SERITECH

The New Concepts in Sericulture

The 26th INTERNATIONAL SERICULTURAL COMMISSION CONGRESS

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BOOK OF ABSTRACTS

07th - 11th September 2022, Cluj-Napoca, Romania

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THE 26th INTERNATIONAL SERICULTURE COMMISSION CONGRESS

SERITECH

new concepts in sericulture

7-11 September 2022, Cluj-Napoca, România

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THE 26th INTERNATIONAL SERICULTURAL COMMISSION CONGRESS

SERITECH – NEW CONCEPTS IN SERICULTURE

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PRÉFACE / PREFACE / PREFAȚĂ / PREFACIO

SERITECH - 7th - 11th September 2022, Cluj - Napoca, ROMÂNIA –The 26th Congress of the International Sericultural Commission aims to develop new concepts in Sericulture

In the past thousand years, human civilization has been practicing and developed the sericulture in order to obtain benefits from it. Sericulture, on the other hand, managed to leave its mark on the development of humankind and to imprint in researchers' conception and economic development its perfection when it comes to the transformation of raw plant material into noble silk fibers.

Today's challenges and the science dynamic from the last decades offer an unprecedented chance for diversified sericulture activities, by defining new profitable concepts such as biotechnology, pharma-farming, bio-economy, organic sericulture, bio/nanomaterials. In order to keep up with the new opportunities, all the specialists from these areas have to cooperate to give a restart to sericulture at the international level.

The future of sericulture is extremely promising given the new opportunities that come with the dynamic research and economy of the 21st century.

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 a bioreactor or into the Pharma farming concept, has to be known and discovered by the researchers, the farmers or, maybe, even more important, by 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.

To overcome the present problems in sericulture we have to find new solutions for sericulture and serology.

Daniel Severus Dezmirean

Congratulations to the Award Winners

Louis Pasteur Award -2022

Dr. Yasushi TAMADA, Japan

Mrs. Somying Chuprayoon, Thailand

Dr. Subhas V. Naik, India

Excellence in Sericulture Science Award -2022

Host Plant Development
Mr. Somchai Luemunkong, Thailand

Silkworm Development
Dr. S. Manthira Moorthy, India

Post Cocoon and Post Yarn Technology
Mr. Meechai Taesujariya, Thailand

Silkworm and Silk in Non-Textile Industry
Dr. Somchai Jomduang, Thailand

LOUIS PASTEUR PRIZE 2022

Mr. Yasushi TAMADA

Present Address	Faculty of Textile Science and Technology, Shinshu University, 3-15-1 Tokida, Ueda, Nagano 386-8567, Japan
E- mail:	ytamada@shinshu-u.ac.jp
Date of Birth	22 April 1957
Position	Faculty of Textile Science and Technology, Shinshu University
Educational Qualifications	M.Sc. (Engineering) at Kyoto University Ph.D. (Engineering) at Kyoto University
Major Contributions	Dr. Tamada undertaken research on chemical and genetical modifications of silk proteins, new fabrication methods using silk protein aqueous solution, analyses of cell behaviour on silk protein substrate, and evaluation of silk materials for cartilage regeneration scaffolds. These works are expected to accelerate the use of silk in pharmaceutical sector.

	The sulfated silk proteins developed by Dr. Tamada has the potential to commercialize as a preventive agent for HIV infection. Initial works for an industrial collaboration with a Japanese chemical company is currently underway. The silk protein resin developed have excellent dielectric properties and thermal conductivity which are being disseminated to field. The silk fibroin sponge materials developed by him is used in cosmetics, aesthetic, and medical fields through collaboration with a reputed chemical company. Dr. Tamada's research work on interactions between cells and silk materials provides crucial information for developing medically applied products such as wound dressings and cell scaffolds for regenerative medicine.
Sericulture Experience	18 years of experience in silk related fields
Publications	64 Nos

LOUIS PASTEUR PRIZE 2022

Mrs. Somying CHUPRAYOON

Present Address	24/23 Phahonyothin 56, Yaek 2-1 (Kamkoon), Phahonyothin street, Saimai sub-district, Saimai District, Bangkok 10220 Thailand
E- mail:	csomying@hotmail.com
Date of Birth	17 March 1956
Position	Expert on Sericulture Production Promotion Management, Queen Sirikit Department of Sericulture and the Director of PASAYA BIOTECH Co., Ltd., Thailand.
Educational Qualifications	Master of Science (Plant Pathology)
Major Contributions	Mrs. Somying Chuprayoon has involved in the development of quality standards for Thai silk, which culminated in developing industrial utilization of hand reeled Thai silk. She was also involved in developing testing and reeling equipment in collaboration with Kasetsart University and National Bureau of

	Agricultural Commodity and Food Standards. These equipment have been readily accepted and popularized in the field. In 2017, she developed a prototype of a silk producer according to TAS 8000-2012 standard to enable farmers to set up a silk production system to meet quality and certified according to standard, receiving “Q” mark. She was instrumental in introducing contract farming system which helped the farmers to increase their income for more than 30% consistently throughout the year.
Sericulture Experience	38 years of experience in Silk Industry
Publications	38 Nos

LOUIS PASTEUR PRIZE 2022

Dr. Subhas Venkappa Naik

Present Address	No.32, 15th Main, Sarakki, NHBCS, J.P.Nagar, 5th Phase, Bangalore-560078, INDIA
E- mail:	**svnaik.cstri@gmail.com**
Date of Birth	20th July 1962
Position	Director (Retired), Central Silk Board, India
Educational Qualifications	M.Tech in Textile Technology Ph.D. in Raw Silk Reeling Technology, Bangalore University
Major Contributions	Dr. Naik was involved in indegenously developing multi-end reeling machine and automatic reeling machine along with the package of practices suitable to the cocoons produced for the Indian conditions. He has also been involved in popularizing 650 MRMs and 127 ARMs all across the country. These

	efforts have significantly enhancing the production, productivity and quality of Indian silk. India is now in a position to produce internationally graded silk for local consumption and resultantly the import of silk to the country has significantly reduced.
Sericulture Experience Technology	31 years of experience in Post Cocoon
Publications	**217 Nos**

Excellence in Sericulture Science Award – 2022

Category: Mulberry Development

Mr. Somchai LUEMUNKONG

Present Address	13/9 Moo 7 Klongyai Subdistrict, Ongkharak District, Nakhon Nayok Province 26120 Thailand
Date of Birth	30 April 1958
Position	Agricultural Research Officer, Senior Professional Level at the Queen Sirikit Sericulture Center (Sisaket), Thailand
Educational Qualifications	Master of Science, Field Crop Breeding
Achievement for Award	Developed three high yielding varieties which are very popular in the field
Sericulture Experience	31 years in Mulberry development
Publications	**37 Nos**

Excellence in Sericulture Science Award – 2022

Category: Silkworm Development

Dr. S. Mathira Moorthy

Present Address	Central Silk Board, CSB Complex, BTM Layout, Madiwala Bangalore, India
Email:	moorthysm68@gmail.com
Date of Birth	14 May 1968
Position	Scientist-D
Educational Qualifications	M.Sc. in Zoology PhD in Zoology

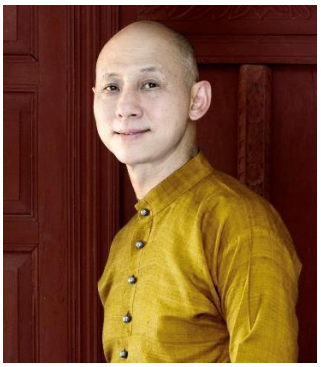
Achievement for Award

Dr. Moorthy has developed a promising bivoltine hybrid for the eastern and central regions of India. Historically, these regions were known to practice multivoltine races as the climatic

	conditions are not suitable for bivoltine rearing. However, the Hybrid developed by Dr. Moorthy has broken this myth and become so popular in the region. Resultantly the bivoltine production in the region has significantly increased from 38 MT in 2010 to 2386 MT in 2020.
Sericulture Experience	28 years in sericulture research and development
Publications	**87 Nos**

Excellence in Sericulture Science Award – 2022

Category: Post Cocoon Technology



Mr. Meechai TAESUJARIYA

Present Address	131 Khampun Museum, Srisaket Road, Khamnamsab, Warinchamrab, Ubonratchathani, Thailand
Date of Birth	24 December 1958
Position	Founder & the owner of Ban Khampun; Ubon Weaving Center and Khampun; Museum of Weaving Culture, UbonRatchathani, Thailand
Educational Qualifications	Bachelor of Art (Political Science; International Relations, Ramkhamhaeng University: Thailand
Achievement for Award	Mr. Meechai Taesujariya has been involved in developing a new textile design called “Pa Kaab Bua” with the combination of techniques like Mudmee, Khit and Mubmai on stripped warp. This has become so popular in Thailand and other part of the world. Mr. Meechai has got several awards for the “Pa Kaab Bua” design in the field.
Sericulture Experience	40 years in traditional silk weaving

Excellence in Sericulture Science Award – 2022

Category: Silkworm and Silk in Non-Textile Industry

Dr. Somchai JOMDUANG

Present Address	353 Moo.9, T. Sanklang, A. Sanpatong, Chaing Mai Province, 50120, Thailand Email: admin@bio-c.co.th
Date of Birth	28 January 1960
Position	Managing Director of BIO CRENOVATION CO.,LTD, Thailand
Educational Qualifications	M.S. (Food Science and Technology). Kasetsart University Thailand Ph.D. (Food Technology), University Putra Malaysia (UPM), Serdang, Malaysia
Achievement for Award	He has been involved in developing many by-products from sericulture with the concept of "Zero Waste". One of the major breakthrough research of Dr. Somchai was identification of pupae extract as a viable agent for vasodilation. This knowledge has the potential to develop medicines for sclerosis and high blood pressure.
Sericulture Experience	20 years in silk industry

Introduction of International Silk Union 2022

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Addresses: Room 1606, No.105, Tiyuchang Road, Hangzhou, China, 310004
E-mail address: isusecretariat@163.com

International Silk Union (ISU) is an international and specialized non-profit social organization in which enterprises and related organizations from the silk producing and consuming countries participate voluntarily. The secretariat is located in Hangzhou, China. Since its founding in 2015, ISU has attracted over 137 companies and organizations from 24 countries and regions, among which there are 11 vice chairman units and 46 executive member units. ISU also set up 6 professional committees. In 2020, ISU was included in the Yearbook of International Organizations by Union of International Associations (UIA). In 2021, ISU signed the MoU with International Sericultural Commission(ISC).

Adhering to the aim of Communication & Cooperation, Development with Concerted Efforts, ISU actively build the international exchange platform, having organized 3 members assembly, 3 chairman expanded meetings, and completed the new ISU organization in 2019, also held series of international forums and seminars for 7 times. ISU has organized member companies to participate in many international silk industry and cultural activities among member countries.

In response to the unreasonable evaluation of silk on its environmental impact by the Higg index, effectively maintain the international image of silk and the interests of the industry, on June 10, 2021, ISU successfully held the International Think Tanks Forum on Silk Sustainable Development, with the presence of more than 200 guests from 22 countries and regions. During the event, together with ISC, Ufficio Italiano Seta, INTERSOIE France, Brazilian Silk Association, ISU launched the Proposal for the Comprehensive and Objective Life Cycle Assessment of Silk Products.

In 2022, ISU gradually conducts the LCA research progress of the whole sericulture and silk industry chain. Organized the international and regional expert meetings for many times to discuss the research paths and shared the series of staged results. ISU expects more representative silk enterprises and organizations all over the world joining ISU, jointly promoting the LCA research of silk and the healthy, stable and sustainable development of the international silk industry.

KEYNOTE LECTURE

MULSUN BIOTECH INTRODUCTION 2022

Feng Jin

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ABSTRACT

Mulsun Biotech is a subsidiary of Babei Group, founded in December 2015, located in Shengzhou City Zhejiang Province. The company focuses on implementing the technology of 'Rearing All-instar Silkworm With Nutritional Feed At An Industrial Scale'. After 7 years of painstaking R&D, it is known as the world's first and only industrialized sericulture enterprise. The company made great breakthroughs, which include feed formula, automatic rearing and environment control system, etc. The quality of silk reaches more than 5A of the national standard. The 5000 years old traditional sericulture had been disruptively innovated.

The Phase One project of the company put into production in 2019, with a daily output of more than 20 tons of high quality fresh cocoons. At present, the company has 400 employees, with an annual output of 7000 tons of high-quality fresh cocoons, which equivalent to the annual production by 100000 silkworm-farmers.

The Phase Two project with an annual output of 40000 tons of high-quality fresh cocoons is under construction, estimated to put into production in October 2022, with a total investment of 1.5 billion RMB and a total construction area of more than 200000 square meters. After completion, it is expected to produce more than 100 tons of high-quality fresh cocoons per day and annual sales revenue of more than 2 billion RMB.

Adhering to taking quality as the cornerstone of enterprise development, the company has established effective quality management system, covering the whole process from raw material procurement, production and quality control, warehousing, product distribution and traceability, ensuring product quality, providing the best quality products and services for downstream enterprises, and creating the most globally competitive industrial chain and supply chain.

SECTION 1:

MULBERRY

Domaine

All aspects and areas concerning mulberry

Chairperson

Dr. K Vijayan

MEET THE CHAIRPERSON

DR. KUNJUPILLAI VIJAYAN

is the current Scientific Advisor of International Sericulture Commission. Before joining to this position, he worked as a Senior Scientist in Central Silk Board Bangalore and retired on 31.05.2021 upon attaining superannuation. Educationally, he has three master degrees viz., MSc, M.Tech and MBA and a doctoral degree and a five year post-doctoral associateship at the Institute of Plant and Microbial Biology, Academia Sinica, Taipei, Taiwan.

He has 35 years of research experience in Plant molecular biology, Plant Breeding, Plant Tissue culture, Germplasm Characterization, Stress breeding and Agronomic assessment of crops**.** He has developed several new protocols for micropropagation of mulberry, in vitro screening of tree plants for stress tolerance, and induction of colchiploids. He has also developed a number of protocols for extraction of DNA, RNA**,** and proteins from mulberry and *Camellia***.** He has deposited more than 1000 DNA sequences to GenBank. In his PhD work he worked out the mechanism and genetics of salinity tolerance in mulberry developed a few salt-tolerant mulberry varieties through breeding. He has published more than 135 international and national research papers. He has also published a book on mulberry breeding and is currently editing a book on mulberry genome which would be published by Springer. He has contributed to a number of book chapters on various aspects of research on mulberry.

LEAD PAPER:

Genomic Research in Mulberry for Higher Silk Productivity

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ABSTRACT

Mulberry is a fast growing deciduous, woody perennial plant being cultivated mainly for its leaf to feed the silkworm *Bombyx mori* L. The quantity and quality of mulberry leaves have a great impact on silk productivity, thus, it is imperative to develop varieties that produce quality leaf in large quantities for a vibrant and sustainable silk industry. Mulberry leaf production is a complex trait jointly contributed by several major and minor traits and each of these contributing traits, in turn, is controlled by several genes and loci. Hence, any attempt to enhance the quality and quantity of leaf warrants a thorough understanding of the genetics of these traits. However, due to several reasons that include higher heterozygosity, inbreeding depression, long generation gap, the genetics of mulberry still remain quite obscure to the breeders. Thus, it is highly necessary to make use of the recent advances in genomic research to dissect the complexity of the genetics of mulberry to facilitate the breeding of mulberry with better understanding of the regulatory mechanism of the expression of traits of interest. The success in whole genome sequencing of mulberry in different species along with development of robust protocols for transgenic have recently made genomic research in mulberry more receptive to modern molecular and biotechnological techniques. Recently a number of robust molecular markers have already been developed and are being used for assessing genetic distance among breeding lines, population diversity among germplasms, and marker assisted selection breeding. Gene over expression and gene knock out have been employed to understand the functional properties and trait expression. Thus, with the advancement in genomic and allied research, mulberry crop development has taken a new direction that would certainly going to break all the bottlenecks that traditional breeding was facing.

Keywords: Abiotic stress, Genome, Mulberry, Sericulture

Introduction

Silk is the most elegant textile fiber in the world with unparalleled grandeur, natural sheen, an inherent affinity for dyes, high absorbance, light weight, soft touch, and high durability. Thus, it is widely called the "Queen of Textiles" (Baruah and Gogoi 2013). Among the commercially exploited silks, mulberry silk occupies more than 90% of the total silk production globally. The mulberry silkworm, *Bombyx mori* L., feeds only on the leaves of mulberry making mulberry one of the economically important trees in Asia. It is estimated that the production of mulberry leaf alone covers more than 65% of the total expenditure for silkworm cocoon production (Lakshmanan 2007). Mulberry (*Morus* L) is a fast growing deciduous, deep rooted, woody perennial plant that originated in sub-Himalayan tracts and spread into Africa, Asia, South America, Europe, North and South America (Le Houerou 1980; Rodríguez et al 1994). Although mulberry can be propagated through seeds, the most common method of propagation is the vegetative method as mulberry exists in different ploidy levels and triploids have a slight edge over other ploidy in growth, leaf yield and leaf quality. It is also found that like most of the agriculturally important crop mulberry growth and leaf yield depend on a number of environmental and edaphic factors. Thus, traditionally mulberry breeding targeted the improvement of leaf yield and leaf quality by developing hybrids through controlled cross among the desired parents and also from open pollinated seeds collected from good mother plants. However, traditional breeding is a laborious and time-consuming exercise that requires nearly 20-25 years to release a variety (Fig. 1). In order to cut short the breeding time and also to develop varieties with specific traits, it is necessary to use the modern biotechnological method like tissue culture, genetic engineering, marker-assisted selection breeding (Vijayan et al. 2022). Towards this end much information has been generated recently in whole genomic sequence, (He et al., 2013; Jiao et al., 2020; Jain et al., 2022), transcriptome analysis (Checker et al., 2012; Wang et al. 2018), transgenic (Lal et al. 2008), proteomics (Wang et al. 2017), metabolomics, etc. and these information has tremendous importance in developing new crop improvement strategies to enhance the leaf productivity and leaf quality to make silk production more sustainable than ever before.

Whole genome sequencing

Evolution of Next Generation Sequencing has made whole genome sequencing quite affordable even to small laboratories, consequently, it has acquired paramount importance in modern crop improvement programs as it provides enough information necessary for identifying genes, their structure, function, position, etc. It helps to understand the causes of genetic variations among varieties and species, involvement of genes in the formation of complex traits, the evolution of species, adaptability of species,

etc. Keeping these advantages of whole genome sequencing efforts have been made to sequence the genome of three different species of mulberry such as *M. notabilis, M. alba* and *M. indica.*

Morus notabilis

The first whole genome sequence in mulberry was done in *M. notabilis* using the shotgun sequencing method (He et al., 2013). *M. notabilis* is a monoploid with 14 chromosomes found in the high-altitude ranges (1200-2800 m) of South Western parts of China. He et al. (2013) reported that the genome size is 330 Mb with approximately 29,000 genes. The total GC content of *M. notabilis* was found to be 35.02% which is similar to other. It was also estimated that ~ 47% of genome size is comprised of repetitive sequences and >50% of the repetitive sequences are of *Copia* like and *Gypsy* like long terminal retrotransposons type of transposable elements. By using RNA-seq data and expressed sequenced tags (ESTs) based approaches ~ 29,338 genes were predicted out of which 27,085 genes were predicted as protein encoding genes and 2,253 genes as partial genes. These results were further supported by *de novo* gene prediction (99.93%), homology-*based* gene prediction (69.94%) and RNA-seq/EST (58.38%) based gene prediction approaches (He et al., 2013). Krishnan et al., (2014a) identified 217,312 microsatellites or simple sequence repeats (SSR) from the whole genome sequence and 961 numbers of SSR from the EST sequences of *M. notabilis*. Among the identified microsatellites, 245 were hexanucleotide repeats, 741-pentanucleotide repeats, 2521-tetranucleotide repeats, 7485-trinucleotide repeats, 21453-dinucleotide repeats and 151152 mononucleotide repeats.

Morus alba

The whole genome sequencing of *M. alba* using Oxford Nanopore, Illumina HiSeq, and high-throughput chromosome conformation capture (Hi-C) data based molecular techniques revealed that the genome size is 346.39 Mb with 180.11 Mb of repetitive sequences (Jiao et al., 2020). The total number of protein encoding genes in *M. alba* was identified as 22.767 genes with an average gene length of 3209 bp, coding length of 1148bp with an average number of 5.09 exons per gene (Jiao et al., 2020). The comparison of sequences between *M. notabilis* and *M. alba* revealed that *M. alba* diverged from *M. notabilis* approximately 10 million years ago (Jiao et al., 2020). In another attempt, Dai et al., (2015) sequenced 21,229 expressed genes of *M. alba*. Similarly, Dhanyalakshmi et al., (2016) generated 10191 ESTs of leaf tissue from drought conditions. Likewise, Liu et al., (2017) identified the 1,01,589 salinity stress responsive genes from the leaf, stem and root region. Sheng et al., (2017) have identified a total of 87,719 genes expressed during the development of flower buds at six different stages. Mathithumilan et al., (2013) identified a total of 900 microsatellites from the

genomic sequences which include 167 (18.56%), mononucleotide-MNR repeats, 303 (33.67%) dinucleotide repeats-DNR, 155 (17.22%) trinucleotide repeats-TNR, and several tetra, penta, hexa and long nucleotide repeats but in less frequency (Mathithumilan et al., 2013). Among the different types of DNR identified in *M. alba*; 'TC' type of dinucleotide repeats was most predominant (25.5%) followed by 'CT', while in most of the plant species 'AT', 'GA' and 'AG' were reported as the most frequent dinucleotide repeats (Lagercrantz et al., 1993; Edwards et al., 1996; He et al., 2003). Among the trinucleotide repeats of microsatellites 'GAA' was most abundant (15.9%), similarly, the tetranucleotide repeats of 'AAAT', pentanucleotide repeats of 'AAAAC', hexanucleotide repeats of 'AAAAAG' were found as most abundant in *M. alba* (Mathithumilan et al., 2013).

