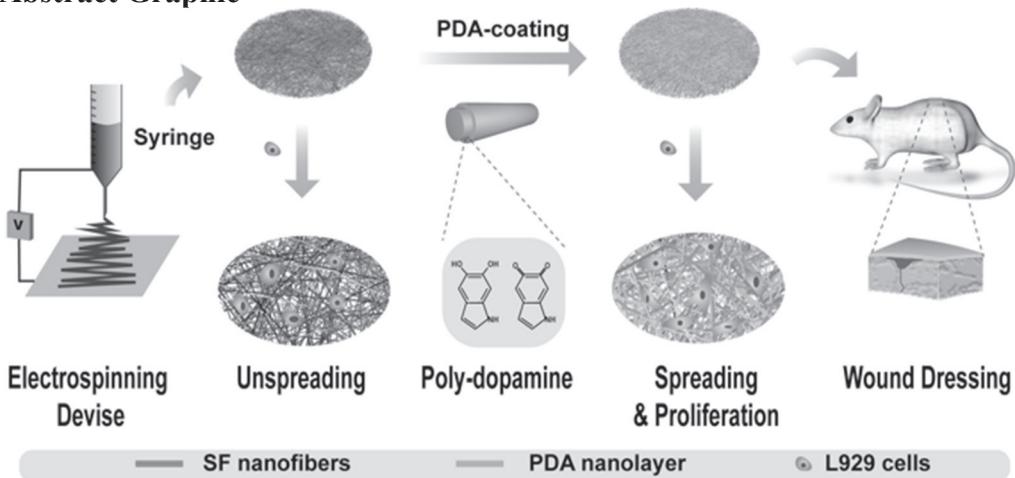
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Abstract Graphic



NT P 06: Development of Silk Nano-particles from Sericin silk protein aiming at novel Drug Delivery System

Peter M. Munguti¹²³, Derya Aytemiz Gultekin², Hidetoshi Teramoto², Sokaku Ichikawa¹, Tsunerori Kameda¹

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Abstract

There is significant research dedicated to fibroin and sericin, the two major protein components of silk from the domesticated silkworm, *Bombyx mori*. Sericin has been largely neglected on the account of hypothetical allergenic activity. Previous studies have demonstrated the sericin derived from normal silkworms has the characteristics of anti-oxidation and biocompatibility, therefore sericin show feasibility to use as biomaterial. However, Sericin is soluble in hot water and solidifies after extraction and becomes less soluble. In addition, sericin with high molecular weight is more difficult to dissolve in water. Therefore, by using un-degraded sericin from new silkworm type, this study seeks to prepare soluble Nanoparticles that can be evaluated for novel drug delivery systems.

Acknowledgment: This Research Was Supported by Science and Technology Research Partnership for Sustainable Development (SATREPS) Japan Science and Technology Agency (JST) / Japan International Cooperation Agency (JICA).

Reference: C. weber, C. Coester, J. Kreuster, K. Langer. Desolvation process and surface characterisation of protein nanoparticles International Journal of Pharmaceutics. 194 (2000) 91-102

NT P 07: Towards human and environmental prosperity

Dessislava Dimitrova, CEO of Bio Stopanstvo Lopyanko Ltd.

We live in a resource – constrained world and our obligation is to minimize the waste. The following major causes of environmental problems that affect the development of sustainability are population growth and poverty, lack of lifelong learning opportunities and equal access to education, unemployment and wasteful and unsustainable resource use. The expected population growth with an estimation of 9.6 billion people in 2050 (UN 2013), wasteful and unsustainable resource use which cause harmful environmental effects and poverty are interrelated with the following issue: According to FAO (2006), livestock production accounts for 70 percent of all agricultural land use. With global demand for livestock products expected to be more than double between 2000 and 2050 (from 229 million tons to 465 million tons), and meeting this demand will require innovative solutions. The opportunity for insects to help meet rising demand in meat products and replace fishmeal and fish oil is very big.

The importance of the bio economy in the Europe Union is very significant in terms of an annual turnover of around two trillion euros and employing around 22 million people. This is one of the most important sectors, encompassed the food & feed industries, agriculture and fisheries, chemicals. Therefore, the bio economy is not a niche but is an area for growth and jobs. The Europe 2020 Strategy calls for a bio economy as a key element for smart and green growth in Europe.

The heart of the Bio economy is the Bio Refinery, where the **Silk Bio Refinery Project**, using renewable resource material in an industrial scale is going to turn into novel biodegradable viable products. The approach that is going to be applied (Circular Economy Approach) will allow to use this renewable resource in a very efficient and sustainable way throughout the whole manufacturing cycle. Using renewable biomass within the Project will lead to new value added products like organic fertilizers, novel food based on Insects for the Feed Industry thus will result in minimizing the CO₂ emissions, protecting the environment and boost the economic growth and job creation in the chosen region.

Silk Bio Refinery Project will deliver sustainable and inclusive growth in the Northwest part of Bulgaria, based on Circular Economy Approach /CEA/ and consistent with the SDG of 2030 Agenda for Sustainable Development, providing green jobs, reducing unemployment and contributing to economic and social progress. More than 100 permanent jobs will be opened in the mother plant, together with 80 places for temporary seasonal employment. A greener economy means new growth and job opportunities. **Silk Bio Refinery Project** will be a good example for further development of the EU guidelines and policies, as well as a pilot industrial enterprise in this direction.

Section 8

Silk processing, trading and marketing

SP-LP: Lead Paper

Silk Processing, Trading and Marketing – Recent Trends

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ABSTRACT

Silk is a highly valued textile fiber of animal origin used almost entirely for the production of high quality textiles. Silk due to its unique characteristics as a textile fibre known as the “Queen of Textiles” the world over.. Though silk accounts for less than 1% by volume of world fiber production, its relatively high value makes sericulture an important industry in the developing countries.

Silk sector encompasses both Agriculture and Industry. Post cocoon sectors consists of silk reeling, twisting, weaving, wet processing and garment manufacture. The progressive movement along the chain of activities is not just limited to conversion of form, but value addition as well.

The major silk producing countries in the world are; China, India, Uzbekistan, Brazil, Japan, Republic of Korea, Thailand, Vietnam, DPR Korea, Iran, etc. About, 177507MT of silk is produced globally(2017). India is the second largest producer of silk next to China.

Wet processing plays a vital role in the marketing of silk and hence It becomes very important that sufficient care is given to enhance the natural beauty of silk. Even though lot of developments have taken in place in wet processing, still there is scope for further improvements particularly in the areas of functional finishes. The present trend in the world silk industry is to look for technologies which gives better quality productivity with less labour/water/energy requirements. Arm dyeing/Yarn package dyeing/fabric dyeing machineries, Digital printing, Decatising / Felt Calendering are some of the preferred machineries being adopted in the silk industry.

In order to broad base the usage of silk and cater to the need of the present generation, various new and diversified products needs to be developed. Further Silk is an excellent biomaterial and there exist a huge scope for using silk for non-textile applications particularly for development of Sericin and Fibroin based products in the areas of Medical, Nutraceuticals and Cosmetics. The R & D efforts in these areas will not only add value to silk but also increase the earnings of stakeholders of industry manifold.

In order to maximize the profit of stake holders and ensuring the benefits to the consumers it essential to strengthen the E-Marketing and forecasting system which will globalise the silk trade.

Silk being highly valued fibre, development of robust branding and purity/quality assurance system is essential to enhance the confidence of stake holder as well as consumers.

Silk being natural eco friendly protein fibre with unique characteristics is widely accepted and hence has a great future.

SP O 01: Study on Present Status of Silk Products Markets in ASEAN Countries

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Abstract

"Study on Present Status of Silk Products Markets in Asian Countries" is a depth study of the market structure and silk production in ASEAN countries. The study also focus on values and purchasing habits on silk of customers in selected countries in order to adopt strategies for small and medium enterprises (SMEs) on silk in Thailand including related organizations. Moreover, the study aims to penetrate the market in potential markets as well as to enhance knowledge of standards and regulations for Thai silk and use it as a model for ASEAN members. The study was carried out by the start of the study in both the social and economic trade including the production and marketing of silk products in Thailand and potential exporting market namely, Indonesia, Malaysia, and Vietnam. After reviewing secondary data, the study was carried out through in-depth research in selected countries to gather information on consumer behavior and values. This SWOT analysis which is based on empirical field observation and on secondary sources was carried out in the study for Thailand, Indonesia, Malaysia, and Vietnam in order to analyze and determine the strategy and tactics (TOWS) of Thai silk in potential selected countries.