Morus indica

The whole genome sequence of *M. indica* was reported by Jain et al. (2022) by employing four distinct technologies, including Illumina (short-read), single-molecule real-time sequencing (long-read PacBio), chromosomal conformation capture (Hi-C), and optical mapping (Bionano). The draft *de novo* genome assembly with 365 scaffolds revealed a total genome size of 505,298,450 bp with 49.2% repetitive DNA, 27,435 protein-coding genes, 1546 genes with more than one transcript. It was also found that the repetitive DNA content (49.2%) of *M. indica* is in between the values of *M. notabilis* (38.8%) and *M. alba* (52.9%). Further, the number of genes predicted in *M. indica* (27,435) was higher than that of *M. notabilis* (27,085) and *M. alba* (22,767). The comparative genome alignment revealed a higher similarity (>50%) between *M. alba* and *M. indica* (Jain et al., 2022). The GC content in *M. indica* was 31.2% which is slightly lower compared to genome of the other two reported species (*M. alba*-33.2% and *M. notabilis*-33.1%), and 10.3% bases accounting for Ns. Most of the portions in the *M. indica* genome had a GC content of 30–40%, which was comparable to that of *Arabidopsis thaliana* and *Fragaria vesca* genomes. These findings and generated MindGP database (http://tgsbl.jnu.ac.in/MindGP) provide a complete resource for accelerating mulberry genomes research in order to better the species. Resequencing efforts with 21 accessions revealed the presence of ~2.5 million SNPs and ~ 0.2 million insertions/deletions.

Chloroplast genome

Considering the opportunity of using the information on the chloroplast genome for targeting varietal improvement through chloroplast gene manipulation to enhance leaf productivity and quality efforts were made to sequence the chloroplast from eight species (**Table 1**). It is found that in general chloroplast genomes of the *Morus* are in the range of 158000 bp to 160000bp, with the largest being that of *M. alba* (159290 bp) and the

smallest being that of *M. mongolica* (158459 bp). It has two identical inverted repeats (IR) regions and two single copy regions – large (LSC) and small (SSC). All the species displayed similarity in their GC content and inverted repeat (IR) content. However, the large single copy region (LSC) of *M. cathayana* (88143 bp) and *M. alba* (88065 bp) was slightly longer than that of the other species. On the other hand, small single copy region (SSC) of *M. multicaulis* (20035 bp) was the highest among the eight species. A similarity in protein coding genes was exhibited by the *Morus* species, but differences were noted in the size of rRNA and tRNA genes of *M. indica*, *M. notabilis* and *M. alba*. Chloroplast genome-based phylogenetic analysis revealed a close relationship between *M. alba* and *M. cathayana*. The family Moraceae was in turn associated with the family Ulmaceae (Luo et al. 2019).

Transcriptome analysis

Data on expressed sequence tags (ESTs), suppression subtractive hybridization (SSH) and global transcriptome are valuable resources for genetic improvement of crops. In mulberry, quite a few efforts have been made to analyse transcriptomes from different species, conditions and plant parts (Lal et al 2009; Checker et al 2012; Wang et al 2014, 2018; Huang et al 2020). A total of 958 and 1878 expressed sequence tags (ESTs), respectively were identified from mulberry leaf and root cDNA libraries (Lal et al 2009; Checker et al 2012). Approximately 1500 ESTs were identified from water-stressed leaves using suppression subtractive hybridization. Wang et al (2014) used *de novo* assembly of 54736 contigs to identify 247 pathways and thousands of SSR markers. Seven unique genes showing different expression levels in control and drought stress groups were also identified with real-time PCR. Likewise to understand the molecular mechanism of anthocyanin biosynthesis in mulberry fruit, comparative transcriptome analyses of *M. atropurpurea* Roxb, (black fruit) and *Morus alba* L., (white fruit) were made using more than 27,085 genes (including 1,735 new genes) differentially expressed at three developmental stages and found that anthocyanin biosynthesis is associated with the expression of 15 core genes and 5 transcription factors (Huang et al 2020). Similarly, to unravel the genomic response of mulberry to stress conditions, 101589 unigenes obtained from 24 mulberry accessions under salinity were analysed and found that the number of down-regulated DEGs (differentially expressed genes) under salt stress is more than that of up-regulated DEGs, and these down-regulated DEGs enriched in the process related to stress responses. Further, it has been observed that the expression pattern of some genes was quite diverse against salt stress and it was genotype- and tissue-dependent. The DEGs involved in signal transduction and transcription regulation were more in low-salt-tolerant genotypes and the majority of these responsive genes showed a reduction in the transcripts (Liu et al 2017). In another attempt, Wang et al (2018) assessed two cDNA libraries of leaf from mulberry genotypes with different 1-deoxynojirimycin contents and found that 11,318 transcripts were significantly and

differentially expressed, and 38 unique genes were identified involved in DNJ alkaloid biosynthesis in mulberry. Li et al (2020b) made a transcriptome analysis of flavonoid-related UDP-glycosyltransferases (UGTs). Further, to understand the role of microRNAs (miRNAs) in gene expression under drought stress, transcriptome-wide high throughput degradome sequencing was used and identified 409 target genes of 30 conserved miRNA families and 990 target genes of 199 novel miRNAs. Of the conserved miRNA families, mno-miR156, mno-miR172, and mno-miR396 had the highest number of targets with 54, 52 and 41 transcripts each signifying that these three miRNA families might play key roles in drought responses in mulberry (Li et al 2017). Similarly, it was also discovered that mulberry has 286,122 MITE-related sequences, including 90,789 full-length elements (Xin et al 2019). Using transcriptome sequencing technology Jiang et al (2020) investigated the molecular mechanisms of mulberry response to Cadmium (Cd) stress. They obtained 195 million clean reads, 2785 and 1211 differentially expressed genes (DEGs) enriched in the pathway of flavonoid biosynthesis, plant pathogen interaction, carbon fixation in photosynthetic organisms and phenylpropanoid biosynthesis. The flavonoids under Cd stress could be the effective antioxidants conserved in mulberry.

Metabolic Engineering Pathways and Gene Discovery

Since leaf is the primary product for which mulberry is cultivated and more than 70% of the mulberry leaf protein is used by the silkworm for synthesizing the silk yarns, the nutritional status of mulberry leaf plays a crucial role in deciding the suitability of the variety for silkworm rearing (Fukuda et al 1959). However, in mulberry, not much work has been done to develop metabolic profiles of the varieties and their relation with silk productivity. Nonetheless, studies on other crops have demonstrated the importance of such studies to understand the metabolic networks and the underlying mechanisms of interaction between metabolism and development. The most commonly used technologies for metabolic profiling are mass spectrometry and nuclear magnetic resonance (NMR). Once the metabolic profiling and underlying genetic interactions are unraveled, it would be easy to engineer plants with desired metabolites. Metabolic engineering has been successful in the development of golden rice and various transgenic crops fortified with flavonoids, anthocyanin, carotenoids, Omega-3 long-chain polyunsaturated fatty acids (LC-PUFAs), vitamins and minerals (Storozhenko et al 2007). In mulberry, screening of glucosidase inhibitors from leaves found glucosidase inhibitory activities in all the constituents of alkaloids, flavones and amylases (Yuan et al 2006). These alkaloidal sugar-mimic glycosidase inhibitors present in higher concentrations in mulberry latex (1,4-dideoxy-1,4-imino-D-arabinitol, 1-deoxynojirimycin, and 1,4-dideoxy-1,4-imino-D-ribitol). Realizing the importance of chemical contents of the leaves and fruits of mulberry, anthocyanin composition, 1-deoxynojirimycin (DNJ), resveratrol, oxyresveratrol, and flavonoids estimated and

found significant variations in concentrations of these compounds in different species and cultivars (Bae and Suh 2007; Song et al 2009). Ni et al (2010) isolated cathayanons F-J and cathayanin A, and two known compounds, cathayanins B-C from the stem bark of *Morus cathayana.* Recently, Li et al (2020a) has assessed the flavones in mulberry and identified a Fe2+/2-oxoglutarate-dependent dioxygenase from *M. notabilis* (MnFNSI) showing the typical enzymatic activity of a FNSI-type enzyme, and directly converts eriodictyol and naringenin into their corresponding flavones. Overexpression of MnFNSI in tobacco increased the flavones contents in leaves and enhanced the tolerance of tobacco to ultraviolet-B (UV-B) stress. Later, Li et al (2020b) also made the metabolic profiling of 44 flavonoid compounds from 91 mulberry resources and found that O-rhamnosylated flavonols and malonylated flavonol glycosides, including rutin and quercetin 3-O-(6″-Omalonylglucoside) (Q3MG), were absent from *M. notabilis* and multiple mulberry (*M. alba* L.) resources. Transcriptome and phylogenetic analysis of flavonoid-related UDP-glycosyl transferases (UGTs) suggested that the flavonol 3-O-glucoside-Orhamnosyltransferase (FGRT) KT324624 is a key enzyme involved in rutin synthesis. A recombinant FGRT protein was able to convert kaempferol/quercetin 3-O-glucoside to kaempferol 3-O-rutinoside (K3G6″Rha) and rutin. The recombinant FGRT was able to use 3-O-glucosylated flavonols but not flavonoid aglycones or 7-O-glycosylated flavonoids as substrates. The enzyme preferentially used UDP-rhamnose as the sugar donor, indicating that it was a flavonol 3-O-glucoside: 6″-O-rhamnosyltransferase. The above studies would certainly augur further research in mulberry to engineer the metabolic pathways through genetic engineering for developing mulberry varieties with more nutritious leaf, stress tolerant and silkworm friendly.

Genomic Resources and their utilization

With the advent of next generation sequencing plenty of genomic resources are available for research to make use of them for their research. The development of inexpensive and easy-to-use allele-specific molecular markers is a critical step in the successful application of high-throughput MAS in breeding programs . Relative to conventional linkage mapping, genome-wide association study (GWAS) is considered a precise high-resolution mapping tool for complicated quantitative features, GWAS inspects genetic distinction at a whole-genome level to locate candidate genes (Zhang et al., 2016). In this connection, the identification of the most abundant and suitable polymorphic SNPs in the genome of mulberry helps to improve biotic and abiotic stress tolerance mulberry genotypes through GWAS (Abdurakhmonov et al., 2008; Vijayan 2010; Sarkar et al., 2017; Vijayan et al. 2022a; 2022b). Additionally, the implementation of genotyping-by-sequencing (GBS) method is necessary to generate desirable SNPs for QTL and linkage disequilibrium (LD) mapping (Sarkar et al., 2017). Recently, a fast increase in available genome sequencing data has resulted in an intensification of computational based pan-

genome analysis . The pan-genome refers to a species' whole set of genes, which is made up of a core genome (which contains sequences shared by all members of the species) and effectively identifies causal genetic variants (e.g., SNPs) which can be useful for the improvement of many agronomically important genes in mulberry.

With ongoing trends of high-throughput sequencing technology, plant scientists achieved significant attainment toward crop improvement. Though inconsistency was also reported specifically for the improvement of complex traits such as yield, drought tolerance etc. because of inadequate understanding of (i) synchronization of nuclear to organelle protein expression,; (ii) highly complex compartmentalized metabolic network system; (iii) complication of the eukaryotic multilevel gene regulation system; and (iv) expression of genes influences be diverse agro-climatic conditions induce an enormous challenge to develop climate-smart crops.

Currently, a stupendous opportunity exists for data mining of wide-ranging online datasets and information available in the public domain. Bioinformatics tools and *in silico* data-mining research have significantly contributed to generating a platform for computational biology (Mondal et al., 2021). A range of repository databases, bioinformatics tools, and experimental datasets of different model and non-model crops are currently available and that will help in several aspects like understanding molecular relationships, divergence, duplication, *cis*-elements, microRNA mediated regulations, gene expression, co-expression network, interaction, post-transcriptional/translational mediated modifications, Gene Ontology (GO) etc. Though, to understand the genetic architecture of complex traits, information was found to be inadequate. Thus further extensive study requires for the improvement of the mulberry crop.

Development of robust and more informative markers

Since the ideal marker for genetic analysis of mulberry should be polymorphic, multiallelic, codominant, non-episatic, neutral and insensitive to environment and morphological markers do not meet these criteria, efforts have been made to develop or use biochemical and molecular markers in mulberry. The first attempt was with Isozymes, which are multiple forms of enzymes that share a common substrate but differ in electric mobility. However, due to the low polymorphism baring a few sporadic attempts of genetic diversity analysis in mulberry (Vijayan et al. 2003, 2004a-c,) not much work has been done with isozymes in mulberry. Side by side efforts has been made to utilize molecular markers. Restriction fragment length polymorphism (RFLP) markers are the first generation of DNA markers and it is based on digestion of the DNA with restriction enzymes and identifying the DNA fragments through digestion with restriction enzymes, electrophoresis on a gel and Southern-Boltting with probes. Since, RFLP needs large quantity of high quality DNA for restriction enzyme digestion and it is difficult to extract such high purity DNA from mulberry due to the high phenolic

contents in the leaf, RFLP becomes unpopular in mulberry (Vijayan 2007). The next and most widely used DNA marker was Random amplified polymorphic DNA, which used arbitrary short oligomers (usually 10-mer) to anneal to random homologous target sites within the genome to generate polymorphic markers arising from base pair substitutions modifying the primer binding sites. Insertions in the genomic sequence that separate the primer binding sites to a distance that prohibits amplification or cause length changes of the amplified product results in RAPD profile variation among individuals (Moeller and Schaal 1999). RAPD was mainly used for characterization of genetic resources (Xiang *et al.*1995; Bhattacharya and Ranade 2001; Srivastava *et al.* 2004; Chatterjee et. al., 2004; Zhao *et al.* 2004; Mishra et al. 2013; Banerjee et al 2016). Side by side Inter simple sequence repeat (ISSR) and Amplified Fragment Length Polymorphism (AFLP) markers were used for germplasm characterization and biodiversity analysis of mulberry (Sharma et al., 2000; Wang et al., 2001 Vijayan and Chatterjee, 2003; Awasthi et al. 2004; Vijayan, 2004; Vijayan et al., 2004a, c Vijayan et al., 2005; Vijayan et al., 2006a-b; Zhao et al., 2006, 2007). Since these markers are dominant, anonymous and suffering from fidelity, efforts were made to develop more robust, informative and reproducible marker systems. Simple sequence repeats (SSR) or microsatellite or short tandem repeat (STR) or simple sequence length polymorphism (SSLP) is one such marker system that has got wider acceptance. Genic and genomic SSR markers were developed and used for several studies as shown in Table 2. With the advent of next generation sequencing, it has been found that vast majority of polymorphisms that exist in DNA sequences are single base pair differences, thus the focus has shifted to develop makers based on these single nucleotide polymorphism (SNPs). SNPs are found in both transcribed and non-transcribed regions and the less likely hood of occurrence of cross over between two adjacent SNPs in comparison with other markers, and the easiness with which automation can be applied for SNPs, this marker system has recently gained a wider acceptance for linkage mapping and biodiversity assessments. In mulberry, many efforts are being made for genome-wide SNP discovery and Muhonja et al. (2020) through double-digest restriction site-associated DNA sequencing (ddRAD-seq), identified 2229 homozygous SNPs of 54 mulberry varieties in the eight species and used for phylogenetic analysis.

Functional genomics in mulberry is still in its infant stage as not much work has been carried out in this area, barring a few attempts to develop expressed sequence tags (ESTs) associated with stress tolerance (Checker et al 2012). ESTs developed from clones and unigenes identified through transcriptome analysis serve as sources of information for gene and trait identification. In mulberry, EST data sets were developed from leaf (Gulyani and Khurana 2011) and root (Checker et al 2012) of the Indian mulberry species *M. indica, M. laevigata* and *M. serrata.* Comparison among these data sets helped identify novel/trait specific genes (Saeed et al 2016). Genes involved in 1-deoxynojirimycin (DNJ) biosynthesis (Wang et al 2018), Helix–Loop–Helix-144

(bHLH144), remorins, Dehydration-15 (ERD15), Nitrite Reductase, chalcone synthase has been found involved in stress tolerance (Checker and Khurana 2013; Wang et al 2014b; Sajeevan and Nataraja 2016; Saeed and Khurana 2016; Wang et al 2017b). Genome-wide scanning identified the transcription factors NAC and WRKY play a role in biotic and abiotic stress responses (Baranwal and Khurana 2016; Baranwal et al 2016). Seventeen ABA-dependent signaling pathway-related genes including five *MnPYL*, six *MnPP2C*, and six *MnSnRK2* genes were identified from the genome sequences of *M.notabilis* and qPCR analysis revealed higher expression of *MaPYL4*, *MaPP2C5*, and *MaSnRK2.6* during fruit development and *MaPYL1/3/5*, *MaPP2C2/4/5/6*, and *MaSnRK2.3/2.6* during the post-maturation stage in *M. atropurpurea* cv. Jialing No. 40 (Zhu et al 2017). Further, a microRNA, the miR166f, enhanced tolerance of a transgenic mulberry to drought stress (Li et al 2018a). Further, Ukaji et al (1999) observed accumulation of *WAP27A* and *WAP27B* proteins in the cortical parenchyma cells of mulberry tree (*M. bombycis* Koidz.) during winter conferring tolerance to cold. Sun et al (2020) demonstrated the role of a chloroplast drought-induced stress protein (*MaCDSP32*) in conferring drought tolerance to mulberry. Likewise, Chen et al (2018) observed strong interaction between *mAKR2A* and *mSOD1* suggesting a role of *mAKR2A* in the development of transmembrane proteins and cytoplasmic proteins under cold conditions. Similarly, Liu et al (2015) observed the transcription factor MnDREB4A conferring enhanced tolerance to multiple abiotic stresses. In order to elucidate genomics of fruit ripening in mulberry, quantitative real-time polymerase chain reaction was performed with 17 genes participating in ABA signal transduction including five *MnPYL*, six *MnPP2C*, and six *MnSnRK2* genes, isolated from the *M. notabilis* genome database in *M. atropurpurea* cv. *Jialing* No. 40 and found that the transcripts of *MaPYL4*, *MaPP2C5*, and *MaSnRK2.6* were expressed at a relatively higher level during the entire development process. Similarly, the transcript levels of *MaPYL1/3/5*, *MaPP2C2/4/5/6*, and *MaSnRK2.3/2.6* were lower during the early-maturation stage and higher during the post-maturation stage, suggesting that they may play a vital role in regulating mulberry fruit ripening (Zhu et al 2017). Efforts are, thus, underway to identify more genes and markers to develop mulberry varieties tolerant to abiotic stress through molecular assisted breeding, though to date not much progress could be achieved in this direction. Recently, Jiao et al (2020) identified several genes from the genome of *M. alba*, among them important are the genes related to the biosynthesis of secondary metabolites and environmental adaptation (e.g., *ABA2*, *CAD9*, and *MPK16*), genes regulating growth and developmental processes and plant yield (e.g., *UBP14*, *SYP124*, and *GATA*). The gene *ABA2* from *M. alba*, is involved in the biosynthesis of abscisic acid (ABA), an important plant hormone that affects the synthesis of storage proteins and also confers tolerance to drought and salt stress. Likewise, *GATA* gene involved in regulating chloroplast development and growth in a cytokinin-dependent manner was also detected. Several rapidly evolving genes of *M. notabilis* mainly involved in metabolic pathways and biosynthesis of secondary

metabolites were also identified and a few important among them are *FRO2* which *has* undergone rapid evolution and has been positively selected in both *M. alba* and *M. notabilis*. *FRO2* confers low-iron tolerance and is also involved in glycine betaine-mediated chilling tolerance and reactive oxygen species accumulation.

The whole genome sequencing of mulberry had impacted significantly the characterization of germplasm as illustrated with 134 mulberry accessions by Jiao et al (2020). Using the newly identified 14,273,912 high-quality SNPs, the phylogenetic relationship among 132 cultivars using 2 wild mulberry genotypes was worked out and it was found that the phylogenetic tree generated with these SNPs was not inconsistent with the traditional species delimitations. Cultivars of Chinese origin were grouped into two viz., Hu mulberry (HU), from Taihu Basin, and non-Hu mulberry (NH), from the rest of China. This latter group is further divided into two subgroups, East and West. A lower level of heterozygosity with high linkage disequilibrium decay was also observed. Likewise, using genome-wide 2229 SNPs Muhonja et al (2020) worked out the genetic relationship among 54 mulberry accessions from seven species (*M. alba*, *M. indica*, *M. bombycis*, *M. acidosa*, *M. latifolia*, *M. kagayamae*, and *M. rotundiloba*). The phylogenetic tree had only three clear monophyletic clades viz, two Japanese native species, *M. acidosa* and *M. kagayamae* from different geographically isolated islands and a Thai species, *M. rotundiloba*, and all other species were found non-monophyletic. It was also observed that no distinct monophyletic clades were formed by varieties from M. *alba* and *M. latifolia*, indicating the formation of hybrids through natural cross hybridizations. These studies suggested that the present classifications of species under the genus *Morus* need revision but it may not be an easy task even with genome-wide DNA markers. Earlier studies with inter-simple sequence repeat (ISSR) and ITS markers also supported such views (Muhonja et al 2020; Zhao 2005).

Brief on Genetic Engineering for Resistance/Tolerance Traits

Genetic engineering consists of the isolation of a gene of interest, ligating it on a vector to transfer it into a plant genome to meet a purpose. The most important advantage of genetic engineering is the ability to manipulate gene expression as desired. In plant breeding, the breeders can work only with plants that are cross-fertile but with genetic engineering genes from any organism including microorganisms can be inserted into the plant. However, the biggest challenges are the development of a robust, reproducible plant regeneration protocol and a genetic transformation method. In mulberry, such an efficient protocol for direct plant regeneration from leaf explants is still to be developed, though direct plant regeneration from hypocotyls has become an easy task (Vijayan et al 2011).