The study indicated that small business owners of Thai silk have an advantage in terms of innovation and a variety of silk products. There are also opportunities to develop cooperation with the ASEAN countries to establish an ASEAN silk cluster that in order to compete in the global market. However, each country has different strengths, weaknesses, and areas of development in sericulture. Therefore, small business owners need different strategies to penetrate the market and establish in selected ASEAN countries. For Indonesia, its silk industry in the downstream is relatively strong. However, there is a weakness in the upstream. Thai entrepreneurs should focus on supporting different upstream inputs to downstream operators in Indonesia. In addition, exporting silk products from Thailand should focus on processed silk products such as cosmetics and medicines which being least developed in Indonesia. For Malaysia, the country with clear demand for cultural consumption, entrepreneurs need to understand the consumer behavior and offer products that meet the needs of consumers in the country. Malaysian people mostly used silk dress that is beautiful, adorned with silver, soft and delicate Texture. For Vietnam, the country with very strong industrial silk production in the upstream, entrepreneurs can take advantage of low cost of Vietnamese raw materials, substituting silk importing from China. Exporting Thai silk fabric to Vietnam need to produce on the scale of the intended use, which is different in each propose. The operation of enterprises should be encouraged and supported by government agencies involved throughout the supply chain regarding to the ability to provide quality and variety silk products which meet consumer demand in the Asian markets.

SP O 02: Effect of Thai Silk Yarn Using Different Reeling Methods on Silk Fabric Properties

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Abstract

A study compared between physical properties of silk fabrics which produced from Thai native silk yarns (Nang Tui x Nang Siw) and Thai hybrid (J108 x Nang Lai Saraburi) in different reeling methods. This study at Na-Seaw, Mueang, Chaiyaphum province, during January – September 2018. There are two experiments, first experiment was using pair t-test design, 10 replications and 2 methods such as Thai traditional silk reeling by hand reeling to the container and re-reeled method were used. the second experiment was design by RCB, 6 replications and 3 methods such as Thai hybrid silk reeling by hand reeling to the container, re-reeled and reeling by using small machine method with 5 Hp motor were used. The results showed that the physical properties of silk fabric on tensile strength, elongation, water absorbency rate, wrinkle recovery, stiffness, drape coefficient ratio and touch feeling of warmth or coolness (Qmax) no statistically significance difference in the first experiment. However, a comparative study of silk fabric between silk reeling to the container and re-reeled methods the properties were tensile strength, elongation and wrinkle recovery slightly (94.85 Kgf, 31.92%, 122.88 degrees respectively) better than silk yarn in re-reeled method (90.59 Kgf, 31.45 %, 128.89 degrees respectively). Meanwhile, tensile strength and elongation of warp yarn of silk fabric from Thai hybrid by traditional reeling to the container treatment was higher and significantly different than small reeling machine with 5 HP motor treatment of warp yarn. For weft yarn, the method of re-reeled had length elongation and significantly different with small reeling machine with 5 HP motor treatment. The absorption property of warp yarn in reeling by small reeling machine with 5 HP motor treatment and weft yarn for hand reeling by re-reeled method were absorbed and significantly different more than the traditional reeling to the container. There were no statistically significant differences of the properties tested of silk fabric on wrinkle recovery, stiffness, drape coefficient ratio and Touch feeling of warmth or coolness (Qmax).

Keywords : silk yarn, silk reeling, tenacity, elongation, wrinkle recovery

SP O 03: Research and Development of Northeastern Thai “Khit” Patterns for a Contemporary Thai Silk Fashion Collection

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Abstract

This study aimed to 1) to develop methods for improving Khit Thai silk and Thai silk products for sericulture, 2) to provide an opportunity to exchange opinions and enhance knowledge among farmers groups working in Thai silk production, experts, enterprises and students in order to create networks of creative business, and 3) to publicize images of Thai silk and drive Thai silk products to international markets. The findings revealed different aspects which are discussed as follows. According to the case study of the farmers groups (the weaving group of Sri Ubon Khit in Nong Bua Lam Phu and the weaving group of Sri Chom Chuen in Udon Thani), the patterns of Thai silk were appropriate for old people to wear to Thai cultural events rather than for other people to wear to other events. These groups reported that they preferred to improve their silk patterns and to increase their customer bases. After that, the group of researchers developed the products by investigating and analyzing the information about the uniqueness of the groups. The processes were carried out by using a questionnaire with fashion designers and experts in fashion design, and by examining global trends in 2014 provided by the Thailand Creative and Design Center (TCDC). Next, 20 Khit patterns were created for each group. Among these created patterns, five of the patterns from each group were selected by the designers and the experts. Then, the patterns were modified in order to match the production of each group. After the modification, the patterns were developed as prototype patterns for one collection of women's clothes. This study enhanced the knowledge of northeastern Khit patterns in terms of developments, creativity, value added, contemporariness, and use.

Keywords: Khit, Contemporary Design, Lifestyle, Ready to wear

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SP O 04: In-situ amidation of silk-wool union fabric with sericin for improved wrinkle recovery and dimensional stability

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Abstract

In-situ amidation of silk-wool union fabric employing sericin as modifying agent for improved wrinkle recovery and dimensional stability was achieved following a pad-dry-cure technique employing a boron based catalyst. Treatment of prior degummed silk-wool union fabric with 4 % aqueous sericin containing 4 % of such amidation catalyst at room temperature followed by drying of the fabric at 80°C for 7 min and subsequent curing at 90°C for 5 min produced optimum results on the fabric in respect of improvements in weight gain, wrinkle recovery, dimensional stability, retention of tensile strength and extensibility. Sericin used for modification of fabric was extracted from Mulberry silk followed by acid hydrolysis for depolymerization employing an appropriate treatment with boiling N/100 hydrochloric acid and neutralization prior to its application on fabric. Separate quantitative Infra-red analysis of the sericin modified silk and wool samples of silk-wool fabric indicates common enhancements of alpha helix and random coil conformations of protein moieties, hydrogen bonded amide group (Amide A) and lysine content in those fibres as a result of incorporation of sericin fraction in those fibres. Such incorporation of sericin fraction in silk-wool union fabric is the consequence of different degrees of chemical linkage established between amino acid of sericin and that of wool and silk fibres and crosslinking of chain polymers of such protein substrates formed during pad-dry-cure process. A separate thermal analysis of sericin modified silk and wool fibres done employing DSC also supports such result.

^{1*} Oral Presentation

SP O 05: Accreditation and Compliance of Pure Silk Products in Trade- A case of “*Silk Mark*” in India

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ABSTRACT

An apparel textile is required to meet five important consumer demands to fulfill its sustainable life cycle. These are Functional properties, Aesthetic properties, Comfort properties, Safety properties and Ecological properties. Silk is the only fiber which meets all the attributes and hence it is termed as “Queen of Textiles”. The manufacturing of silk products includes precocoon operations such as agriculture, sericulture, social forestry and post cocoon operations including reeling, twisting weaving and wet processing. Silk production is a great socio-economic equaliser as the money gets transferred from the rich end user to the deprived producer through its production process.

Silk is a protein fiber, highly biodegradable and eco friendly in nature and it is termed as reference textiles due to its elegance, exquisiteness and glamour. Man has repeatedly attempted, unsuccessfully, to replicate the unique characteristics of silk but has failed every time. As a result, the imitations of silk which are far cheaper are sold in the name of pure silk that deprives its producer of the recognition for his hard work and the buyer is deprived of the value for money that he spends. In order to prevent the cheaper imitations to be sold in the name of pure silk and to encourage the consumption of pure silk and build consumers confidence ‘**Silk Mark**’ label has been brought out by the Central Silk Board, Ministry of Textiles, Government of India. Silk Mark label pertains to accredit the purity of silk of constituent textile fibers in the pure silk products.

The scheme is run on a scientific management system in line with ISO standards by the ‘Silk Mark Organisation of India (SMOI)’. The manufacturers and traders of silk are provided with license to make use of the labels on legally enforceable arrangement. The label is affixed on the product based on objective testing of the fibers as per protocol of fiber identification as per national and international standards.

It is important to note that there are no purity labels operating in the silk sector across the globe. Hence, there is a need for all the silk producing and consuming countries to join hands and make a global mark “***International Silk Mark***” for the benefit of not only consumers but also for the industry stakeholders who otherwise get deprived of the real value of their products.

SP O 06: Studies on yarn finishing to improve functional properties of loom finished silk fabrics

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ABSTRACT

India is the largest consumer of silk in the world and approximately 70% of silk in India is produced as handloom finished fabrics mainly for Indian ethnic wear. Such loom finished silk fabrics are generally made with degummed & dyed silk yarn and then woven on handloom. Generally the colour combination and weave effect which can be introduced on handloom cannot be reproduced on power-looms. However, loom finished silk fabrics have some limitation *i.e* any finish at the fabric stage leads to disturbance in its structure and inherent properties affecting the overall appeal to the consumer. On the other hand, any finish given at the yarn stage after degumming and dyeing of silk yarn might help in introducing or enhancing functional properties besides restoring originality of handloom fabric.