Target Traits and Alien Genes

In mulberry, the main trait that is targeted much is the leaf yield, which is the product of cumulative contributions from a number of associated traits such as plant height, leaf weight, number of branches, leaf retention capacity, nodal length, root length (Vijayan et al 1997a). However, under saline conditions, a change in correlation was observed as the leaf yield had a significant correlation with plant height, leaf size, shoot weight, root weight, root length, protein, NRase activity and WUE of the plant. Similarly, the plant height was also found to change its correlation with most of the characters studied. This clearly shows that under different salinity levels the selection criteria for plants need to be adjusted (Vijayan et al 2009a). It has also been observed that mulberry possesses certain traits to confer higher tolerance to stress conditions. Some of these traits are thicker epicuticular wax, elongated roots, synthesis and accumulation of osmolytes like proline, glycine beataine, etc. (Vijayan et al 2008). Plants have evolved several mechanisms like paraheliotropic movements, thicker epicuticular wax, elongated roots, salt-secreting hairs, synthesis and accumulation of osmolytes, etc to tolerate the stress to facilitate retention and/or acquisition of water, protect chloroplast functions, and maintain ion homeostasis (Vijayan et al 2008a). The genes involved in these pathways and mechanisms need to be incorporated either through conventional breeding or through modern techniques like genetic engineering. Since the transgression of genes and traits into mulberry is very difficult due to the breeding behavior of the plant the easiest method is through genetic engineering. In genetic engineering, genes may be knocked out, overexpressed, or modified through gene editing. Over expression of *DREB*s (dehydration responsive elements binding proteins), MYB (myeloblastosis), *ERF* (Ets-2 Repressor Factor), *bZIP*, and *WRKY* transcription factor families have shown promising results in several plant species (Jung et al 2007). Further, Lu et al (2008), have identified a low-temperature induced gene *WAP25 f*rom Mongolian mulberry, one of the wild species of genus *Morus* that grows in cold regions and cloned the gene (GenBank accession N0. DQ104333) into expression vector pIG121/*Wap*25 and transformed *Petunia hybrida* Vilm via *Agrobacterium.* This study exhibited the possibility of genetic improvement of other mulberry species such as *M. alba, M. indica, M. latifolia* which are being used for silkworm rearing and are highly susceptible to cold and other stresses.

Likewise, in plants, the most widely manipulated cell organelle is the chloroplast as chloroplast transformation has multiple advantages over nuclear genome engineering. In chloroplast transformation, transgene is integrated via homologous recombination, thus, eliminating gene silencing and position effect. Further, the chances of spreading the transgene genes through pollen transmission are also very minimal. Although in mulberry no such plants has been developed, chloroplast engineering has successfully employed in several other plant species to confer enhanced resistance to stresses through a simultaneous expression of protease inhibitors and chitinase (Chen et al 2014), herbicide resistance, insect resistance (Jana 2010). Since the sequencing of the mulberry

chloroplast genome has already been completed (Chen et al 2016); identification of endogenous regulatory sequences for optimal transgene expression is easier than before. Further, different gene delivery systems like particle bombardment, *Agrobacterium* assisted gene transfer along with robust selection and regeneration protocols for transplastomic cells have already been developed in mulberry. It is also pertinent to note that it would be easier to get regulatory approval for chloroplast transformed plants than nuclear transformed. Thus, in the coming days, more focus will be on chloroplast genome engineering in mulberry for the development of transplastomic mulberry with improved agronomic traits and tolerance to abiotic stresses.

Biosynthesis and Biotransformation

Bioinformatics is increasingly becoming an indispensable tool for genomics research due to its untapped potential to extract information from nucleotide sequences of various types. Whether it is a whole genome sequence or transcriptome, bioinformatics is essential to analyse them properly to draw inferences. Although bioinformatics and genomics have been developed well in many other crops, the same has not been developed well in mulberry. Baring a few resources like MorusDB (http://morus.swu.edu.cn/morusdb) providing information on genomic data and EST of *M. notabilis*; (http://btismysore.in/mulsatdb/) (Krishnan et al 2014b; Li et al 2014) not much information is available on this aspect.

Prospects of Cisgenics

Cisgenesis is the genetic modification of a recipient plant with a natural gene from a sexually compatible plant and it involves only genes from the plant itself or a close relative with a single step gene transfer mitigating the risks associated with alien gene introgression. Cisgenic plants can harbor one or more cisgenes, but they do not contain any transgenes (Hou et al 2014). In the case of a cisgenic plant, the gene of interest, together with its promoter, is present in the species or a sexually compatible relative for centuries. Therefore, cisgenesis does not alter the gene pool of the recipient species and provides no additional traits (Schouten et al 2006). Similarly, unlike transgenesis, cisgenesis does not pose any deleterious effect on the non-target organisms or environment as the gene transfer would be much like that of traditional breeding. However, cisgenesis has great potential to overcome the major bottlenecks like linkage drag, sexual incompatibility, etc. that impede traditional breeding as in cisgenesis only the gene of interest is isolated from the donor plant and inserted into the recipient plant. Hence, cisgenesis is very useful for outcrossing and highly heterozygous plants like mulberry with long generation gaps. In mulberry so far only a few reports of cisgenesis are available. Saeed et al (2015) incorporated β-carotene hydroxylase1 (bch1) in mulberry cultivar K2 through *Agrobacterium* mediated genetic transformation and found the enhanced level of carotenoids and tolerance to high light, heat and UV

irradiation. Fang et al (2019) identified a *MuPR1* genes and their expression increased resistance to diseases. Nevertheless, the recent progress in mulberry genome sequencing would expedite the identification and isolation of genes of interest from the gene pool to develop more cisgenic plants.

Future perspectives

The global population explosion, urbanization, salinization of arable lands and global warming are the major challenges world agriculture is going to face in the coming days. Sericulture, being an agro-based industry, has to face these challenges along with competition from other agricultural crops. Although most of the sericultural important countries have come up with high yielding varieties, expansion of mulberry cultivation into nontraditional areas like resource constrained marginal lands, suboptimal conditions, lands and soil-stressed conditions such as drought and salinity like abiotic stress affected areas continue to be a problem yet to be resolved. Soil salinity already affects more than 6% of the total global area and is increasing daily due to intensive irrigation practices (Flowers and Yeo 1995). The United Nations Environment Program estimates that approximately 20% of agricultural land and 50% of cropland in the world is salt-stressed (Yokoi et al 2002). In India, nearly 142 million ha of land are affected by drought (http://www.gisdevelopment.net) and about 7.3 million ha of arable land are affected by salinity and alkalinity (http://www.cssri.org). Thus, there is a great potential for expansion of mulberry cultivation into these lands if suitable mulberry varieties are developed, which would be possible with the help the modern molecular tools. Towards this end, continuous efforts are being made to understand the gene(s), their function and gene-linkage(s) in mulberry. Recent advances in genomic research should help research do it much easier than before. Further, a multidisciplinary approach involving genetics, biochemistry, biotechnology, physiology, and plant breeding is required to develop robust higher yielding varieties. The current pace of advancements in biotechnology and molecular biology would definitely take research in mulberry to a new height where tailor made varieties could be developed to enhance mulberry leaf productivity both horizontally and vertically.

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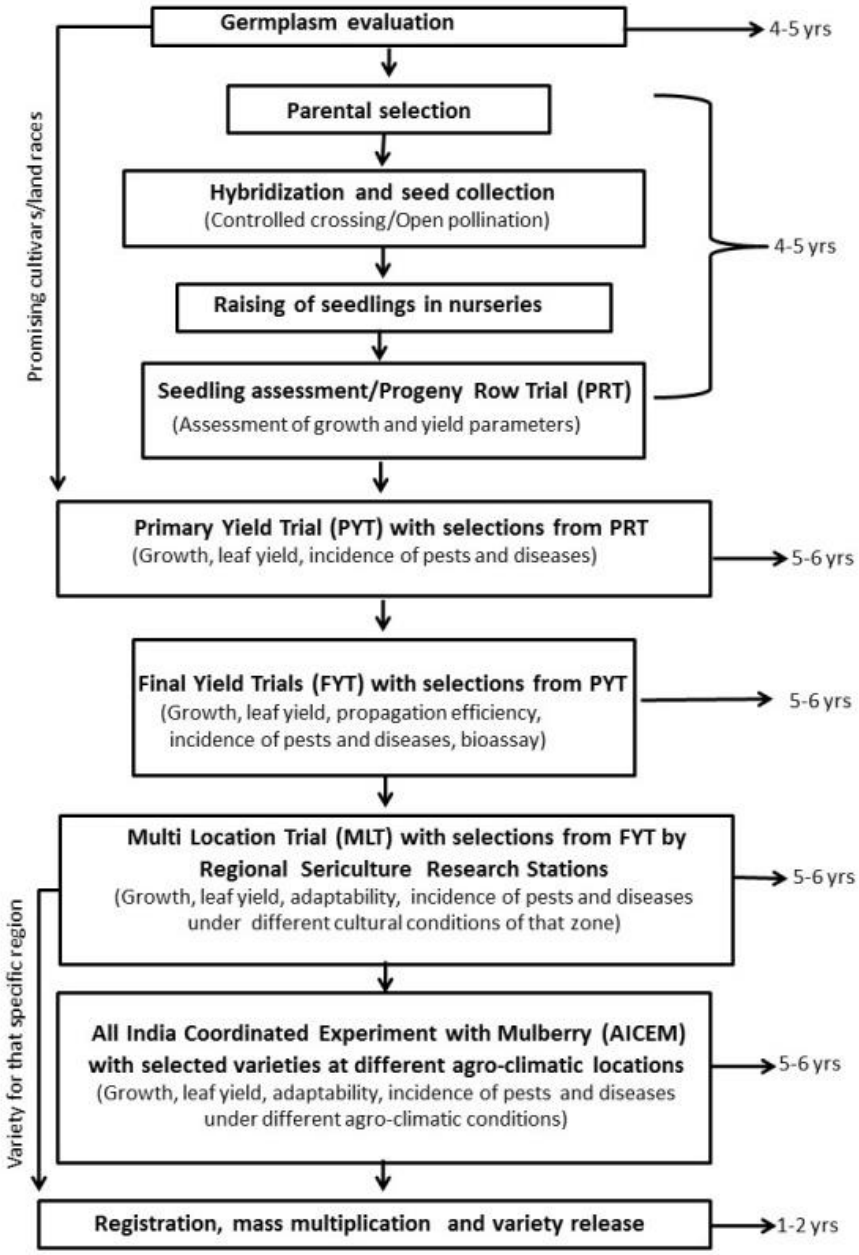

Fig. 1 Steps and time requirement for mulberry variety development

Table 1 Chloroplast genomes of *Morus* species

Species	**Genome size (bp)**	**Method**	**Reference**
Morus indica	158484	Long PCR and shotgun sequencing	Ravi et al. 2006
M. mongolica	158459	cpDNA on Illumina Hiseq 2000 platform	Kong and Yang 2016
M. atropurpurea	159113	Illumina Hiseq 2500 platform	Li et al. 2016
M. multicaulis	159154	Illumina Hiseq 2500 platform	Li et al. 2016
M. notabilis	158680	Whole genome Illumina sequencing	Chen et al. 2016
M. multicaulis	159103	cpDNA on Illumina Hiseq 2000 platform	Kong and Yang 2017
M. cathayana	159265	cpDNA on Illumina Hiseq 2000 platform	Kong and Yang 2017
M. alba	159050	-	Luo et al. 2019
M. alba	159290	Illumina sequencing	He et al. 2020

Table 2 Molecular markers used for genetic characterization in *Morus* spp. (adapted from Vijayan et al 2018)

Sl. No	Marker type	Purpose	Country	References
1.	ISSR	Cultivar analysis for crop improvement	India	Vijayan and Chatterjee (2003b)
2.	ISSR, RAPD	Genetic diversity in mulberry (genus *Morus*)	India	Awasthi et al (2004)
3.	ISSR, RAPD	Phylogenic relationship among five species	India	Vijayan et al (2004a)
4.	ISSR, RAPD	Genetic diversity among wild populations of mulberry	India	Vijayan et al (2004b)
5.	ISSR, RAPD	Genetic relationship of Indian and Japan accessions	India	Vijayan (2004)
6.	ISSR, RAPD	Genetic diversity among indigenous to India	India	Vijayan et al (2005)
7.	ISSR	Genetic relatedness among cultivated and wild mulberry	China	Zhao et al (2006)
8.	ISSR	Molecular characterization and identification of markers	India	Vijayan et al (2006a)
9.	ISSR, RAPD	Genetic relationships between wild and cultivated mulberry (*Morus*) species	India	Vijayan et al (2006b)
10.	RAPD	Genetic variability and phylogenetic relationship among 15 white mulberry genotypes	Turkey	Orhan et al (2007)
11.	ISSR	Genetic diversity among 66 local varieties belonging to 8 populations	China	Zhao et al (2007a)

12.	ISSR and SSR	Genetic diversity among 27 mulberry accessions including 19 cultivated and 8 wild accessions	China	Zhao et al (2007b)
13.	ISSR	Phylogenetic relationship among 18 germplasm collection and association with biochemical parameters	India	Kar et al (2008)
14.	AFLP	Genetic variability among 43 accessions belonging to *M. alba*, *M. nigra* and *M. rubra*	Turkey	Kafkas et al (2008)
15.	ISSR	Genetic diversity among ecotypes	China	Zhao et al (2008)
16.	RAPD	Molecular characterization of inter and intra-specific hybrids	India	Tikader and Dandin (2008)
17.	AFLP	DNA fingerprinting of ten cultivars	China	Huang et al (2009)
18.	ISSR and RAPD	Association with sprouting and sex expression traits	India	Vijayan et al (2009b)
19.	SRAP	Genetic diversity among 23 mulberry germplasm accessions from China	S Korea	Zhao et al (2009)
20.	RAPD	Phylogenetic relationship among 47 genotypes	Turkey	Ozrenk et al (2010)
21.	ISSR	Genetic diversity among 73 local mulberry varieties for development of core collection	China	Lin et al (2011)
22.	RAPD	Genetic variability among control and ethyl methane sulphonate (EMS) treated clones of mulberry genotype RFS135	India	Anil Kumar et al (2012)

23.	RAPD and ISSR	Genetic diversity and phylogenetic relatedness among 20 mulberry varieties	India	Chikkaswamy and Prasad (2012)
24.	RAPD and ISSR	Genetic diversity among 20 mulberry varieties	India	Chikkaswamy et al (2012)
25.	RAPD and ISSR	Genetic diversity among 21 mulberry genotypes collected from 4 geographic regions of Turkey	Turkey	Ipek et al (2012)
26.	RAPD	Genetic diversity among 36 genotypes collected from South India	India	Naik et al (2013)
27.	RAPD, ISSR and SSR	Standardization of novel and efficient DNA extraction protocol	India	Anuradha et al (2013)
28.	RAPD and ISSR	Genetic stability of cryo-preserved dormant buds of different Morus species belonging to indigenous and exotic collection	India	Choudhary et al (2013)
29.	SSR	Genetic diversity among 36 mulberry genotypes (‘breeders’ collections)	India	Krishnan et al (2013)
30.	RAPD	Genetic diversity among nine mulberry genotypes with contrasting traits for water use efficiency (WUE)	India	Mishra et al (2013)
31.	SSR	Genetic diversity among ten accessions belonging to *M. alba* and *M. indica*	Kenya	Wangari et al (2013)
32.	SSR	Phylogenetic relatedness among 17 mulberry genotypes	India	Wani et al (2013)
33.	SSR	Assessed the hybrid nature of two high yielding mulberry varieties	India	Arora et al (2014)

34.	RAPD, ISSR and SSR	Genetic diversity among 850 germplasm accessions collected from 23 countries for development of core collection of diverse accessions	India	Krishnan et al (2014a)
35.	SSR	Genetic diversity in wild mulberry species of India	India	Naik et al (2015)
36.	ISSR, RAPD	Genetic diversity and relationship of mulberry		Banerjee et al (2016)
37.	RAPD and ISSR	Genetic fidelity of in vitro regenerated mulberry plants (cv. S1)	India	Saha et al (2016) Rohela et al (2018, 2020)
38.	SSR	Characterization of Genic SSR Markers from Transcriptome and their Transferability to Related Species of Moraceae	India	Thuliman et al (2016)
39.	SSR	Association mapping of Charcol root rot diseases	India	Pinto et al (2018a)
40.	RAD-Seq	Identification of dominant genetic markers relevant to male sex determination in mulberry	Japan	Atsumi et al 2019
41.	SSR	The molecular characterization of an extended mulberry germplasm by SSR markers	Spain	Garcia-Gómez et al (2019)
42.	SSR	Molecular characterization of mulberry genotypes and species in Turkey	Turkey	Orhan et al (2020)
43.	SNP	Phylogenetic analysis of eight species of Morus	Japan	Muhonja et al (2020)

44.	SSR	Genetic diversity, identification and utilization of novel genetic resources for resistance to *Meloidogyne incognita* in mulberry	India	Arunakumar et al (2021)

PRELIMINARY STUDIES ON MULBERRY AS PHYTOREMEDIANT

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ABSTRACT

Excessive use of chemical fertilizers and pesticides in agriculture coupled with drainage or sewage disposal towards uncultivated lands and even in water bodies poses a greater threat for accumulation of heavy metals in our soils which finally results in impeding physiological and biochemical processes in plants growing on such soils. Although some heavy metals such as Co, Cu, Zn etc are required in traces by different forms of organisms yet excessive amounts of these elements can become harmful to them. Heavy metals like Pb, Cd, Hg do not have any beneficial effect on different life forms instead they result in sickening the soils by way of modifying soil biological properties and result in inhibition of cytoplasmic enzymes and damage to cell structures due to oxidative stress. Many of the known remediation techniques to remove heavy metals from soil are expensive and environmentally destructive. Phytoremediation is an emerging technology for removal of heavy metals which is cost effective, has aesthetic advantages and long term applicability. Mulberry is a plant whose leaf is used for silkworm rearing, yet the present study aiming at investigating the heavy metal uptake (aluminium, zinc, and lead) from soil by *Morus species* has indicated that the highest accumulation of all studied metals was found in the roots. The heavy metals did not transport from the roots to the shoots. Even plants did not show any extreme toxicity symptoms despite the inoculation of high doses of all the three heavy metals. In addition, the determination of tolerance index and a translocation factor showed that *Morus species* is suitable for phytoextraction and phytostablization of aluminium, lead and zinc in all treatments. The outcome of the study besides indicating the phytoremediation potential of mulberry also throws open chances of adding further value to sericulture for its sustenance by way of utilizing the mulberry as phytoremediant.

Keywords: Mulberry, Heavy metal, Phytoremediation.

PRELIMINARY STUDY ON MULBERRY GROWTH AND YIELD PREDICTION IN PHARE PROVINCE

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ABSTRACT

Currently, mulberry is planted all parts of Thailand that are varying on growth conditions. Moreover, there is increasing risk on plant growth and yield due to climate change. Therefore, mulberry growth and yield prediction has been preliminarily studied in Phare province in order to study basic requirements for mulberry growth and yield and to be able to estimate plant growth and yield by a modeling. This project has been performed in experimental plots (soil series: So, USDA: Fine, smectitic, isohyperthermic Lithic Haplustolls) at The Queen Sirikit Sericulture Center Phare from 2015 to 2019. Plots' coordinate is 47Q 613881 1985316. This research has 2 activities, and the experimental design was RCB with 3 blocks and 3 replications. There were 5 application rates of Nitrogen, Phosphorus and Potassium chemical fertilizers and they were separated plots to study. It has been found that growing mulberry trees for a long period of time at least 3 years decreased soil's pH in every method. From analyzing nutrients in young leaves in each level, young fully expanded leaves (YFEL) and leaves younger than the YFEL (YFEL-1) have Nitrogen, Phosphorus and Potassium concentration in adequate to high level from giving Nitrogen, Phosphorus and Potassium fertilizers. However, leaves older than the YFEL (YFEL+1) has deficient level. From these results, mulberry trees need Nitrogen more than Phosphorus and Potassium for having their concentrations in adequate to high level. From finding relationship between fertilizer rates, it has been found that Nitrogen fertilization rate has relationship with yield production. Especially, second and third harvesting having yield responses to nitrogen, phosphorus and potassium fertilizers in the quadratic form and at the highest rate of nitrogen at level of 187.50 kg/ha/year, phosphorus and potassium at level of 125.00 kg/ha/year and tends to decrease when fertilizer rates are increased.

When finding relationship between expected yield production from simulation planting program with yield production from harvesting, it has been found that Agreement Index

is between 0.59–0.96 and acceptance percentage is 88.89. From these results, it shows that acidity in soil increases from fertilizer for at least 3 years. Therefore, soil is needed to be adjusted to have suitable pH and fertilizer should have the right rate for mulberry trees. This helps decreasing production cost and leaving no residue in soil. Also, using PLANTGRO simulation helps estimating of production of Mulberry var. Buriram 60 to some extent.

Keywords: Mulberry, PLANTGRO, Yield Prediction

CHEMICAL PROPERTIES OF MULBERRY FIELD SOIL AND QUALITY OF MULBERRY LEAF AFTER APPLICATION OF LIQUID ORGANIC MANURES

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ABSTRACT

A field experiment was conducted to study the chemical properties of mulberry field soil and quality of mulberry leaf after application of liquid organic manures to V-1 mulberry garden planted at 90+150 × 60 cm spacing in red loamy soil during 2020-21. Application of bio digested liquid organic manure equivalent to 150 % N ha^{-1} has recorded the highest major nutrient contents (available N, P_2O_5, K_2O and S of 316.36, 51.51, 164.52 kg/ha and 7.78 ppm) in soil compared to control. Application of bio digested liquid organic manure equivalent to 150 % N ha^{-1} also significantly increased the mulberry leaf qualities such as nitrogen, phosphorous, potassium, chlorophyll, crude protein and carbohydrate contents.

Keywords: Mulberry, jeevamrutha, amritpani, bio digested, chemical properties, chemical properties of soil.

EVALUATION OF TRIPLOID MULBERRY GENOTYPES FOR GROWTH AND YIELD PARAMETERS UNDER OPTIMAL AND SUB-OPTIMAL CONDITIONS

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ABSTRACT

Sericulture is an agro-based industry, which heavily depends on mulberry (*Morus* spp.) for its sustainability, as mulberry leaf is the only available feed for the silkworm *Bombyx mori* L. Most of the improved mulberry high yielding varieties are diploids and triploids in their ploidy. It is evident that, triploid mulberry varieties are known to be superior to other ploidy levels on rooting, leaf yield, leaf nutrient components and silkworm rearing performance. Triploids are generally developed through hybridization between tetraploids and diploids. In the present study, evaluated six triploid genotypes *viz.*, Tri-1, Tri-5, Tri-6, Tri-8, Tri-9 and Tri-10 which were developed through hybridization between tetraploid and diploids. Based on the previous evaluation under primary yield trial for growth and yield attributing characters these six triploid mulberry genotypes were short listed. These genotypes were evaluated under optimal condition (irrigation and fertilizer inputs) and suboptimal condition (60% of recommended dosage of fertilizer and irrigation inputs) for five crops. Based on 5 crop data, it is found that 3 genotypes *viz*., Tri-10, Tri-8 and Tri-9 performing better than the check varieties (G-4 and Vishala) in terms of leaf yield, above ground bio-mass and other growth parameters. The best performing genotype from the study will be recommended for the farmer's cultivation.

Keywords: Mulberry, triploid, evaluation, optimal and sub-optimal.

FERTIGATION IN MULBERRY CULTIVATION- AN EFFECTIVE METHOD TO ENHANCE WATER AND NUTRIENT USE EFFICIENCY

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ABSTRACT

In mulberry sericulture, the quality of leaf plays key role for determining the cocoon productivity. The sustainable quality mulberry production is not by many farmers due to improper irrigation and nutrient management are important factors. Fertigation is an effective approach for the enhancement of resource use efficiency like water, nutrient etc. A fertigation experiment in mulberry has been undertaken to optimize the water and nutrient requirement for sustainable leaf productivity. Three doses of chemical fertilizers *i.e* 50% RDF (Recommended Dose of Fertilizer), 75% RDF & 100% RDF (336 kg N, 180 kg P_2O_5 and 112 kg K_2O ha^{-1} in the form of Urea, DAP & MOP) were supplemented to the mulberry through fertigation system. All the doses were supplemented in 6 splits/crop *i.e* 7 days interval starting from 15th to 49th days after pruning. Conventional practice was maintained with surface irrigation and soil application of 100% RDF as control. Data on mulberry (S1635) growth and yield attributes were recorded in nine crops during 2017-2019. In fertigation, NPK nutrients supplied nearer to the root-zone at different growth stages, thus resulted higher water and nutrient use efficiencies (70% & 66%) which in turn improved the leaf yield by 26%. The quality parameters *viz.*, total soluble protein and total soluble sugar were also significantly improved in the treatment over the control. When the mulberry was supplemented 75% RDF showed no significant difference in leaf yield as compared to the treatment wherein 100% RDF was applied, and it provides the scope for the reduction of 25% chemical fertilizers. Further, the quantity of irrigation water also can be reduced up to 24% without compromising the yield and quality. Thus, drip fertigation is found to be one of the important climate resilience technologies for sustainable mulberry leaf production.

Keywords: drip fertigation, water use efficiency, nutrient use efficiency, leaf yield, mulberry

SIMULTANEOUS EXPRESSION OF *ATDREB2A* AND *ATSHN1* GENES IN TRANSGENIC MULBERRY (*MORUS* SPP) CONFERRED TOLERANCE TO DROUGHT AND SALINITY STRESS AND REDUCED POST-HARVEST WATER LOSS

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ABSTRACT

Mulberry foliage productivity is challenged by various types of abiotic stresses such as drought, salinity, alkalinity, low temperature. The introduction of the transcription factor encoding gene in mulberry could be a viable option to mitigate the environmental constraints. In this study, three transgenic mulberry lines containing *AtDREB2A* and *AtSHN1* genes were developed through *Agrobacterium tumefaciens* mediated genetic transformation using cotyledon and hypocotyl explants of G4 cultivar. Integration of heterologous genes in transgenic lines was confirmed by gene-specific PCR assay. Transgenic mulberry lines showed 1-2 fold expression of *AtDREB2A* and *AtSHN1* genes. Transgenic mulberry lines showed better net photosynthetic rate, SPAD value, more relative water content, and proline content than wild-type (WT) mulberry plants under 60% field capacity. Leaf discs assay of transgenic lines showed less chlorophyll degradation and electrolyte leakage than WT mulberry under 25% PEG (polyethylene glycol), 200 mM NaCl and 10 µM methyl viologen treatments. Further, these transgenic mulberry lines showed less chlorophyll leaching and post-harvest water loss from leaves compared to the WT mulberry plant. The transgenic plants developed in this study could find its applications in mulberry breeding programs in the future.

Keywords: Genetic transformation, Abiotic stress, Transcription Factor, Tree breeding

IMPACT OF INSECTICIDES, FUNGICIDES, HERBICIDES AND BIO-PESTICIDES USED FOR PEST, WEED AND DISEASE MANAGEMENT IN MULBERRY ON SOIL BIOTA IN TAMILNADU

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ABSTRACT

Mulberry, an exclusive food plant of silkworm *Bombyx mori* is infested by many pests and diseases and to mitigate its losses, many insecticides, fungicides, and botanicals are used in mulberry. The indiscriminate use of synthetic chemicals in pest management induces resistance, resurgence, and residues. Hence, a study was taken up to find the impact of insecticides, fungicides and bio-pesticides on the soil biota in mulberry ecosystem at Regional Sericultural Research Station, Salem with the following treatments *viz*., Dimethoate (3 ml/lt of water), Dichlorvos (2.63 ml/lt of water), Carbendazim (2 g/lt of water), Mancozeb (2 g/lt of water), Glyphosate (7.5ml/lit of water with 10grams of ammonium sulphate, Gramaxone (7.5 ml/lit of water) and bio-pesticide Navinya (10 g/lit of water) along with control. The impact of pesticides on soil macro, meso and macro biota was ascertained by enumerating soil organism present in the known volume of soil before and after treatment on 10th, 20th and 30th day after treatment with the recommended chemicals for two years. The nutrient agar medium for bacteria, potato dextrose agar medium for fungi and Actinomycetes isolation agar medium for Actinomycetes were used to enumerate the soil microbes. The treatment Dimethoate recorded the minimum population of earthworms (4.1/cu.ft of soil) followed by Dichlorvos (5.1/cu.ft of soil) compared to the control (10.0/cu.ft of soil) after two years. Similarly, all treatments showed the nil population of ground beetles (0/cu.ft of soil) except Navinya (1.0/cu.ft of soil). Results on the enumeration of soil microbes revealed maximum reduction of bacterial population after first year of treatment in Dimethoate ($72.1x10^6$ CFUs/g of soil) followed by Gramaxone ($80.1 x10^6$ CFUs/g of soil), Carbendazim ($85.2 x10^6$ CFUs/g of soil) and Mancozeb ($95.2 x10^6$ CFUs/g of soil) when compared to the control ($100.1x10^6$ CFUs/g of soil) over population of soil microbes in pre-treatment. Similarly, the maximum reduction of fungal colonies and Actinomycetes was recorded in Dimethoate ($4.2 x 10^4$ CFUs/g of soil) and $2.3 x10^2$ CFUs/gram of soil) compared to the control ($11.2 x 10^4$ CFUs/g of soil) and $6.5 x10^2$ CFUs/gram of soil) respectively. The results of residue analysis revealed residue of Carbendazim (0.23ppm)

and Gramaxone (0.07ppm) in the soil after two years of treatment. The results indicated that the use of synthetic pesticides is harmful to soil biota and also leave residue in the soil and hence the botanicals/biopesticides for pest management is found to be safer to soil microbes and silkworm than synthetic chemicals.

Keywords: Actinomycetes, bio-pesticide, Dimethoate and Dichlorvos

SELECTION OF SUPERIOR MULBERRY HYBRIDS BASED ON GENETIC DIVERSITY, ROOT ROT DISEASE RESISTANCE AND HIGHER YIELD

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Root rot is a major soil-borne disease of mulberry caused by fungal pathogens like *Fusarium solani, F. oxysporum, Lasiodiplodia theobromae, Macrophomina phaseolina* and *Rhizopus oryzae*. Presently growing popular varieties under farmer's field are found to be susceptible to root rot disease. Development of improved variety having resistance to root rot pathogens through breeding programmes is effective approach to avoid crop loss. Due to high heterozygosity of the mulberry, segregating F_1 progeny generated by pseudo-test cross is being utilized for mining QTLs. In the present study, the mapping populations consisting of 200 F_1 progenies from the cross between M. multicaulis (ME-0168) and Thailand Male (ME-0033) was developed and established under field conditions. Identified twelve SSR markers showing parental polymorphism and genotyped the mapping population using twelve parental polymorphic markers. The male and female allele combinations have been produced in different progenies for different markers. The number of alleles varied in the range of 1 - 4. SSR primers MESTSSR31 and MASSR33 revealed four alleles while M2SSR89A showed single allele per locus. These 200 F_1 progenies were evaluated under progeny row trial for growth and yield parameter in five crops. Also, the mapping population was extensively phenotyped against root rot causing fungal pathogens (*F. solani* and *L. theobromae*) under glasshouse conditions in two seasons. Identified 45 resistant progenies against both the pathogens, among these six progenies showed higher yield under progeny row trial. The major QTLs conferring resistance to root rot disease of mulberry will be identified. Root rot resistance breeding is eco-friendly with long-term impact on the productivity and sustainability of mulberry cultivation in India.

Keywords: mulberry, root rot disease, SSR markers, mapping population

EVALUATION OF MULBERRY GENOTYPES FOR YIELD-RELATED QUANTITATIVE TRAITS UNDER VARIED CLIMATIC REGIONS OF NORTH-WEST INDIA.

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ABSTRACT

Systematic evaluation of mulberry genotypes under varied climatic conditions for leaf yield and yield attributing traits is a pre-requisite and continuous process for identification of elite genotypes suitable for a specific region or varied agro-climatic conditions. Under All India Coordinated Experimental Trials for Mulberry; three mulberry test genotypes *viz.*, C-1360, AGB-8 and PPR-1 developed by CSR&TI, Berhampore/Mysore and Pampore were included along with local check variety for their suitability for regional, zonal and national level cultivation based on their performance. These test genotypes are under evaluation at four test locations of Northern zone of India in randomized block design for sprouting, yield and yield attributing traits during spring and autumn seasons. Of which two test sites *i.e.* CSR&TI, Pampore and P4 BSF, Manasbal are in temperate region while the other two test sites *i.e.* RSRS, Miransahib, Jammu and RSRS, Sahaspur, Dehradun in sub-tropical region of North West India. Among the test genotypes, C-1360 was early sprouted at all the four test locations during 2021 and 2022. The temperate test genotype PPR-1 was late sprouted at RSRS-Miransahib and Sahaspur location. The combined ANOVA revealed significant variation among the test genotypes, location and variety x location interaction for yield and yield attributing traits at all the four locations no difference observed for seasonal performance of test genotypes with respect to yield traits at all the locations. The precise and accurate evaluation of test genotypes for two more years will be helpful in identification of mulberry test genotypes for cultivation in a specific region or diverse regions of Northern zone for the enhancement of cocoon productivity.

Keywords: Agro-climatic region, Cocoon, Mulberry, Sprouting, Season

DETERMINING THE EFFECT OF PLANT HORMONES, NUTRIENTS & BIOACTIVE SUBSTANCES IN IMPROVING MULBERRY LEAF LONGEVITY

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ABSTRACT

Early leaf senescence is a major constraint for mulberry sericulture in Eastern & Northeastern (E & NE) states of India. Leaf senescence in the popular variety of this region, S-1635 amounts to 25-30% in normal condition whereas it is further aggravated to 40-45% under stress conditions. Different plant growth regulators (Benzyl amino purine: BAP, Kinetin: KIN, Indole acetic acid: IAA, Naphthalene acetic acid: NAA, Ascorbic acid: AA), nutrients (Urea, KNO_3, $CaNO_3$, $ZnSO_4$,) and bioactive substances (Sodium nitroprusside: SNP & Sodium selenate: SS) in different doses (high, medium & low) were investigated for their role in delaying senescence of leaf discs obtained from senescing mulberry leaves floated on treatment solutions in petri dishes under dark conditions incubated at 25±2ºC. 5 ppm IAA (81.9%), 20 ppm BAP (86.6%), 10 ppm KIN (84.3%), 50 ppm AA (82.6%) and 30 ppm of SNP (84.4%) were able to retain significantly higher chlorophyll content after 7 days of treatment under dark conditions in both the popular & high yielding mulberry varieties S-1635 & C-2038 compared to control: distilled H_2O (35.6%). BAP, IAA, AA & SNP were again evaluated in combination along with their individual controls and also overall control (distilled H_2O) for confirming their further role in minimizing breakdown of chlorophylls, bringing down protease activity and arresting reactive oxygen species (ROS). Even when applied in combination, exogenous application of BAP (20 ppm) alone, SNP (30 ppm) alone, BAP+IAA (10 ppm + 2 ppm) & BAP+AA (10 ppm + 25 ppm) were found to be most effective in delaying senescence. SNP, BAP, BAP+IAA and BAP+AA were able to retain more than 85% of chlorophyll compared to control (34 %) in both the varieties. Decrease in total soluble protein was least in case of BAP (47.6%) treated leaf discs followed by SNP (52.9%) in both the varieties compared to control (77.3%). BAP+AA treated leaf encountered least increase in protease activity in both the varieties (51.1%) compared to control (236.8%). AA, BAP & BAP+AA also recorded less increase in IC_{50} value of DPPH after 7 days of incubation indicating higher antiradical activity in the leaf

discs treated with these plant hormones. This study indicates potential role of SNP, BAP, BAP+IAA and BAP+AA in improving mulberry leaf longevity which could be further evaluated under field conditions.

Keywords: Mulberry, Leaf longevity, Leaf disc assay, Leaf senescence, Plant growth regulators, Bioactive substances & Chlorophyll retention

STATEMENT OF MULBERRY PROPAGATION IN THE GLOBAL CENTER OF EXCELLENCE FOR ADVANCED RESEARCH AND PROMOTION OF SILK PRODUCTION OF CLUJ-NAPOCA

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ABSTRACT

Mulberry (*Morus spp*) is a perennial tree plant, very long-lived and with a high economic value. It grows in temperate climates, both spontaneously and in crops. The most common varieties are white mulberry (*Morus alba*), red mulberry (*Morus rubra*) and black mulberry (*Morus nigra*). It is of major importance in the silk industry, as well as recent studies have shown the use of mulberry in obtaining functional foods and pharmaceutical supplements, which is why its cultivation would have high economic benefits.

The aim of this paper was to identify alternative methods of multiplying biological material, in order to increase the production of qualitative mulberry leaves and fruits. All research is conducted as part of the activity of the Global Centre of Excellence for Advanced Research and Promotion of Silk Production of Cluj-Napoca (CGECAS-PPM), which aims to invigorate the sericulture and moriculture in Romania. In order to achieve this goal, our currently ongoing project so called DUDFOOD comes as a lever for the CGECAS-PPM in terms of specific objectives we are now working on: obtaining new fodder recipes based mulberry leaves, establishing and reviving of mulberry nurseries and plantations (testing of micropropagation techniques; testing of alternative systems for the production of dendrological material by: aquaponics, hydroponics, aeroponic and conventional for *Kokuso 21* variety) as well as developing a dietary supplement.

As a start, a conventional culture has been initiated and maintained in the greenhouse conditions. The development of the seedlings has been accelerated by exposing them to purple LED Grow Light. As for alternative methods, the most common method shown in the literature was micropropagation, using MS as culture medium and different combinations of growth regulators, depending on the desired results. We managed to initiate the organogenesis and callus formation starting from buds as explants, in the micropropagation laboratory from The Biodiversity Research Centre, UASVM Cluj-

Napoca. However, growing in systems such as hydroponics, aeroponics or aquaponics could represent a solution when there is no land available for conventional cultivation or enough water to ensure the daily need for plant growth.

In conclusion, the exploitation potential of mulberry is extremely high, due to the prospects of using alternative techniques of multiplication of biological material (micropropagation, ponic systems) to obtain leaf production throughout the year that could be used in sericultural practice, food, or pharmaceutical industry.

Keywords: morus, propagation, Kokuso 21, micropropagation, aquaponic, hydroponic

EFFECT OF VARIETIES AND NUTRIENT MANAGEMENT PRACTICES ON NUTRITIONAL COMPOSITION OF MULBERRY LEAVES

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ABSTRACT

An experiment to study the leaf nutritional composition of high yielding mulberry varieties under varied nutrient management practices were conducted at Central Sericultural Research & Training Institute, Mysore during January - April, 2021. The study comprises of two mulberry varieties (V1 and G4) and three nutrient management practices *viz.*, 100% RDF (Recommended Dose of Fertilizer), 80% RDF and 60% RDF. Results of study revealed that the varieties and nutrient management practices brought considerable improvement in mulberry leaf nutrient concentrations such as nitrogen, phosphorus, potassium, sulphur, iron, manganese, zinc and copper. No significant difference was obtained between the varieties studied with respect to leaf nutrient concentration, but the highest values of these parameters were recorded in V1 variety. Among the nutrient management practices, 100% RDF significantly improved all mulberry leaf nutrient concentration such as N, P, K, S, Fe, Mn, Zn, Cu followed by 80% and 60% RDF. The 100 % RDF significantly increased the nitrogen concentration in mulberry leaf by 5.1 % and 10 %; phosphorus concentration by 11 % and 34 %; potassium concentration by 9 % and 13% over 80 % RDF and 60 % RDF respectively. Similarly, 80 % RDF significantly increased the nitrogen and phosphorus concentration in mulberry leaf by 5.0 % and 20 % over 60 % RDF. But there was no significant difference observed between 80 % RDF and 60 % RDF with respect to potassium and sulphur concentration in mulberry leaf. The nutrient management practices had a significant effect on all the micronutrients concentration of mulberry leaf. The significantly higher value of Fe, Mn, Zn and Cu were recorded in the 100% RDF followed 80% RDF and 60% RDF. The 100% RDF significantly increased the concentration of Fe, Mn, Zn and Cu by 3.4%, 22%, 38% and 6% over 80% RDF and by 9.3%, 31%, 53% and 29% over 60% RDF. The balanced application of NPK nutrients in 100% RDF resulted in better vegetative growth might have encouraged the absorption of macro and micronutrients from soil. Therefore, V1 variety along with 100% RDF proved to be most promising treatment for improving nutrient concentration of mulberry leaves.

Keywords: fertilizer dose, nutrient concentration, variety

EFFECT OF MULBERRY IRRIGATED WITH TREATED SEWAGE WATER ON SILKWORMS AND COCOON PRODUCTION

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ABSTRACT

A field research was conducted in a V1 mulberry garden established under paired row system to study the influence of raw and treated sewage water irrigation on growth of mulberry and subsequent effect on silkworm (PM × CSR_2) growth and cocoon parameters. The raw and treated sewage water were collected from GKVK sewage treatment plant and irrigated to mulberry garden. Silkworms fed with mulberry leaves raised on recommended dose of NPK kg/ha/year + FYM along with raw and treated sewage water irrigation showed positive influence on late age silkworms. Observations recorded on silkworm growth and cocoon parameters revealed that significantly higher fifth instar larval weight (32.02 g/10 larvae), ERR (99.0 %), single cocoon weight (1.706 g), pupal weight (1.385 g), shell weight (0.321 g), shell ratio (18.65%) and shorter fifth instar larval duration (181.91 hrs) Similarly, reeling parameters of cocoons showed significantly longer filament length (853.00 m) and higher filament weight (0.28 g) in silkworms fed with mulberry leaves from the plots irrigated with raw sewage water.

PROTOCOL FOR REMOVAL OF HEAVY METALS FROM SERICIN SOLUTION USING SODIUM ALGINATE BEADS AND MULBERRY LEAF

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ABSTRACT

Heavy metals above the permissible limit in biological samples are toxic to human and other living organism. In this study removal of heavy metals from sericin solutions by using mulberry based material and sodium alginate beads has been carried out. The mulberry leaf powder and 1% sodium alginate beads were used for removal of Fe, Cu, Mn, Zn, Pb, Co from solutions. The effect of pH, temperature and adsorbent concentrations were investigated in experiments. The results showed that the removal of heavy metals by mulberry leaf powder and sodium alginate beads were effects by all the adsorption parameters. A protein sample mixed with known concentrations of heavy metals and subjected to filtration through activated mulberry leaf powder and sodium alginate beads separately at pH 6-7 at room temperature. The results showed that activated mulberry leaf powder has removed 40-70 % in removing of Pb, Co, Fe, Mn, Cu and Zn respectively. Similarly, sodium alginate beads have removed 60-80% Fe, Cu, Mn, Zn, Pb and Co. 100 % removal of heavy metals from protein samples needs to be studied. The result indicates that ecofriendly nontoxic mulberry leaves may be used as a low-cost alternative to more expensive adsorbent.

Keywords: Heavy metals, mulberry leaf, sodium alginate beads, protein solution.