In this study, an effort has been made to improve the functional properties of loom finished silk fabrics by providing certain chemical finishing treatments at silk yarn processing stage to impart desirable properties and versatility. Here the silk yarns have been degummed, dyed, treated with different finishing chemicals and cured to impart water and oil repellence, anti-microbial property and aroma finish. Further, combination of these finishes has also been tried on silk yarns to get combined effects on the fabric. The different fabric samples thus woven on handloom using treated yarns are analysed for functional properties imparted *viz.*, water and oil repellence, anti-microbial, mechanical, fastness properties and durability of finish. The test results of treated samples are compared with control and found that certain parameters have improved significantly and also the finishes are exhibited effectively on silk fabrics without affecting its handle, feel and lustre.

Key words: Aroma finish, functional properties, loom finish, water and oil repellence, yarn finish

SP P 01: Development of Natural Dyes Shades from Color Hol Silk Wisdom to Expansion of Silk Textile Products Innovation Termtem Studio Brand

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Abstract

The development of natural dyes shades project from color Hol silk wisdom to expansion of silk textile products innovation aimed at studying and developing a body of knowledge and wisdom on natural dyeing from Hol cloth, applying the knowledge and techniques of natural dyeing wisdom from Hol cloth to design process of contemporary textiles, and experimenting on creative product prototypes development utilizing the concept of natural dyeing from Hol cloth good for making a Termtem Studio brand collection.

Color shades acquired from data synthesis of Hol cloth wisdom from the experiment of dyeing silk, creation of natural dyes from Hol cloth, and proportional experiments in this study were determined by the researcher. Step 2 experiment with natural dyeing for a variety of shades by mixing natural dyes or repeated dyeing with indigo and wax using the ratio of indigo pot in Step 1 consisted of an experiment of red dye with wax overlaying with indigo, yellow dyeing with Khae core overlaying with indigo, yellow dyeing with Prahod bark overlaying with indigo, blue dyeing overlaying with indigo as well as orange dyeing with Khae and Prahod overlaying with wax.

Results from the analysis, experts, and entrepreneurs in fashion, dyeing silk threads that created natural dyes with Hol cloth process can create color shades used as a guideline for color selection in textile design and create color wheel of natural dyes consistent with universal color wheel by process of color comparison in Pantone CMYK and Pantone fashion home paper (TPX) systems. It is a family of colors suitable for drafted textile design for fashion process on the conceptual framework of craft textile art group that extends to semi-industrial fashion products, Mudmee silk pattern from motif, diamond pattern from the shape of alms bowl pattern for creating of basic shapes or as called in the Isan region Khom pattern. It is cut and rearranged following the notion of cultural identity and fashion.

Keyword: natural dyes, textile designs, Hol silk

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SP P 02: Bio-crafts for value addition in Indian Silk Industry

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ABSTRACT

The exploration of nature in art can take endless forms and serve many purposes, because nature provides us with such a vast wealth of inspiring phenomena. The artist developed a passion in creating art works in Silkworm cocoons as medium focusing on applying design principles while creating an art work since the cocoon responds to the artist in giving rise to many shapes. Various themes are combined into installations that feature exotic flowers, colored hues of violet and blue. The color violet specifically establishes a dream like surreal quality, suggesting notions of calmness and royalty, and formally unifies the disparate art works in each installation. When we use a variety of materials and processes in each art work, the methodology was kept consistent. Each art work often consists of multiple works in a range of different media grouped around specific themes and meanings. During research and production, new areas of interest arise and lead to the next body of work.

Sericulture in India is a sustainable farm-based economic enterprise generating higher return per labour/day spent through various inter-related activities like mulberry cultivation, silkworm rearing, silk reeling and fabric making and finishing. Apart from the major areas of income, additional revenue can be accrued from proper utilization of by products. Value addition can be achieved through making handicraft using cocoons like, preparation of garlands, bouquets, flowers and garlands and surface ornamentation of handloom fabrics including dyeing, batik printing, painting of the fabrics, embroidery, jardosi, stone finishing etc., which all are having good market value. Therefore, it is conceived to make Bio-crafts and surface ornamentation which are having highest demand in the domestic market, which will fetch additional income since the benefit cost ratio is very high. This paper highlights the future perspectives in taking forward this particular *fine art* to create International market and thereby generating valuable livelihood in sericulture.