SEASONAL INCIDENCE OF TUKRA IN MULBERRY GARDENS – A STUDY AT P2 BASIC SEED FARM, HORSLEY HILLS AND AMONG SERI FARMERS OF THE ANNAMAYYA DISTRICT IN ANDHRA PRADESH

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ABSTRACT:

Mulberry (Morus sp.) is the sole host plant for domesticated silkworm, *Bombyx mori* L. Hence for the success of sericulture industry, it is essential that the silkworms require quality mulberry leaves in abundance. The incidence of Tukra is associated with mulberry mealy bug, *Maconellicoccus hirsutus* which is polyphagus. The average incidence and loss in mulberry leaf yield is estimated to be 34.24% and 4500 kg/ha/y, respectively (Kumar *et al.*, 1994; Manjunath *et al.*, 1996). This loss in leaf yield forces the farmers to forego a rearing capacity of 450 dfls, thus incurring an economic loss of about Rs. 25,000/- per ha/yr. The survey of Tukra incidence was conducted in Rayachoty, B.kothakota and Thambalapalle mandals of Annamayya district in Andhra Pradesh. The data of the survey shows that incidence of Tukra was found throughout the year and maximum incidence was found during winter season i.e., in December followed by November. The pest incidence was again high during May. The pest incidence reached its peak in December. (24.8%, 22.5% and 20.2% respectively in Annamayya district). The percentage of pest incidence was negligible as compared to December in the month of July (8.10%, 7.20% and 6.00% in Annamayya district). An IPM package comprising mechanical (clipping and burning of infested portion) chemical (spray of 0.2% DDVP) and biological (release of *Cryptolaemous montrouizeri*- a predatory beetle @ 250 adults/acre), was implemented in the Basic Seed Farm, Horsley Hills was found effective against the pest incidence. Lack of awareness, practical difficulties, reluctance on advanced practices and non-availability of technological inputs were the major constraints among seri farmers for the technology adoption. The findings of the study throws light on the seasonal incidence of Tukra, extent of adoption of protection measures against Tukra by the seri farmers, constraints perceived by the Seri – farmers and strategies to be adopted for protection of Mulberry gardens.

Keywords: *Maconellicoccus hirsutus*, protection measures, seasonal incidence, Tukra

IDENTIFICATION, EXPRESSION ANALYSIS AND NON-FUNCTIONAL MUTATIONS IN *MILDEW RESISTANCE LOCUS O* (*MLO*) GENES ASSOCIATED WITH POWDERY MILDEW RESISTANCE IN *MORUS* SPP.

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Powdery mildew disease is one of the major diseases of mulberry affecting quantity and quality of leaf available to produce the silk. Deployment of powdery mildew tolerant varieties is an important approach in management of disease as spraying of fungicides has harmful effects on growth and development of silkworm. Susceptibility (S) genes in plants facilitate the infection and subsequent proliferation of the pathogens.Therefore precise identification of S genes responsible for powdery mildew disease and subsequent identification of non functional mutants in germplasm or by induced mutations impart disease resistance. In this study, genome wide analysis identified 16 *MLO* genes (S genes for powdery mildew disease) in mulberry. *MLO* genes from *Morus notabilis* and *Morus alba* were compared for their gene and domain organization. *MLO2*, *MLO6A*, *MLO6B*, *MLO12A* and *MLO12B* were clustered with functionally characterized *MLO*s associated with powdery mildew susceptibility from other dicot species with phylogenetic study. *MLO2*, *MLO6A* and *MLO12A* transcripts were induced upon powdery mildew infection. Further, the conserved motif D/EFSF, which is invariably present in all the functionally characterized MLO proteins, is also present in MLO2, MLO6A, MLO12A, MLO8 and MLO1C. Combined analysis identified *MLO2* and *MLO6A* as candidate genes involved in powdery mildew susceptibility in mulberry. The expression levels of candidate genes were analyzed in tolerant mulberry germplasm and also identifying non-functional mutations through sequencing of candidate genes is in progress to link disease tolerance to *MLO* gene function.

Keywords: *Morus alba*; Powdery mildew, Mulberry, *MLO* genes

TOODA CAPSULE: A SILK ROUTE CONNECTING AYURVEDA AND BYPRODUCTS OF SERICULTURE

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ABSTRACT

Sericulture is a prime commercial crop of Karnataka creating lots of employment and profit. The medicinal utility of sericulture by-products with collaboration between KSSRDI and SSCASR, has resulted in Tooda Capsules. The formulation is designed with Tooda leaves (Mulberry) and other 3 ingredients, all of which were collected from authentic sources and processed to obtain Tooda capsules. The drugs included in the formulation are those which have Hepatoprotective, Immuno modulatory, antidiabetic and Antihyperlipidemic actions, indicative of their probable clinical utility.

Keywords: Tooda, Mulberry, Sericulture, Ayurveda

DEVELOPMENT OF AN AYURVEDIC FORMULATION USING SERICULTURE BYPRODUCTS FOR THE MANAGEMENT OF DIABETES.

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ABSTRACT

Ayurvedic herbal dosage forms are formulated through the transference of active ingredients by different manufacturing processes. Among these dosage forms, '*Sandhana kalpana*' is a unique form in which acidic and alcoholic fermented formulations are prepared. The "Toodasava" is formulated with 9 ingredients in the method of fermentation as ascribed in Ayurvedic classics. The advantages of this dosage form include increased palatability, improved drug delivery, rapid absorption, longer shelf life among others.

Keywords: Toodasava, Sandhana Kalpa, Fermentation, Ayurveda

SECTION 2:

BOMBYX MORI

Domaine

Rearing, feeding, pathology and breeding aspects of *Bombyx mori* (mulberry silkworms)

Chairperson

Prof. Dr. Daniel S. Dezmirean

MEET THE CHAIRPERSON

Professor Daniel Severus Dezmirean, PhD

Head of Sericulture Department at Faculty of Animal Sciences and Biotechnologies, University of Agricultural Sciences and Veterinary Medicine Cluj Napoca, Romania; Coordinator of Global Centre of Excellence for Advance Research in Sericulture and Promotion of Silk Production (GCEARS-PPM) under the ISC recognition.

The main topic of interest - silkworm rearing in extensive and intensive farming, new concepts in rearing and feeding for silkworms (Pfarma- Farming), evaluation and conservation of sericulture and moriculture local breeds and hybrids and silkworms' pathology.

He managed and implemented many projects in Romania in the field of general sericulture and sericology, granted by international (World Bank) and national (UEFIS CDI, MARD) authorities.

(Project DUD FOOD – PNDR 2018-2023, SM 16 Support for the establishment and functioning of operational groups (GO), development of pilot projects, products and processes in the tree sector 9, (Morus ssp.) Project value: 1 785 692.44 lei – Project manager.)

(PN-III-P2-2.1-CI-2018-1181: CI 198 25/07/2018: Product development (gel) with biotechnological potential, using bioactive compounds from leaves and fruits from Morus ssp., 2018-2019, Project value:50,000 lei - Project manager.)

(PN II – Partnerships – 51014 - Conservation of genetic potential and biodiversity of local sericultural resources, 2007-2010, CO-SERISTECH, Value: 2000000 lei - Supervisor for project implementation)

(Project World Bank and MAPDR No. 1767, Grant Agreement 2238/23.11.2001;2001-2005, The rearing of silkworms in Family Farming Module, Value: 45000 euro – Project manager.)

He is also supervisor for 15 graduate thesis for students, three PhD thesis in the field of sericulture and the publishing activity is represented by 34 paper and a book chapter.

Professional merits - Gheorghe K. Constantinescu award as a team member, for the paper:

" Nutritional and Hormonal Supplements in Feeding of Silkworms", offered by The Academy of Agricultural Sciences and Forestry „Gheorghe Ionescu – Şişeşti", Romania

LEAD PAPER:

THE ROLE OF SEED ORGANIZATION IN SHAPING THE FUTURE OF MULBERRY BIVOLTINE SILKWORM SEED PRODUCTION IN INDIA

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India has drawn an ambitious plan to produce 20000 MT of import substitute mulberry bivoltine raw silk by the turn of this decade with matching horizontal expansion in the mulberry expanse, apart from concentrating on the linear growth in productivity. To become self reliant through internal production and to put an end to import of raw silk are the country's short term goals. The importance of developing and maintaining a strong silkworm seed organization in such a national plan cannot be overstated. To cope up with the projected raw silk growth trajectory, the country has been making calculated strides in the seed organization development under the stewardship of Central Silk Board through its seed production arm, National Silkworm Seed Organization (NSSO). The Organization has been consistently producing about 40 million bivoltine hybrid disease free layings (DFLs) per annum until 2018-19 and since then has been on a strategic mode to develop provincial bodies and private entrepreneurs to make substantial contribution, in addition to the own production. To reach the peak annual production in 2018-19, NSSO grew at a compounded annual growth rate of 16.21 % during the trailing five years. The organization's role in maintaining and multiplying the component races of commercial silkworm hybrids is pivotal to the healthy existence and excellence in the field performance. NSSO sources the Parent-3 seed ideally four times a year from the Parent-4 station which replenishes the stock periodically from that of the breeders. The P-3 stocks are carefully managed, maintained and down-multiplied until it forms the parental source of commercial hybrids. Any deterioration in benchmarked performance criteria is swiftly reported back to the breeders for prompt corrective measures. Through two P-3 and fourteen P-2 basic farms along with one P-1 seed production centre, NSSO takes care of the country's complete requirement of bivoltine basic seed. By 2030, this would lead to the supply of 563 gold standard P-3 DFLs, 49300 P-2 DFLs and 4.70 million P-1 DFLs to produce a total of 280 million commercial bivoltine DFLs. Realizing that the future lies in private participation, NSSO has been nurturing private entrepreneurs. Their production surged from 0.23 million to 8.64 million DFLs in the trailing four years. Added to this, NSSO's leadership position helps it play pivotal role in assisting the research organizations to conduct on-site trials

and become a stakeholder in the new silkworm hybrid development. In the past five years, a total of 1.10 million bivoltine hybrid DFLs were produced and supplied under this initiative. The paper deals with the importance of this vibrant system, the dynamics that drive the system, the procedures that are meticulously adhered to and its role in shaping the future of Indian bivoltine silkworm seed and silk production.
Key words: Basic seed, bivoltine, disease free laying, seed organization, silkworm.

INTRODUCTION

Sericulture is popular in India and particularly in southern provinces it has evolved as an attractive cash crop owing to its short crop and cash flow cycle of less than a month. The attractive cost economics of sericulture compared to other agricultural crops is a highlight. India is poised to taper off the import of raw silk from the current level of about 3300 MT per annum, in the coming 2-3 years and to meet the increasing domestic demand. India has set reasonable targets to meet the demand and drawn a workable road map for the next five years. A robust silkworm seed organization is key to the systematic growth of sericulture and silk industry of any country and India as a consistently growing sericulture country is no different. An established system makes relentless efforts to improve on a continuous basis in the pursuit of making it fool-proof so that all the components of the system become the part of a time-tested standard operating procedure. In India, raising of *Bombyx mori* silkworm has been in the lime-light for decades in comparison with the other four types of silkworms with a share of ca. 74 %. Ease of raising the larvae and assured market for the primary transactable produce, i.e., silk cocoon could be the two important reasons for its supremacy apart from the backing of a strong and reliable seed organization. Within mulberry sericulture, it is important to acknowledge that about 69 % of raw silk produced is still that of cross breed. Though mulberry sericulture in India has been growing at a decent pace of 6.90 % per annum for the past 10 years, the focus has gradually shifted to more lucrative bivoltine sericulture. The silk yarn reeled out from cross breed silk cocoons is of relatively low quality in comparison with bivoltine silk yarn as per the international standards. The shift of focus is more prominent in the target of raw silk production set and the roadmap drawn by India to reach by the year 2030. By the turn of this decade, India would want to reach a production level of 42300 MT mulberry raw silk per annum from the present level of 25818 MT for which the production has to grow at an annual rate of 6.27 %. Out of this taller target and projected growth trajectory, the target fixed for bivoltine raw silk production is 20000 MT through a quantum jump from the present annual production of 7941 MT with an envisaged annual growth of 12.24 % in comparison with the annual growth rate of 2.8 % set for raw silk produced from cross breed (from 17877 MT to 22300 MT) for the next eight years. It is fairly evident from these targets and priorities that India is poised to disrupt the present production ratio of 75:25 in favour of Cross breed to bivoltine to that of 53:47. One of the bigger challenges

India would face to achieve the bivoltine raw silk production target is to see that a robust and dynamic seed organization is in place that would complement and seamlessly back the efforts made to achieve the raw silk production target. This paper discusses the Indian model of Silkworm Seed Organization, the components involved in shaping such a strong seed organization led by National Silkworm Seed Organization (NSSO) and the role it plays to liaison among participants and stakeholders.

Relevance of Indian model

People's Republic of China has, over the decades remained the undisputed leader in world raw silk production arena. As per the latest statistics available, Chinese raw silk production has literally nose-dived during the period from 2015 to 2020 from 170000 MT per annum to 53359 MT per annum. This is at an annual de-growth rate of a whopping 20.69 %. The share of contribution by China to world raw silk production was 84.12 % in the year 2015 which also substantially came down to 58.14 % in the year 2020. During the same period, India has been growing steadily though at slower pace of 3.43 % per annum to reach from 28523 MT to 33770 MT. A recent study also made an effort to examine the growth and de-growth in various raw silk producing countries and their annual rate of growth (Thripura Sundari and Rama Lakshmi, 2018). Interestingly, the difference in raw silk production between China and India itself was close to 5 times the Indian production in 2015. This has substantially narrowed down over the five years and the difference is only 0.58 times of Indian raw silk production in 2020. During this period, India's contribution of raw silk to the world production increased steadily and handsomely from 14.11 % in 2015 to 36.80 % in 2020 and as a result, the gap between the highest raw silk producer and second largest producer has been diminishing quite strikingly. The importance of a robust seed organization is central to such a steady development.

Table: Difference in raw silk production (MT) between the highest (China) and the second highest (India) over the years

Year	China	India	Difference	X factor*
2015	170000	28523	141477	4.96
2016	158400	30348	128052	4.21
2017	142000	31906	110094	3.56
2018	120000	35261	84739	2.40
2019	68600	35820	32780	0.91

2020	53359	33770	19589	0.58
CAGR	-20.69	3.43	-32.66	-34.90

*Multiple of India's production to the difference

(Source: https://www.inserco.org/statistics)

Table: Country-wise % contribution towards global raw silk production

BM

Year	China	India	Uzbekistan	Thailand	Vietnam
2015	84.12	14.11	0.59	0.35	0.22
2016	82.28	15.76	0.65	0.37	0.27
2017	79.99	17.97	0.68	0.38	0.29
2018	75.16	22.09	1.13	0.43	0.43
2019	62.87	32.83	1.87	0.64	0.73
2020	58.14	36.80	2.22	0.57	1.06

The structure of Mulberry Silkworm Seed Organization in India

The responsibility of mulberry silkworm seed organization in India is jointly held by Central Silk Board (Union of India) through National Silkworm Seed Organization (NSSO) and the Sericulture departments of provincial (state) governments. Private participation is widely encouraged in silkworm seed sector in India. Due to the inherent ease in management, large number of registered seed producers in India are engaged in cross-breed (multivoltine x bivoltine) seed production unlike in bivoltine hybrid seed production. The basic stock of multivoltine races are predominantly maintained and multiplied by the state sericulture departments. While seed cocoons of pure multivoltine races are raised exclusively in the legally protected and notified geographical seed areas, bivoltine seed cocoons are also raised through identified progressive seed cocoon producers apart from those belonging to notified seed areas. State sericulture departments are the custodians of such notified seed areas and they are well maintained to protect the genetic purity of races and the sanctity of the concept. The onus of maintenance and multiplication of the component races of the popular bivoltine hybrid combinations lies primarily with NSSO.

Role of National Silkworm Seed Organization

In Indian bivoltine sericulture history, NSSO plays a significant role being the custodian of the high quality basic bivoltine seed stock. The organization is equipped with state-of the-art infrastructure at its Basic Seed Farms (BSFs), Silkworm Seed Production Centres (SSPCs) and Cold Storage Plants (CSPs) spread across various states. Highly experienced scientists and technical personnel are stationed in these centres. Their expertise in all the facets of seed organization is unmatched. This has helped NSSO to build a strong brand over the years of its operation and hence has been enjoying the leadership role in production and distribution of high quality bivoltine hybrid eggs across India. The primary responsibility of NSSO is to systematically maintain the component races of all the silkworm hybrid combinations that also include specific multivoltine races identified for certain regions. The component races of popular authorised silkworm hybrids are handed over by the research stations to NSSO for its further maintenance and multiplication while being used for preparation of the eggs of authorised silkworm hybrids. Added to this, NSSO offers technical guidance and training to prospective seed sector entrepreneurs and implements the provisions of the Central Seed Act on the ground, through the Seed Analysts and Seed Officers indentified for the purpose.

Down multiplication of Basic stocks

The research stations after developing the silkworm hybrids, approach the Silkworm Hybrid Authorization Committee (HAC) which after due consideration decides to have large- scale multi-location third party evaluation of the hybrid. After being satisfied with the performance of the new hybrid, it is recommended to be authorized for commercial exploitation. If the hybrid gets accepted in the field and becomes popular among the farmers, NSSO takes the responsibility of maintaining and down-multiplying the component races. Needless to say, all the hybrid combinations authorized for commercial exploitation are not equally accepted in the field. The component races of hybrid combinations which are yet to be popular in the field, are maintained either at the main research stations or in the satellite breeding station until need arises. Majority of such races eventually find their way to the germplasm station for long term maintenance. In India, there are 34 bivoltine x bivoltine hybrids, 25 multi x bivoltine hybrids and 5 multi x multi hybrids authorized so far to meet different requirements of farmers, such as high yield, that are suitable to different climatic conditions, different regions, etc. But out of these, presently there are only 5 bivoltines, 3 multi x bivoltines and one multi x multivoltine hybrid popular in the field. Some of these combinations are popular in the field for decades and better or equally good replacements are yet to be accepted in the field. Still, efforts are continuously on to

develop more new hybrids. Similar situation has been reported from China as well as indicated by Chen and Wang, 2019). Although a number of hybrid combinations to suit various requirements of farmers are available in China, the hybrid Jingsong x Haoyue with high cocoon yield and excellent silk quality has been the leading popular hybrid for the past 40 years for the spring season. The healthy silkworm variety 932.Furong x 7532.Xianghui authorized in 1995 remains the most popular variety for summer and autumn seasons even after 25 years. Hence, constant quest for new hybrid combinations may not find its place in the field, unless the farmers accept them.

The pure races of the popular combinations are maintained following all standard procedures adhering to the original breed characters, at the breeding stations as breeders' stock and on yearly basis replace the Parent-4 stock at the P-4 Basic Seed Farms. The P4-Basic Seed Farms through meticulous planning conduct four cycles of multiplications in a year through cellular rearing and produce the P-3 silkworm eggs and supplies them to P3-Basic Seed Farms. P-3 Basic Seed Farms also conduct four cycles of cellular/composite rearing and produce the required quantity of P2 Basic seed. The P2 Basic Seed Farms generate high quality P2 -seed cocoons and supply to the dedicated P1- Basic Silkworm Seed Production Centre (Datta *et al.*, 1996). The P1 Seed Production Centre produces high quality P1 Basic Seed. These are procured by the commercial SSPCs of NSSO and distributed to the Adopted Seed Rearers (ASRs). The parent silkworm rearing at the rearing facilities of the ASRs are constantly monitored by the experienced technical personnel of the SSPCs and the seed cocoons harvested at the most appropriate time is procured by the SSPCs.

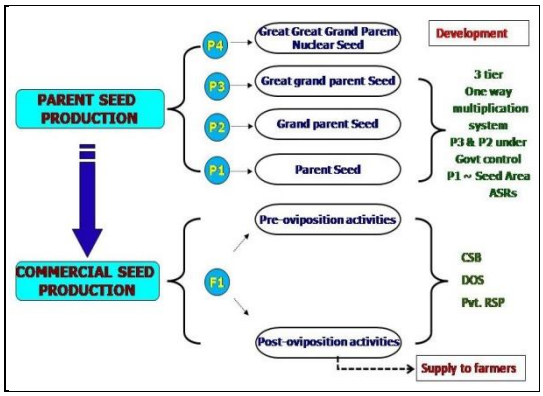

Figure: Indian Bivoltine silkworm seed organi-zation and scheme of seed multiplication

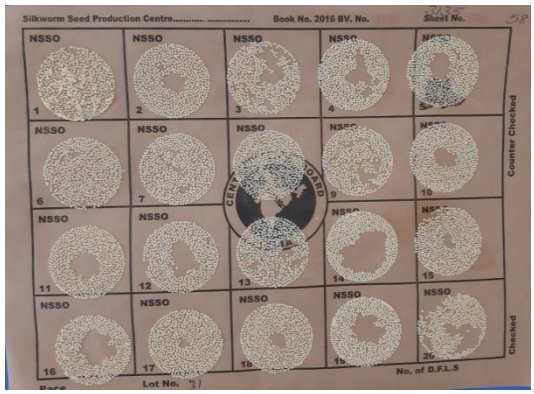

Figure: Basic silkworm seed produced by P1 SSPC, ready for preservation

Bivoltine Hybrid Seed Production in India

Historically, bivoltine hybrid seed production in India has been considered as a tough job mainly because of the expertise required to handle the bivoltine pure races to produce bivoltine eggs in loose form. Bivoltine seed cocoons need special care after procurement, cocoons are to be cut open, pupae to be taken out and separated into male and female, avoid intra-breed mating to produce true hybrids. In comparison to this, cross breed egg production is much easy mainly because of the bimodal moth emergence in the female component (multivoltine) in which male moths emerge much before the female moths prepare to emerge. Due to this ease of handling, private seed producers largely concentrated on cross breed seed production. The percentage share of different players in the Bivoltine hybrid seed production as depicted below says it all even after consistent efforts to encourage these players to enter into bivoltine seed production.

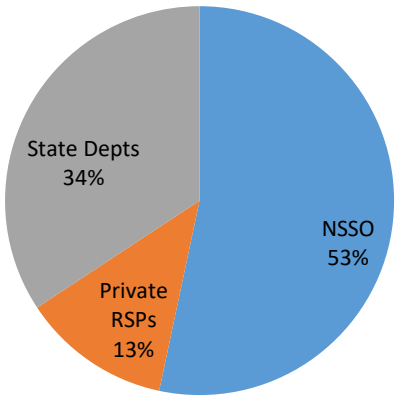

Figure: Share of different players in bivoltine hybrid seed production

Generation of Seed Cocoons

In NSSO's silkworm seed production scheme, quality is non-negotiable. In all the 14 state-of-the-art bivoltine SSPCs under its belt, the seed cocoon producers are carefully selected giving due weightage to mulberry plantation maintained, infrastructure and skilled manpower available and their experience in silkworm rearing. On selection of the seed cocoon producers, their registration under the CSB (Amendment), Act is facilitated so that they are also mandated to abide by the stipulations as per the CSB Seed Regulations, 2010. Well before a Registered Seed Cocoon Producer plans to take up the seed crop, the maintenance of mulberry plantation is closely monitored including pruning schedules, cultural operations, and fertilizer application and irrigation frequency depending on the soil types. Water conservation has been one of the top priorities wherever water is going to be scarce even in the future. A

welcome departure can be seen at many a place from the traditional bush type mulberry in which water consumption is on a higher side to short tree type plantation to reduce water usage.

Figure: Luxuriant bush type mulberry plantation of ASR

Figure: Short tree type mulberry plantation to reduce water usage

Seed Cocoon Procurement process

A mutual agreement is arrived at, between the SSPCs and Registered Seed Cocoon Producers to continuously supply the seed cocoons of benchmarked quality as per the pre-decided quality linked price available in the approved price grid. The farmers abide the terms and conditions religiously and agree to sell the seed cocoons only to the SSPCs regardless of the price movement in the Government regulated seed cocoon markets outside. This is relevant to the sustenance of NSSO's model of bivoltine hybrid seed production because the price of seed cocoon skyrockets during certain period when seed cocoon production is generally affected in the field and demand shoots up. The three important criteria for procurement of the bivoltine seed cocoons apart from being disease-free, are: 1) the pupation percentage should be above 80, 2) the cocoon yield should be above 50 kg per 100 DFLs and 3) the number of cocoons per kg should be between 550 and 700. If the seed cocoons satisfy these criteria, it is procured at a price as per price grid that ranges from Rs. 950 to Rs. 1000 per kg where seed cocoons with 80 % pupation fetch Rs.950 and that with 96 % and above fetch Rs.1000. An increase in each percentage point above 80, fetches the farmer an additional Rs. 3 until it reaches 95. The seed farmers remain loyal to the SSPCs and abide by the terms of the agreement mainly due to the assured market and pricing without any uncertainty, throughout the year. This is one of the important reasons for the success of this model.

Figure: Collapsible mounting device with seed cocoon still on, stacked at ASR's place

Figure: Seed cocoons brought to SSPC by the ASR ready for transaction

Egg production efficiency at SSPCs

The egg production efficiency at each of the SSPCs is closely monitored by NSSO. High egg production efficiency is the key to the sustenance of the centre and is measured in terms of average silkworm eggs recovered from each kg of seed cocoons. The norms set by NSSO for the bivoltine hybrid combination is 65 g of eggs per kg of seed cocoons. It is pertinent to mention here that the SSPCs need to stringently follow the quality norms to constantly generate the alpha against the set norm. While the seed cocoon lots with lower pupation percentage results in lower recovery, that with higher pupation percentage beat the norms by handsome margin. The management practices followed to maintain the temperature and relative humidity inside the seed production facility during the process of seed cocoon or pupa preservation, mating and ovi-position influence the egg production efficiency, substantially. This is why there is an inter-SSPC variation in the production efficiency in spite of a standard operating procedure (SOP) in place.

Table: Bivoltine Seed cocoons generated through Adopted Seed Rearers and the consolidated Egg recovery at the level of SSPCs

Year	No. of ASRs	Seed cocoons generated		Hybrid eggs produced (Million nos.)	Consolidated egg recovery (g/kg cocoons)
		Million nos.	Weight (kg)		
2016	1208	122.16	187,935	34.27	75.48
2017	1252	101.66	156,400	31.43	74.83
2018	1242	157.36	242,088	40.73	70..00
2019	1288	125.60	193,230	35.63	70.73
2020	1021	119.60	183,995	33.44	68.38
2021	918	114.56	176,251	30.41	68.36

Preservation of silkworm hybrid eggs

The bivoltine hybrid eggs are rarely used instantly in India except on emergency and on sudden spike in demand. In normal course, these eggs are subjected to a process of artificial wintering or hibernation for a period ranging from 4 to 10 months in specially designed Cold Storage Plants which are equipped with many enclosures in which temperature can be set between 2.5 °C and 25 ° C as per the requirement. A congenial relative humidity is also maintained in the enclosures, throughout. NSSO follows the hibernation schedules perfected after series of experiments by its subordinate research laboratory (Ravindra Singh *et al*., 2015). NSSO currently has three cold storage plants at different locations with a total installed storage capacity of 20 million DFLs and is in the process of installing another facility with a storage capacity of 15 million DFLs. Hibernating the eggs in varied preservations schedule helps NSSO to plan its sale of eggs as per the demand. When the organization finds it difficult to meet the spike in demand with the hibernated eggs, for brief periods, it resorts to supply of freshly prepared eggs after breaking the diapause using the hydrochloric acid treatment (Biram Saheb *et al*., 1990).

Figure: Incubation of loose eggs (Hybrid seed) at the Cold Storage Plant

Figure: Incubation of sheet eggs (Basic seed) at the Cold Storage Plant

Liaison with sericulture research stations for hybrid authorization programme

A silkworm seed organization's main strength is the availability of silkworm hybrid combinations that consistently perform in the field with steady crop performance. The Sericultural Research stations in India make concerted efforts to develop new hybrid combinations through conventional breeding or that assisted by newer techniques. After the hybrid combinations are repeatedly tried in the laboratory for better performance, they are subjected to On-farm-trials. Consistently good results of these combinations make the breeders eligible to approach the HAC for recommendation of the new hybrid for commercial exploitation in the field. For the committee to consider the case for recommendation, each hybrid has to be subjected to large scale field trial with

considerable number of farmers. The minimum number of DFLs to be tried in the field for such a consideration is half a million, over a period of time. The research stations do not have the wherewithal and the expertise to produce half a million DFLs for such trials. NSSO steps in at this juncture and offers its assistance by generating the seed cocoons of the component races of the prospective hybrids, though its ASRs, process the cocoons at its seed production centres and preserve the eggs in the pre-decided hibernation schedules at its Cold Storage Plants and releases the DFLs as and when required by the researchers. Under this understanding, for the hybrid authorization trials of new bivoltine hybrids, NSSO produced and supplied 1.12 million DFLs during the past 5 years.

Table: Year-wise production and distribution of hybrid eggs of new combinations or authorization trials

Year	No. of DFLs
2017	310700
2018	313600
2019	173900
2020	179200
2021	145100
Total	1122500

Commercial young instar silkworm rearing

The growth of bivoltine sericulture in India in the last decade has been exponential. A decade ago, the share of bivoltine sericulture was 10 % which grew at a faster pace to reach 31 %, presently. Ninety per cent of India's bivoltine raw silk production is contributed by the southern states including 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 earlier. One of the important reasons for this spectacular shift from rearing cross breed silkworm to bivoltine hybrid silkworm by farmers is the concept of procuring partially reared healthy and uniform young silkworm from a commercial facility and continue rearing in their own facility. Efforts by NSSO in sensitizing the young entrepreneurs and also the farmers at large in illustrating the benefits, such as increase in the crop cycles at the farmers' level and consistency in crop success with reduced

labour consumption helped in popularizing the commercial chawki rearing as a viable business enterprise and that also led to consistent crop success at farmers' place. This naturally led to increased bivoltine seed off-take. Initial incentives by NSSO coupled with the advent of seed sector reforms played significant role in popularizing bivoltine hybrids in the field. The chawki rearing enterprise package developed by the research institute ensured taking up 32 crop cycles per year by a CRC entrepreneur with a minimum of 2 acre mulberry garden (Nair *et al*., 2019). The strength of the seed organization was on a sterling display in changing the mindset of the farmers in going for bivoltines mainly through the concept of chawki silkworm rearing.

Participation of private players and State Sericulture Departments in seed organization

A collective seed organization led by NSSO to meet the challenges of bivoltine silkworm seed sector has been the pressing need. State sericulture departments and Registered Private Players are the other two players here. Strengthening the state sericulture departments and roping in the serious private players is particularly important considering the scale at which the bivoltine seed sector has to grow in the next five years and beyond. Going forward, NSSO alone will not be in a position to meet the country's demand for bivoltine silkworm seed. Hence, NSSO is in the process of developing private entrepreneurs in bivoltine hybrid seed production. During the past four years by constant encouragement, assistance in generating high quality seed cocoons, providing technical inputs & training and extension of cold storage facilities, NSSO could bring in 12 small scale entrepreneurs to bivoltine hybrid seed production. It is understood that Bivoltine seed production needs better infrastructure, expertise of higher order and enough fund support to tide over the financial crunch during the period of Seed preservation (4-10 months). Taking these into consideration, NSSO is offering handholding to private RSPs in the form of technical inputs, required training, and assistance in generation of high quality seed cocoons and facilities for preserving the hybrid seed in different hibernation schedules. Starting with an annual production of 228000 DFLs in the year 2017, they have reached a production of 9.30 million DFLs in 2021. Looking at the prospects of bivoltine silkworm seed production as a viable and profitable long-term business venture, one of the leading corporate houses in India dealing with agriculture seed, has now entered the field. As the first step, the company has registered itself as the seed producer and started the production after four of its personnel got intensive training. As of now, the company produces 100,000 DFLs a month with an ambitious plan to scale it up to 20 million DFLs per annum, in the near future.

But, similar proactive initiatives are not forthcoming from the side of some of the states who are major contributors of bivoltine raw silk to the Indian production. The

states of Karnataka and Andhra Pradesh from the south and Jammu and Kashmir from the North are yet to start making substantial strides towards bivoltine hybrid egg production. At the same time, the state of Tamil Nadu with about 5 million bivoltine DFLs and Maharashtra with about 2 million DFLs contribute to country's bivoltine hybrid seed production with definite plans to further scale up. The State Departments cite varied reasons for their inability to contribute. Some of them are as follows:

- Lack of required infrastructure
- Difficulties in marketing due to towering NSSO brand and low demand for own product
- Lack of confidence

On the contrary, the challenges as listed below faced by the small-scale private entrepreneurs are different from the above and appear far more genuine.

- ✓ Shortage of working capital
- ✓ Blockage of funds during the long period of seed preservation
- ✓ Non-availability of preservation space when they want it the most
- ✓ Non-uniform financial assistance offered by different state departments to seed sector enterprises
- ✓ Predatory pricing and cash- burning by the state departments
- ✓ Low production efficiency norms fixed by state departments which disrupts the production metrics, destroys the business environment and deny the level-playing field.
- ✓ Reluctance by the state departments for adopting uniform selling price even after uniform procurement price is adopted.

If all the players decide to arrive at a consensus and work together, many of these challenges can be effectively mitigated and the bivoltine hybrid seed production target can be met without hassles.

Quality maintenance and Certification

Indian sericulture seed sector is governed by the provisions of Central Silk Board (Amendment), Act 2006. As per the Act, the seed sector producers, such as seed cocoon producers, seed producers and chawki rearers need to register themselves following the stipulated procedure with the Registration Committee headed by the Director, NSSO as the Chairperson. The registration is valid for five years. The registered producers are mandated to strictly abide by the terms of registration that include self certification of the products that it is disease free and follow the quality

norms as defined in the CSB Seed Regulations, 2010. The registered producers are mandated to file quarterly production returns to the Registration Committee. The Seed Officers and Seed Analysts identified under the Act, by the Apex Committee, Central Silkworm Seed Committee (CSSC) undertake quarterly product certification and annual system certification, respectively. The onsite inspection and real time reporting is managed through a state-of-the-art mobile application, namely e-Cocoon developed for the purpose. Central Silk Board offers a refresher training to all the Registered Seed Producers (RSPs) and Registered Chawki Rearers (RCRs) before their registration is renewed, every five years. The registration and renewal processes are managed online through a hassle-free registration platform developed for the purpose for prompt and timely award of registrations. A total of 28955 registrations have been awarded until 31 July 2022 with 19964 registrations in mulberry sector and the remaining in vanya (wild silk sector). The registrations in mulberry sector include 17723 seed cocoon producers, 880 seed producers and 1359 chawki rearers. Interestingly, all the registered producers have not remained active throughout. A fact check revealed that as of now, only 10918 registered producers are active that include 9466 seed cocoons producers 799 seed producers and 653 chawki rearers (*Source*: *www.csb.gov.in*)

Summary

Indian sericulture exhibited considerable strength and more so resilience to register steady growth over the decades. The role played by the seed organization in backing up such a growth is immense. NSSO played a substantial part in this growth story by focusing on production and distribution of high quality commercial silkworm eggs, triggering an enterprise revolution in commercial young stage silkworm production and distribution and creating quality awareness among the farmers. The enhanced economic returns the farmers derive is consistent and the foot-falls in the bivoltine silkworm seed production centres are steadily on the rise. The organization realizes the importance of being ground-footed and making continuous efforts to remain highly relevant and complement India's efforts in scaling newer heights in bivoltine raw silk production.

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ANTI PROTOZOAN ACTIVITY OF DIFFERENT LOCALLY AVAILABLE CHEMICALS AGAINST DREADFUL PEBRINE DISEASE (*NOSEMA* SPP.) OF SILKWORM (*BOMBYX MORI* L.)

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ABSTRACT

Pebrine disease of silkworm caused by Nosema spp. is most dangerous disease because of its transovarian mode of transmission, fast secondary spread and recurrence and has posed a great challenge for its control throughout Globe especially in India. The disease ruined the silk industry in France and Italy as early as in 1845. Disease outbreak can cause 100% crop loss for years if not managed properly. Keeping in view the magnitude and severity of disease some locally available chemicals with known anti protozoan activity were evaluated at different concentrations for management of this dreadful disease. The overall results obtained after completion of 3 years trial have shown significant potential of all the test chemicals for management of the disease, out of three test chemicals Sodium bicarbonate at 0.6% was found most effective as compared to metrinidazole and carbendazium in all the parameters under study.

Keywords: silkworm, disease, chemicals, management.

MOLECULAR MARKER ASSISTED BREEDING FOR THE DEVELOPMENT AND EVALUATION OF BMBDV/BMDNV2 RESISTANT PRODUCTIVE COMMERCIAL HYBRIDS

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ABSTRACT

Sericulture has been one of the main branches of agriculture in Asiatic countries since hundreds of years. Like any other lepidopterans, the silkworms also are affected by pathogens especially viruses. Bombyx mori nucleopolyhedrovirus (BmNPV) and Bombyx mori densovirus (BmDNV) now named as a Bombyx mori Bidensovirus (BmBDV) are the major prevalent viruses. Under favorable conditions, Bombyx mori bidensovirus (BmBDV)/ Bombyx mori Densonucleosis virus-2 (BmDNV-2)/BmBDV cause flacherie disease which can bring down cocoon productivity up-ato 20%. nsd-2 gene (non-susceptibility to densovirus-2), which happens to be/which is a putative BmBDV receptor is identified to be involved in resistance under recessive mutation condition. nsd-2 gene encodes a putative amino acid transporter that was originally predicted to be localized to the membrane & functions as a receptor for the entry DNV-2 virus into the silkworm. The silkworm larvae get infected with BmBDV upon feeding on contaminated mulberry leaves and upon entry into the host, the virus specifically infects and multiplies in the nucleus of midgut columnar cells. The natural deletion occurring in the nsd-2 gene disrupting gene function has contributed to the evolution of BmDNV-2 resistant silkworm breeds. From our study, we found that the productive and popular breeds such as CSR2, CSR4, CSR17, CSR50 and CSR27 carried the susceptible allele alone whereas, the breeds CSR6, CSR16, CSR26, CSR51, DUN 17, DUN18, few N series breeds from CSR&TI, Mysore, SK6, SK7, NFC 8 (P), NFC R, BHP 8, BHP9, B.con1, B.con 4 from CSR&TI, Behampore and J2P carried the resistant allele in some individuals. The commercially reared hybrids especially FC1xFC2 (double hybrids) are susceptible to BmBDV infection and therefore, genetic resistance through selection and introgression of resistant gene into parents followed by development and evaluation of hybrids is essential to prevent the crop loss due to BmBDV. In productive breeds like CSR6-R, CSR26-R (parents of FC1) the individual male and female moths were checked

for the presence nsd-2 resistant alleles in homozygous condition, because in these breeds the resistant alleles are already present in either homozygous or heterozygous condition. However, in CSR2 and CSR 27, parents of FC2 the resistant alleles are completely absent, therefore both the breeds were introgressed with donor parent J2P through back cross breeding. The individual male and female moths (sibmated BC4 F1 individulas) possessing nsd-2 resistant alleles in homozygous condition were identified and subjected to bioassay. Further, the BmDNV-2 resistant productive breeds like CSR6-R, CSR26-R, CSR2 and CSR 27(FC1xFC2 parents), SK6, SK7 BHP 8, BHP9, B.con1, B.con 4 from CSR&TI, Behampore were validated for resistance to BmDNV-2 through bioassays and confirmed the absence of viral genome at molecular level, thereby demonstrating complete resistance of developed breeds upon BmDNV-2 infection.

SEX-LIMITED FOUNDATION CROSSES FOR COCOON COLOUR OF SILKWORM, BOMBYX MORI L. – A PATH BREAKING TECHNOLOGY IN SILKWORM EGG PRODUCTION IN INDIA

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ABSTRACT

The agro-climatic conditions of tropical India and the socio-economic status of the farmer has always compelled the breeders to develop economically viable cross breed of silkworm, Bombyx mori L. The commercial silkworm seed production centers produce such cross breeds through the mating of polyvoltine female parent with bivoltine male parent, which results in discarding the pupae of one of the sexes in both the parents to avoid self-mating during emergence. Thus, the sex separation is usually carried out at pupal stage which is laborious, expensive and a time-consuming practice in addition to damage caused while cutting open of cocoons for pupae. In this context, introduction of viable breeds with sex-limited traits i.e., the character found on only one sex at different stages of life cycle assume great significance of practical utility to the sericulture industry, especially during the process of silkworm seed production. Efforts were made with cocoon colour sex limited breeds as male component for the preparation of existing cross breed, though the rearing of such sex-limited breed as a single parent is difficult as the pure races are sensitive for rearing in summer season. Hence, attempts have been made in development of Sex-limited Foundation Cross (SLFC27) for cocoon colour to use as a male parent in the production of commercial cross breed (PM x SLFC27). The added advantages of sex-limited foundation crosses are easy to multiply at farmers level with improved fecundity, reduce the labour cost at the grainage as the yellow cocoons (Female) could be sent for reeling and 100% males can be utilized successfully for the preparation of cross breed. This newly developed crossbreed with Sex-limited Foundation Cross (SLFC27) as a male parent is being popularized for replacing the traditional ruling hybrid to minimize the grainage economics and also to reduce drudgery in silkworm egg production centers which would lead to significant economic gain in Sericulture Industry.

Keywords: *Bombyx mori* L., cocoon colour sex-limited breeds, foundation cross, cross breed.

EFFECT OF LIQUID ORGANIC MANURES ON LARVAL AND COCOON TRAITS OF SILKWORM (*BOMBYX MORI* L.)

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ABSTRACT

The study was carried out at Department of Sericulture, UAS, GKVK, Bengaluru during the 2020-21 under irrigated condition to study the effect of soil application liquid organic manures in mulberry and its effect on larval and cocoon traits of silkworm, mulberry V-1 variety planted under paired row spacing. Three different liquid organic manures were tested against recommended dose of fertilizer (control), leaf quality was assessed via feeding to silkworm. Significantly increased fifth instar larval weight (27.66 and 41.15 g/10 larvae), respectively was recorded in both cross breed (PM x CSR2) and double hybrid (FC1 x FC2) Silkworms fed with mulberry leaves produced from soil application of bio digested liquid organic manure equivalent to 150 % N ha-1. Double hybrid (FC1 x FC2) silkworm, larvae fed with treatment Bio digested liquid organic manure equivalent to 150 % N ha-1, showed significantly higher cocoon weight (24.76 g/10 cocoons), shell weight (5.89 g/10 shells), cocoon shell ratio (23.78 %), single cocoon filament length (1138.80 m) and filament denier (3.65).

DEVELOPMENT AND OPTIMIZATION OF A TAQMAN ASSAY FOR *NOSEMA BOMBYCIS*, CAUSATIVE AGENT OF PÉBRINE DISEASE IN *BOMBYX MORI* SILKWORM, BASED ON THE *B-TUBULIN* GENE

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ABSTRACT

"Pébrine" is a devastating disease of mulberry silkworm *Bombyx mori*, that is highly contagious causing severe crop loss in Indian sericulture. The disease is caused by the genus *Nosema* belonging to microsporidians, which are obligate intracellular parasites related to Fungi. *Nosema* spores in silkworms are primarily diagnosed through traditional light microscopy technique, which is labour intensive and less reliable often leading to false positive results. In this study, we present the development and optimization of a new TaqMan based assay for the detection and quantification of the *Nosema bombycis* pathogen using *β-tubulin* gene primersin pébrine infected silkworms. The assay displayed an excellent quantification linearity over multiple orders of magnitude of target amounts and a limit of detection (LOD) of $6.9x10^2$ copies of target per reaction. The method is highly specific to *N. bombycis* with no cross-reactivity to other *Nosema* species commonly infecting the wild silkworms. This specificity was due to three nucleotides variations observed in the probe-binding region, unique to *N. bombycis*. The assay is highly reliable with <5% co-efficient of variation (CV) for both intra-assay and inter-assay variability. Further to enhance the reproducibility and reliability the assay was tested on the *N. bombycis* infected silkworm larvae, fat body, midgut and ovary tissues. The detection was also mapped through pupation and metamorphosis to the emerging female moth, and her larval off-spring, confirming the vertical mode of transmission of *N. bombycis* in silkworms. The TaqMan assay tested in

the infection study performed as expected indicating its better performance and versatility. The assay is highly reliable, simple to use as well as implement and can complement the present microscopy technique, for routine diagnostics purpose and surveillance in silkworm egg production centres with sufficient infrastructure.

Keywords: silkworm, *Bombyx mori*, pebrine, *Nosema bombycis*, TaqMan, *β-tubulin.*

A PRELIMINARY INVESTIGATION ON IMAGE-BASED COCOON GENDER IDENTIFICATION USING DEEP CONVOLUTION NEURAL NETWORK

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ABSTRACT

Silk production plays an important role in the rural economy of India. Silk is a natural filament created by the silkworm while wearing a protective covering during pupation. During the cross breeding (hybrid) and for egg production, the male and female silkworm cocoons should be separated, so that the females of one species can be crossed with the males of another species to produce true hybrid eggs. Thus, the accuracy of the identification of the male and female cocoon or pupae is of immense importance for hybrid generation or silkworm egg production. But silkworm egg production is a highly technical job, which requires specialized organization where the task is generally performed by engaging well-trained professionals. If the cocoons are not separated with precision in accordance with their genders, there is a possibility that certain amount of coupling between the sexes without any selection causes production of low or inferior quality seeds. Therefore, the identification of male and female cocoons for grainage operations is very crucial for production of seeds in terms of both quality and quantity. Despite its prevalence and utility, the identification of male and female cocoons is done manually, which is time consuming as well as error prone due to human fatigue induced by its repetitive nature. In this work, we attempt to automate the identification of male and female cocoon using Deep Convolutional Neural Network that uses only the images of the cocoons captured by a standard mobile camera. In our approach, we first collect cocoons from the field and then we took the images of the cocoons. Afterwards, a set of experts are asked to identify the gender of the cocoons using the usual physical cut-based approach. We then use the cocoon images and its corresponding labels (male or female) to train the transfer-learned Deep CNN model. In transfer learning we used pre-trained VGG-16 model to get the image features from the Image net dataset. This gives us some

generic features of the images. In the next step, we use these features to fine-tune it further to adapt to our gender identification task. Our experiments show that the model is able to achieve 67% accuracy on test set measured using five-fold cross validation. We believe this result is a promising direction given that very small cocoon dataset was used to train it. With larger dataset and some additional features (such as weight of the cocoon) it can potentially boost the performance of the deep learning method.

IN SILICO APPROACH FOR IDENTIFICATION OF DRUGS/INHIBITORS TO INHIBIT THE PI3K-AKT PATHWAY IN *BOMBYX MORI* FOR CONTROLLING GRASSERIE INFECTION

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ABSTRACT

Grasserie is a serious viral disease of silkworm (*Bombyx mori*), caused by the N*uclear polyhedrosis virus* (NPV) (ds DNA belongs to baculovirus family) causes more than 20% of crop losses in the sericulture industry. Presently, details about effective and sustainable therapeutic agents/Inhibitors to control the NPV infection are not available/scanty. PI3K-Akt Pathway is an intracellular signal transduction pathway, that plays a crucial role in the regulation of cell survival, apoptosis, proliferation, and metabolism. The virus infection leads to activation of pathway and further viruses utilize the host machinery to modulate cellular events and thereby augment viral replication. In NPV infection, PI3K-Akt was found to be the hub of all signals triggered by the virus. Earlier reports suggested that drugs could be enhanced by targeting multiple host proteins in a pathway. The host-viral interaction depends mainly on protein-protein interactions.

Inhibition of host protein in a pathway or infectious agent's proteins leads to inhibition of viral infection. The present research aims to develop a drug or inhibitor against the targeted protein molecules for controlling BmNPV infection in *Bombyx mori* through inactivating PI3K-Akt Pathway. Identified 08 proteins like Akt, BmSTAT, mTOR, P143, PI3K, PIP3, RTK and VATPase. *The KEGG pathway database contains detailed information about the PI3K-AKT pathway. Utilizing the KEGG database, the protein has been selected for in silico screening.* The intermediaries of PI3K-Akt pathway proteins were targeted which are involved in the infection and multiplication of viral particles.

The selection was based on the function, importance, or contribution of the protein to an infection pathway for NPV. The protein sequences were retrieved from the database and their structure was predicted by the homology modeling method. A Ramachandran plot was used for structure verification, which measures the stereochemical quality of the predicted protein structure by PROCHECK, a program that utilizes Ramachandran plots for structure verification. T*he commercially available 96 anti-viral molecules against the predicted protein structure identified ten effective drugs based on the binding affinity*

score of AutoDock Vina. The AutoDock Vina assigns the score based on the nature of the interaction, their affinity with ligand molecules, and the number of rotatable bonds. The selected best-performing drugs under in silico conditions will be used in vivo and in vitro evaluation.

Keywords: PI3K-Akt pathway, NPV, drugs, inhibitors, in silico analysis.

DEVELOPMENT OF MULTIVOLTINE BREEDS THROUGH MARKER ASSISTED SELECTION (MAS) WITH SPECIFIC REFERENCE TO DIAPAUSE AND NON-DIAPAUSE CHARACTER IN SILKWORM *BOMBYX MORI* L.

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ABSTRACT

India is the second largest mulberry silk producing country in the world. Though bivoltine sericulture is promoted, the sericulture industry is dominated with crossbreed silk accounting to 71.61% of the total silk production. The crossbreed silk are inferior in quality compared to bivoltine silk and is usually non-graded. The crossbreed rearing is preferred due to its high adaptability to varying environmental conditions. To produce gradable cross breed silk, improvement of multivoltine parent is essential. This is possible by introgressing bivoltine traits through crossing with selected bivoltine breeds. But, in the process, undesriable traits such as diapause character is also expressed in the newly evolved breeds which needs to be addressed.This could be achieved by employing biotechnology approaches like Marker Assisted Selection (MAS) during selecting the progenies for the subsequent generations. The diapause hormone (DH), a neuropeptide secreted from the sub-oesophageal ganglion is responsible for induction of embryonic diapause in silkworm, Bombyx mori L. However, there are several other genes that are responsible which regulate diapause and nondiapause character in silkworms. The study was aimed at screening such non-diapause genes that can be attributed towards developing the multivoltine breeds/hybrids with superior silk quality. The multivoltine breeds (PM, MV1, HB4) and bivoltine breeds (S8, BM2E) were selected as source breeds and several combinations of hybrids were developed. 50% of the egg sample was collected in early embryonic stage of 18-24hrs of oviposition, total RNA was isolated using the Trizol and was quantified using NanoDrop. The broods of these hybrids were screened by RT-PCR for the expression of 20 diapause and non-diapause genes. Among these twenty genes, 3 genes viz., Acyl coenzyme A dehydrogenase, Nucleosome assembly protein and Bm period correlating to non- diapause expression were associated with parental races and further used for stabilizing lines. These were analysed through

RT-PCR for relative expression against control. The broods with genes exhibiting more of non diapauses character was carried forward and stabilised (12th Generation). The crossbreed (Multivoltine × Bivoltine) thus prepared with the stabilised line (13th - 15th Generation) did not exhibit diapause character. The understanding of difference in gene expression pattern has helped in developing new improved multivoltine breed (s) and thus help to decipher the difference in gene expression patterns in improving the crossbreeds with non- diapause character. The crossbreeds thus developed exhibited non-hibernating character aiding towards improved silk quality for the industry, further boosting the economic returns of the farmers.

Keywords: *Bombyx mori*, marker assisted selection (MAS), crossbreed, diapause, non-diapause.

CONSERVATION AND CHARACTERIZATION OF SILKWORM GERMPLASM IN INDIA FOR BIODIVERSITY AND POSTERITY

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ABSTRACT

Genetic diversity is a crucial element necessary for better chances of survival and optimal utilization of a species. Germplasm conservation is important for maintaining the diversity and to conserve the genetic traits of commercially valuable species. Mulberry silkworm germplasm is of high national importance for sustainability and posterity of the Indian sericulture industry. Central Sericultural Germplasm Resources Centre (CSGRC), Hosur was established in 1991 as the sole base collection center for mulberry and silkworm genetic resources. The center has been systematically and meticulously conserving mulberry silkworm genetic resources from different parts of the country and abroad and hence recognized as a National Active Germplasm Site. It also provides a public database of collected and evolved mulberry silkworm accessions. In addition to conservation, it provides an array of genetic materials to researchers to develop improved breeds and involved in registration of authorized breeds/hybrids to protect IPR rights of the breeder. Presently, 383 bivoltine, 83 multivoltine and 23 mutant silkworm genetic resources are systematically conserved in the gene bank. Another pivotal role of this center is to characterize, evaluate and provide valuable information on the silkworm genetic resources in order to facilitate their utilization by stakeholders. Evaluation and characterization for trait-specific germplasm, region and season-specific breeds and tolerance to biotic and abiotic stress are carried out and potential silkworm genetic resources are identified and recommended. Recent projects on molecular characterization of germplasm, screening of germplasm for resistance/tolerance to specific diseases will facilitate enhanced utilization of the germplasm by stakeholders for silkworm crop improvement. The thrust area of germplasm conservation through modern techniques like cryopreservation needs to be explored as a future plan of action. The paper discusses the current status, evaluation and characterization methods, information management and future conservation strategies to maintain seri-biodiversity for the benefit of sericulture industry.

EVALUATION OF GENETIC VARIABILITY, HERITABILITY AND GENETIC PARAMETERS IN THE BIVOLTINE SILKWORM (*BOMBYX MORI* L) GERMPLASM ACCESSIONS FOR PRODUCTIVE TRAITS

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ABSTRACT

Evaluation and estimation of genetic potentials of silkworm breeds are of prime importance in order to identify promising silkworm genotypes for its commercial exploitation through breeding to enhance the silk productivity for sustainable use. The objective of the study is to assess the diversity in the bivoltine silkworm germplasm and to estimate genetic parameters (PCV and GCV), heritability and Genetic Advance of commercially important traits in selected silkworm genetic resources. 368 bivoltine silkworm accessions from germplasm are considered for assessment of variability. However, the heritability, genetic advance and genetic parameters was estimated in selected 20 top performing bivoltine silkworm accessions/genotypes shortlisted based on the multiple trait analysis by Mano index values. The variability was assessed by Principal Component Analysis (PCA) with biplot analysis to determine the level of contributions of each character /parameter and the distance between the observations and relation between observation and variables (Characters). Cluster analysis was done with UPGMA. Additionally, mean data of selected traits were analyzed and presented in Heatmap (cluster for selected traits as well as cluster of silkworm accessions). Wide range of variability was observed based on CV (%) values in the productive parameters viz., fecundity (11.316), weight of the larva (9.285), cocoon yield (7.892), single cocoon weight (8.272), shell weight and (12.289) SR % (7.082). Pooled ANOVA of 20 selected silkworm accessions indicates significant variations @1% level over the five generations in all the parameters. Higher heritability and genetic advance was recorded in larval weight, cocoon weight, shell weight and shell ratio besides, higher genotypic variance and phenotypic variance in cocoon weight. The results enumerate the importance of evaluation of silkworm germplasm and estimation of genetic parameter for selection of parental stocks for subsequent breeding programme in development of desired breeds.

AN IMPROVED CROSSBREED, 12Y X BFC1 FOR EASTERN AND NORTH EASTERN INDIA

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ABSTRACT

India is the second largest global silk producer dominated (70%) by multivoltine silk. West Bengal state is known for un-favourable seasons (high humidity & high temperature) and only two favourable seasons; and the sericulture farmers prefer to rear crossbreed (N x SK6.SK7), which is associated with non-gradable quality silk. Continuous exploitation of N x SK6.SK7 by the farmers did not result any considerable improvement in economic returns and further compounded by intrinsic abilities of Nistari. The improved crossbreed, 12Y x BFC1 would serve as an improved alternative to the Nistari crossbreed, which has been developed for obtaining higher yields and also to realize silk of international grade. 2.29 lakh 12Y x BFC1 dfls were tested with the farmers of West Bengal and other North Eastern states during 2020-22. The results reveal that 12Y x BFC1 performed better than N x SK6.SK7 in terms of rearing and reeling parameters. The overall performance shows an improvement of 12.49% and 10.22% in terms of cocoon yield and shell content, respectively, which is quite significant (Two-way ANOVA). The 12Y x BFC1 hybrid combination has been authorized for commercial exploitation in Eastern and North Eastern India for realizing higher cocoon yields with gradable silk.

Keywords: crossbreed, multivoltine, gradable silk, cocoon yield, shell content.

DIFFERENTIAL IMMUNE RESPONSES AGAINST *STAPHYLOCOCCUS AUREUS* INFECTION IN GEOGRAPHICALLY DISTINCT STRAINS OF NISTARI (*BOMBYX MORI L.)*

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ABSTRACT

Nistari, an indigenous polyvoltine silkworm breed predominantly reared across Eastern and Northeastern region of India is well known for abilities to combat biotic and abiotic challenges. The four geographically diverse strains of Nistari (Plain, Mark, Chalsa and Debra) could be distinguished on larval and cocoon characteristics. The present study aims to evaluate total and differential hemocyte counts as well as variation in immune response genes (*Relish*, *Spatzle*, *Dorsal* & *Cactus*) upon infection with *Staphylococcus aureus.* Total hemocyte count (THC) and differential hemocyte count (DHC) were recorded in control (uninfected) and *S. aureus* infected Nistari strains, from IV instar till spinning. The infected and control populations exhibited presence of five types of hemocytes (prohemocytes, granulocytes, plasmatocytes, spherulocytes and oenocytes). However, significant variation in hemocyte counts was observed among the strains; and in between infected and control populations. THC increased significantly ($P<0.05$) in the early days upon infection and decreased considerably ($P<0.05$) during the later stages in all Nistari strains as compared to respective controls. Maximum THC variation was observed in Chalsa (3 dpi) with 4.91 x 10^6 cells/mL. DHC revealed highest counts of prohemocytes, plasmatocytes and granulocytes in Chalsa strain during initial days of infection in comparison to other Nistari strains. Survival (%) of Chalsa (73%) was highest upon infection followed by marked (68.9%), Debra (56%) and Plain (53%). qPCR analysis revealed upregulation of *Relish* gene in the midgut at later stages of infection, as well as substantial differences in expression of other immune-related genes

in the midgut and fat bodies of infected Nistari strains. These results provide insights into the defense responses of different strains of Nistari against *S. aureus* infection.

Keywords: *Bombyx mori*, Nistari, *Staphylococcus aureus*, hemocyte count, immune response genes.

EFFECT OF MULBERRY IRRIGATED WITH TREATED SEWAGE WATER ON SILKWORMS AND COCOON PRODUCTION

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ABSTRACT

A field research was conducted in a V1 mulberry garden established under paired row system to study the influence of raw and treated sewage water irrigation on growth of mulberry and subsequent effect on silkworm (PM × CSR_2) growth and cocoon parameters. The raw and treated sewage water were collected from GKVK sewage treatment plant and irrigated to mulberry garden. Silkworms fed with mulberry leaves raised on recommended dose of NPK kg/ha/year + FYM along with raw and treated sewage water irrigation showed positive influence on late age silkworms. Observations recorded on silkworm growth and cocoon parameters revealed that significantly higher fifth instar larval weight (32.02 g/10 larvae), ERR (99.0 %), single cocoon weight (1.706 g), pupal weight (1.385 g), shell weight (0.321 g), shell ratio (18.65%) and shorter fifth instar larval duration (181.91 hrs) Similarly, reeling parameters of cocoons showed significantly longer filament length (853.00 m) and higher filament weight (0.28 g) in silkworms fed with mulberry leaves from the plots irrigated with raw sewage water.

THE IMPACT OF IMPROVED ARTIFICIAL DIET WITH LINDEN HONEY ON *BOMBYX MORI'S* TRAITS

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ABSTRACT

Nowadays, the silkworm (*Bombyx mori*) gained a lot of attention from the scientific community due to its applicability in various life science fields. Keeping this in mind it is of great interest to combat the seasonal limiting problem when it comes to the exclusive silkworms nourishing source, namely the mulberry leaves. There are numerous artificial diets available for rearing silkworms in order to overcome the mulberry seasonal restrictions. Herein, aiming to enhance certain biological and economic traits of *B. mori*, we included linden honey in the artificial diet acknowledging honey's complex composition that includes a significant amount of vitamins. We analyzed the impact of two concentrations of linden honey, 2% and 5%, respectively. Our results showed that by adding 2% of linden honey in the artificial diet all studied parameters, for instance the larval length and weight or the number of deposited eggs, were lower than in the control group. On the other hand, by supplementing the artificial diet with 5% linden honey all parameters not only were enhanced in comparison with the group that received 2% honey, but all traits were increased compared with the control group.

Keywords: silkworms, artificial diet, linden honey, economic traits.

CONCEPT OF CHAWKI REARING CENTRES AND ITS IMPACT IN BIVOLTINE SILK PRODUCTION IN INDIA

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ABSTRACT

Central Sericultural Research and Training Institute (CSRTI), Mysuru is the premier institute in India which concentrates on research and development on mulberry sericulture technologies and played a vital role in promotion of sericulture for the past 60 years. One such technology/Concept is Young age silkworm rearing center popularly called as Chawki Rearing Center (CRC) which was developed by CSRTI- Mysuru in collaboration with Japan International Cooperation Agency (JICA) as a viable CRC model for appropriate chawki rearing practices in mulberry sericulture since 2005 in India and served as an important component in quality bivoltine silk production. The purpose of CRC is to rear quality young age silkworm systematically and scientifically by providing favorable microclimate (Temperature and Relative humidity), nutritious leaves and better hygienic conditions up to second moult and thus chawki silkworm rearing plays a vital role in bivoltine sericulture. And also chawki worm's supply from CRC helps to reduce the cost of cocoon production, silkworm rearing duration with famers, helps in synchronization of crops and distribution of labour for other works. Hence, the entrepreneurs of Chawki Rearing Centres (CRC) are the driving force for farmers community by supplying quality chawki worms. Commercial chawki silkworm rearing has emerged as an ideal rural vocation for poverty alleviation, employment generation, women empowerment and aided in improving the rural economy of the country. It was developed as a commercially viable for marginal and small-scale land holders due to its low investments, high assured returns, short gestation period, rich opportunities for enhancement of income and creation of family employment throughout the year. The concept of Chawki Rearing Center (CRC) was demonstrated successfully by National Silkworm Production, Central silk board under National Silkworm Seed Project (NSSP) which encouraged sericulture entrepreneurs to enter into commercial chawki silkworm rearing business. So far, Central Silk Board, Govt of India, under Ministry of Textiles issued Registration certificate/ license to 1321 entrepreneurs to open Chawki rearing centers in 19 states of India. Model Commercial chawki rearing centre of CSRTI, Mysuru provides training to

entrepreneurs for three months to get the license to open Commercial CRC. Trained CRC owners gained knowledge about bivoltine hybrids loose egg brushing technique, had awareness about mulberry variety suitable for chawki rearing (V1 and G2), application of Farmyard manure and plant protection measures, reduction in number of feedings, and also transportation of chawki worms. Commercial CRC can be run as a family business and also CRC provides employment to several youth especially women with good salary and welfare measures. The raw silk production in India increased from 18,370 MT in 2008-09 to 33,770 MT (Mulberry-23896 MT and Vanya silk-9874 MT) in 2020-21 which includes 6783 MT of bivoltine silk and the contribution to the country's economy through employment potential increased to 87.3 lakh persons, where CRC played a significant role.

SECTION 3:

NON-MULBERRY SILKWORMS

Domaine

Rearing, feeding, pathology, breeding, hostplants

Chairperson

Dr. K. Sathyanarayana

MEET THE CHAIRPERSON

Dr. K. SATHYANARAYANA, Director, CTRTI, Central Silk Board, Govt. of India, Ranchi and the Chairman, Non-Mulberry Silkworms Section

Dr. K. Sathyanarayana is presently the Director of Central Tasar Research & Training Institute, Central Silk Board, Ministry of Textiles, Govt. of India, Ranchi, Jharkhand, India, an exclusive institute in the World, which deals the overall development of tasar culture with a mission to transfigure the R&D efforts for increasing production of quality tasar silk so as to better socio-economic conditions of rural and tribal populace in over 10 Central and Northern states of India. He is also the Director of Basic Tasar Silkworm Seed Organization, CSB, Bilaspur, Chhattisgarh, India, which takes care of all the segments of tasar silkworm seed multiplication. Presently, he provides R&D guidance to scientists of CTR&TI Ranchi. Besides core research areas, his present focus includes effective utilization of by-products of Tasar silk industry such as sericin from tasar cocoon cooking waste water, cocoonase, fibre/ grainage wastes for cordyceps, pupae in fish feed & for chitosan in industrial use etc., to increase the primary producers' share across the tasar silk value chain and also to make tasar culture a zero-waste enterprise.

Dr. K. Sathyanarayana was the key in drafting various policy guidelines and in effective formulation, monitoring and evaluation modules for both research and vital developmental projects in sericulture sector including carbon sequestration from tasar host plant augmentation, which were supported by various funding agencies viz., Ministry of Textiles, UNDP, Ministry of Rural Development, Ministry of Science & Technology, Livelihoods Carbon Fund etc. He was also instrumental in forging many successful collaborations amongst Government, Non-Government, Corporate and Community Organizations for sustenance of various developmental initiatives. During his 34 years of service in various fields, contributions of Dr. Sathyanarayana were recognised with many prestigious awards/ appreciations including Best CSB Scientist Award 2020, besides Times of India Social Impact Awards, Citi Group Micro-entrepreneurship awards, Best FPO awards etc., for the project modules empowering tribal women and youth in Left Wing Extremism affected areas. He has published over 150 research publications in National and International Journals, which also includes books/book chapters/proceedings and designed many training modules. Presently, more than 20 field oriented research projects in various areas of Tasar Culture are under progress including conservation of tasar ecorace bio-diversity, pest and disease control etc., in collaboration with many research institutes of national repute.

LEAD PAPER:

Unleashing Stakeholder base: A Paradigm Shift in Indian Tasar Silk Promotion

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Amongst non-mulberry or Vanya silks in India, tasar silk production contributes to about 8% of overall raw silk and 27% of Vanya silks. Tasar silk has higher tensile strength, elongation, and stress-relaxation values, making it as competent and desirable as mulberry silk, besides meeting many of Sustainable Development Goals. Presently, about 3.5 lakh rural and tribal families are directly or indirectly associated with Indian tasar culture. Tropical tasar silkworm, *Antheraea mylitta* is distributed in 17 states and one union territory in the country. However, it is reared intensively in Central and North Indian states. Since last two decades, tasar sericulture has taken great strides from being subsistence level activity to micro-enterprise, due to increase in stakeholder base in R&D, technology development transfer, extension, service delivery, scaling up, conversion, diversification etc., through collaboration and convergence. This lead to increase in tasar silk production from 237 MT to 2689 MT in the last two decades, besides interventions across the tasar silk value chain. Some of the major gaps addressed include faster and easy propagation methods of primary food plants, *Terminalia tomentosa* and *T. arjuna*, identification of *Lagerstroemia speciosa* with low gestation period as an additional tasar primary host plant. In view of one third of contribution from collection of cocoons of 44 wild eco-races, with most of them feeding on *Shorea robusta*, which is abundantly available in the forest of ~4 million ha, sustainable conservation models of these eco-races like, Raily and Baraf (Chhattisgarh), Modal and Jata (Odisha), Sarihan and Laria (Jharkhand), Bhandara (Maharashtra) and Andhra Local (Telangana) have been developed. Several molecular markers such as RFLP, RAPD, SCAR, ISSR and SSR have been used for the characterization and high density SNP markers are selected for identification of the eco-races. In view of increasing cost of production, collaborative research was taken up in the field of by-product utilisation viz., cocoonase, sericin, pupae utilisation for human and animal consumption, chitin for industrial use, seri-waste for cordyceps production etc., to increase share of primary producer across the tasar value chain. Similarly, replicable micro-entrepreneurship models were developed on scale across tasar silk value chain, especially for large scale tasar host plant augmentation as part of carbon sequestration initiatives, tasar silkworm seed production, extension,

technology transfer and services, collective marketing and conversion etc., in collaboration with Civil Society Organizations through vibrant producer organizations run by tribal youth and women. Multi-stakeholder collaboration in research front through advancement of technologies viz., genome sequencing, introduction and induction of desired genes, marker assisted selection breeding, by-product utilization coupled with convergence initiatives from various development partners including corporate under Corporate Social Responsibility, would bound to enhance the profit and sustainability of tasar sericulture activities besides scaling up micro-enterprises across the tasar silk value chain and also the landscape.

Key words: Tropical Tasar, livelihood, convergence, multi-stakeholder base, tasar silk value chain

IDENTIFICATION AND CHARACTERIZATION OF THE PATHOGEN CAUSING VIROSIS IN MUGA SILKWORM, *ANTHERAEA ASSAMENSIS* HELFER

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ABSTRACT

Muga silkworm, *Antheraea assamensis* Helfer is susceptible to various microbial diseases *viz.*, pebrine, flacherie, virosis and muscardine. Approximately 40% muga crop loss is accounted for virosis and its prevalence causes mortality up to 80% during larval stages itself in seed and pre-seed crops during the summer season. Virosis in muga silkworm rearing is one of the key constraints hindering the silk production and productivity. However, information on causal pathogen of muga virosis with regard to identity, pathogenicity and epidemiology is not yet known. In the current study, viral pathogen of muga virosis was isolated, purified and characterized. Light and scanning electron microscopic analysis showed the viral polyhedra with hexagonal structure. The viral genome was found to be a segmented double stranded RNA. Viral structural (polyhedrin) and non-structural (RNA dependent RNA polymerase-RDRP) genes were cloned and sequenced. Sequence analysis revealed that the pathogen causing muga virosis is a cypovirus (*Antheraea assamensis* cypovirus, AaCPV4) affiliated to *Reoviridae family (sub-family* Spinareovirinae*)*. Phylogenetic analysis of AaCPV4 showed close relationships with other CPV variants infecting wild silk moths and 97% homology to *A. proyeli* CPV and 95% homology to *A. mylitta* CPV. Infectivity and pathogenicity of AaCPV4 to muga silkworms will be discussed.

Keywords*:* Muga silkworm, virosis, cypovirus-4, polyhedrin, RNA dependent-RNA polymerase.

GENETIC DIVERSITY AND POPULATION STRUCTURE OF *ANTHERAEA MYLITTA* ECORACES REVEALED BY HIGH-DENSITY SNP MARKERS

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ABSTRACT

Antheraea mylitta, polyphagous sericigenous insect predominantly found in various tropical zones of India which occupies different ecological and geographical regions and shows certain degree of phenotypic variation for which they are known as 'ecoraces'. The invaluable populations/ecoraces are under the threat of extinction due to to deforestation and other anthropogenic activities. Out of 44 ecoraces, the current status of many are not known. The identification and conservation of the ecoraces are very important in tasar sericulture. Identification of ecoraces based on phenotype is highly variable and influenced by the environment. Several molecular markers have been used but could not get clear population structure. High-density single nucleotide polymorphisms (SNPs) are used as highly favored makers to analyze genetic diversity and population structure, to construct high-density genetic maps and provide genotypes for genome-wide association analysis. In order to perform genome-wide SNP analysis in *A. mylitta*, double digest Restriction Associated DNA (ddRAD) sequencing technology was performed with 144 individuals belonging to 18 various ecoraces. Totally 135,058 SNPs were identified at RD10 with 0.05 MAF and integrity > 1. Intraspecific and interspecific SNPs were observed to be more in Bhandara and Jirbam ecoraces, respectively. Analysis of population structure using AMOVA revealed significant structuring (F_{ST} = 0.066; F_{SC} = 0.041; F_{CT} = 0.026). The mantle test revealed no significant correlation between genetic and geographical distance. Genetic divergence at the intraspecific level is mainly the result of limited gene flow among the population. The number of possible population clusters was investigated and observed that most of the ecoraces are not to be clearly differentiated. This study suggests that even though there is a large degree of phenotypic variation among the various *A. mylitta* ecoraces, genetically they are not more distinct, and the phenotypic differences may largely be influenced by the respective ecology. Our research also provides genome wide SNPs for further targeted breeding in tasar sericulture.

BREEDING WILD SILKWORMS: LESSONS LEARNT FROM MUGA SILKWORM, *ANTHERAEA ASSAMENSIS*

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ABSTRACT

Genetic improvement of wild silkworms in the form of high yielding disease tolerant breeds will directly help the stakeholders in increasing the production and subsequently improve the local economy by increased profit. The Indian golden silkworm, locally known as muga, (*Antheraea assamensis*) being reared outdoors is difficult to breed through conventional breeding methods as the breeders will have less control over the whole process of breeding. In outdoor rearing on trees, each crop is in different season and prone to natural enemies making selection for breeding characteristics difficult. No egg/pupal hibernation in cultivated stock and, problems in long term cold storage and synchronization of larval stages further complicate the breeding programme. In the present study, we envisaged to utilize the genetic resources from different geographical locations for the development of better muga silkworm breeds/hybrids through conventional breeding. Systematic breeding experiments were carried out using muga genetic resources collected from different locations of its natural habitat. The resultant breeding material from the initial crosses were used to select better lines and those lines were then studied further to shortlist a single promising line that is now being used for limited trials at different locations in Northeast India. In this breeding programme three traits were mainly considered for improvement namely, cocoon compactness, filament length and fecundity. Directional selection with initial generations in cellular rearing and subsequent rearing in group with continuous selections for desired characters led to the increase in filament length and fecundity. An improved 'cold reeling' procedure was standardized to select for better cocoon characteristics as well as high fecundity. The problems faced during the breeding of wild silkworms that require outdoor rearing and the effect of environment on breeding characteristics will be discussed. Apart from the development of improved breeds of muga silkmoths, this work also help obtain parental stock for breeding, which may be used by other insect breeders for improving the silk quality and disease tolerance.

DEVELOPMENT OF CHAWKI REARING TECHNOLOGY IN ERICULTURE

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ABSTRACT

Eri silkworm, *Samia ricini* (Donovan) is multivoltine insect and considered as most popular commercially exploited Non-mulberry silkworm. Eri silkworm is reared indoors like that of mulberry silkworm for production of cocoons. Ericulture is slowly moving from a cottage rearing set up to industrial scale production due to increasing demand and also due to government schemes. However, there is a lack of complementing technologies for scaling up of cocoon production. Especially, to maintain uniformity in entire rearing batch and to increase the productivity there is no commercial chawki rearing practices developed yet. The abiotic factors like temperature, humidity, light and air during rearing have a significant role that affect all the development stages of eri silkworm. The other factors like poor nutrition management in castor, improper disinfection methods, poor hatching, improper bed spacing, improper bed cleaning methods lead to the worms susceptible for diseases, more missing larvae and unequal sized worms, which directly influence on cocoon productivity and silk. To address these problems, we have standardized the chawki rearing practices for eri silkworm from egg stage to young worms distribution stage (at 2nd moult) by developing various techniques *viz.*, suitable castor variety for chawki worms, quantity of chawki leaves can be harvested per hectare, leaf quality requirement for eri worms, rearing house and appliances required, disinfection schedule, handling of eggs, incubation of eggs, black boxing, brushing care, quantity of feed required, bed cleaning schedules, bed spacing, moulting care, lime quantity, chawki rearing environment, chawki certification and distribution care. This has lead to uniformity in the crop which directly helps to increase the production and productivity in ericulture. Several demonstrations and field testing of eri chawki rearing have been carried out to show that this technology works at field level. The yield from chawki rearing was compared with the conventional method in farmers' field and found to be significantly higher (>30%). The technological intervention in the form of eri chawki rearing centers will help in increasing overall silk production. Also this technology can provide employment in rural areas of Northeastern and other emerging eri growing parts of India.

PROBLEMS AND PROSPECTS OF QUALITY TROPICAL TASAR SILKWORM (*ANTHERAEA MYLITTA* DRURY) SEED PRODUCTION IN INDIA

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ABSTRACT

Quality silkworm seed production is always a challenging task for successful silkworm cocoon crop harvest which leads to improve the socio economic conditions of the farmers in India. Tropical tasar silkworm (*Antheraea mylitta* Drury) is a wild insect which completes its larval life in the natural conditions, but after cocoon formation the harvested cocoons are kept inside the grainage house under artificial conditions for further processing to obtain disease free quality silkworm seed production, which is a prerequisite for successful tasar cocoon harvest in the field. There is a demand of around 51.00 lakh Dfls of tasar silkworm seed in the country annually to cater the needs of tribal farmers. Grainage is the most important aspect in tasar to ensure the production of quality tasar silkworm seed. During the handling of tropical tasar grainage activities due to long term preservation (5-7 months) of seed cocoons during pupal diapauses a number of problems *viz.*, loss of live stock (25 to 50 %), unsynchronized emergence (10 to 20%), low matting aptitude in captivity (40-70%), longer oviposition period (6-7 days), low oviposition potency (100-150 eggs per moth), low egg recovery (50-65 %), low hatching percentage (40-60%), high disease level (> 5.0%), *etc.*, are the major hindrances for successful grainage performance. In the present paper the various technical problems and prospects during quality tropical tasar silkworm seed production in India has been discussed.

Key words: Tasar, silkworm, seed, quality, technology, grainage.

UNIQUE TECHNIQUE FOR TASAR SILKWORM, *ANTHERAEA MYLITTA* CELLULAR SEED PRODUCTION ON PAPER SHEET

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ABSTRACT

Antheraea mylitta Drury (Lepidoptera: Saturniidae) is a semi-domesticated tropical wild tasar silkworm reared by marginal tribal farmers of India. Due to improper egg laying frequency, oviposition in tasar grainage is generally kept for three continuous days in earthen cups (C) after amputating the gravid moth wings (W^-). However, there is no report on the number of eggs laid on each of the three successive days. Hence, egg laying pattern of W^- moths in (C) was elucidated in ecorace Daba trivoltine (DTV) undergoing three life-cycles in a year. Also, in order to enhance the oviposition frequency by inducing stress, wing cut with leg cut (W^-L^-) was performed. Oviposition of (C)W^-L^- was observed in all three grainages during the year 2020 and compared with (C)W^- moths. Oviposition was observed at 5PM-9 PM, 9PM-12AM, 12AM-6AM and 6AM-5PM on the first day followed by every 24 h in the next two days. Oviposition was also accomplished on plain paper sheets (S). It is observed that (C)W^- obtained 63–67% and (C)W^-L^- obtained 72–80% egg laying on first day. Similarly, (S)W^- and (S)W^-L^- obtained 68–71% and 74–83% on first day. Further, a significantly high oviposition was observed within first four hours in both earthen cups and on paper sheets by W^-L^- moths laying 49–69% and 55–65% eggs compared to W^- laying 25–45% and 39–44% eggs, respectively. A total of 44–51, 47–54, 44–48 and 46–52 eggs/g moth weight was obtained in (C)W^-, (C)W^-L^-, (S)W^- and (S)W^-L^-, respectively in three consecutive grainages. Thus, the data reports the number of eggs laid per gram gravid moths, egg laying pattern of W^- moths in (C) within the first day and in three successive days and the enhanced egg laying of moths in first four hours itself after a simple leg amputation. Oviposition of W^- moths in earthen cups and on paper sheets are not significantly different indicating earthen cups in contemporary tasar grainage could be replaced with

paper sheets. Thus, the report demonstrates for the first time a fast, efficient and scalable cellular oviposition of *A. mylitta* on paper sheets comparable to *Bombyx mori*.

Keywords: Vanya silk, Tasar culture, stress, fecundity, cellular egg laying, MANOVA.

CHARACTERIZATION OF *CORDYCEPS MILITARIS* FRUITING BODIES GROWN ON TASAR SILKWORM

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ABSTRACT

Cordyceps militaris is an entomopathogenic fungus (Ascomycota: Cordycipitaceae) and is one of the most important medicinal mushrooms. *C. militaris* produces many bioactive compounds, including polysaccharides, cordycepin, adenosine, amino acid, organic selenium, ergosterol, sterols, cordycepic acid, superoxide dismutase (SOD), and multivitamins. Cordycepin (3-deoxyadenosine) is one of the most important biologically active metabolites. It has been regarded as a medicinal agent responsible for immunological regulation, anticancer, antifungal, antiviral, antileukemia, and anti-hyperlipidemia activities. In Sikkim (India) cordyceps is used to cure 18 types of diseases. The value of the cordyceps varies with the cordycepin levels in the fruiting body. Price of *C.militaris* grown on non-insect based media varies from Rs. 1-2 lakhs per kg dried fruiting bodies in the Indian Market. The demand for this mushroom is increasing in India. Waste generated in the tasar silk industry (rejected eggs, spent pupa and moths after mating) is enormous which was turned into value by mass production of *C.miliatris* strain DMRO 1163 (procured from ICAR-IIMR, Solan, India). We observed that when Tasar silkworm rejected live pupa was injected with DMRO 1163 strain, fruiting bodies developed are one or two. Thus, using silkworm pupae alone is not suitable for commercial mass production. So, we prepared silkworm refuses as powder and cereals as a substratum (Cereals provide the holding capacity, porosity and carbohydrates to fungi). Biological efficiency (wet weight of fruiting bodies ÷ weight of substrate x 100) in pupa powder + rice was 95 %, pupa + finger millet was 58%, pupa + wheat was 85 %, pupa + oats was 65% and pupa + barley was 72 %. The time taken for production of fruiting bodies was 52-55 days in pupa + rice and >65 days in the rest combinations. Biochemical parameters in fruiting bodies are far superior in silkworm media than the non-insect media. Thus, we conclude that, *C. militaris* would produce a superior quality of fruiting bodies with higher secondary metabolite profile when tasar silkworm pupa+rice was given as substrate. The by-product (Cordyceps) developed using the tasar refuses can benefit the entrepreneurs and overall, the Tasar Silk industry.

Keywords: *Cordyceps militaris*, Tasar silkworm, Cordycepin, waste to wealth.

OCCURRENCE OF NATURAL ENEMIES AND THEIR POTENTIALITY ON MANAGEMENT OF GALL FLY, *TRIOZA FLETCHERI MINOR*, CRAWFORD, ON TASAR HOST PLANTS

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ABSTRACT

The observations were carried out to explore on natural enemies of *Trioza flecheri minor* on primary host plantations of tasar silkworm. The results of the studies indicated that among the natural enemies recorded on *T. flecheri minor* the *Trechnites aligarhensis* Hayat, Alam and Agarwal and *Aprostoctus* sp. were the major parasitoids. The incidence of *T. f. minor* was significantly more on *T. arjuna* compared to *T. tomentosa* and peak incidence was observed during the August and September months. Parasitization of *T. f. minor* was significantly more on *T. arjuna* (43.10 %) as compared to *T. tomentosa* (28.12 %). Similarly, occurrence of *T. aligarhensis* was highest on the *T. arjuna* compared to *T. tomentosa* where as *Aprostocetus* sp. was more on *T. tomentosa* and then *T. arjuna*. About 22.98 per cent and 12.59 per cent galls on *T. arjuna* and *T. tomentosa* parasitized by the *T. aligarhensis*, respectively and 14.18 per cent and 09.50 per cent galls on *T. arjuna* and *T. tomentosa* parasitized by the *Aprostoctus* sp. There is much scope for management of psyllids using potential natural enemies on tasar silkworm host plants. Therefore, this study was intended to study the *T. f. minor* population during silkworm rearing seasons and identification of its major natural enemies and their potentiality. Identified parasitoids can be considered as one of the major component in the management of major insect pest, psyllid on tasar host plants.

OAK TASAR CULTURE A SIGNIFICANT MEANS OF LIVELIHOOD IN UTTARAKHAND, INDIA AND IT'S IMPACT ON CARBON MITIGATION

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ABSTRACT

Uttarakhand, the 27th state of Republic of India, came in to being on 9th November 2000, has total area of 53483 Sq. Km. with total 86% mountainous area. The state has highly varied topography with two different climatic regions, the hilly terrains and the plain region. Uttarakhand with its vast diversified and congenial temperate climatic conditions has the distinction to produce all the four types of silks i.e. Mulberry, Tasar, Eri & Muga silks. Presently, sericulture activities in the state are being conducted in 706 villages of 12 districts, involving 10500 families which are producing total 35 MT of raw silk. The state is bestowed with nearly 0.29 million hectares of natural oak tasar silkworm *Antheraea proylei* food plants, comprising of *Quercus leucotricophora*, *Q. floribunda* & *Q. semecarpifolia* spread through 1000-2700 meter AMSL. Plantation of 1450 hectare *Quercus serrata,* a comparatively fast growing oak tasar food plant species from North-Eastern states has also been augmented in the state. Presently total 2290 families are involved in oak tasar sericulture activities. Considering the vast potential of oak tasar culture in the state an Oak Tasar Development Project, under Tribal Sub Plan has been launched in Uttarakhand by Central Silk Board and Directorate of Sericulture, Uttarakhand with the objective to strengthen the infrastructure and the most required strong seed sector. In addition to providing sustainable livelihood to the local communities, silk industry in Uttarakhand is also playing significant role in providing ecosystem services like hydrologic regulation, climate stability, soil formation and carbon sequestration. The paper discusses the impact of oak tasar culture on the livelihood, role of sericulture in providing ecosystem services and the climate change along with the value of Carbon dioxide (CO_2) equivalent mitigation through sericulture activities in the state.

IDENTIFICATION AND CHARACTERIZATION OF POTENTIAL DIAZOTROPHIC AND PHOSPHATE SOLUBILIZING BACTERIAL STRAINS FROM THE RHIZOSPHERE OF TROPICAL TASAR SILKWORM FOOD PLANTS

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ABSTRACT

Tropical tasar silkworm rearing is mainly practiced on systematically raised plantations of *Terminalia arjuna* and naturally grown *T. tomentosa* in forest areas. Owing to its high returns from low investment area under systematic plantation has increased and supporting the livelihood of >2.5 lakhs rural families. However, quality of cocoons from systematic plantation is depleting due to decreased leaf nutrient quality, which in turn due to depletion in soil nutrients. Majority of tasar plantations are deficient in available nitrogen (N) and phosphorus (P). Plantations rarely receives manures and fertilizers due to poor economic condition of tribal farmers. Under this situation application of Plant Growth Promoting Rhizobacteria (PGPR) in the form of biofertilizer is most appropriate approach as it is economic, sustainable and eco-friendly. Identification of potential PGPR strains native to tasar food plant habitat is pre-requisite to prepare biofertilizer. In present study effort was made to isolate 204 strains of Nitrogen Fixing Bacteria (NFB) and 258 strains Phosphate Solubilizing Bacteria (PSB) from 114 soil samples collected from the rhizosphere of tasar silkworm food plants (*T. arjuna*, *T. tomentosa* and *Shorea robusta*), covering 3 major tasar rearing states of India *viz.*, Jharkhand, Odisha and Chhattisgarh. Indole-3-acitic acid (IAA) production is an important property of NFB, which improves root growth by stimulating cell proliferation and cell elongation and thereby enhances nutrient uptake by plants. Based on qualitative screening, 41 NFB isolates out of 204 NFB strains shown IAA production, quantitative estimation of which shown a range of 25-70 µg/ml and average of 47 µg/ml. Twenty strains produced higher IAA than check *Azotobacter chrococcum*. Nitrogen fixing ability of 41 NFB strains shown a range of 1.9 – 43.5 µgN/ml with an average of 8.4 µgN/ml. These NFB strains also found to solubilize inorganic phosphate (Pi) in National Botanical Research Institute Phosphate (NBRIP) liquid medium with the range of 17 - 294 µgP/ml and average of 132 µgP/ml. P-solubilizing ability of 258 PSB strains in NBRIP broth revealed that, 27 PSB strains shown >200 µgP/ml followed by 40 strains between 150-200 µgP/ml. Top 57 PSB strains were further tested for other properties, in which 32 can synthesize IAA,

11 can produce ammonia, 16 can mineralize organic form of P. Based on 16S rRNA gene sequencing, dominant genera of selected strains are *Serratia, Enterobacter* and *Pantia*. Based on *in vitro* performance 16 strains each of NFB and PSB were evaluated under pot condition. Based on the treatment effect over *T. arjuna* plant growth parameters, soil available N and P, and leaf nutrient uptake 5 potential NFB strains (NFB5-2, NFB8, NFB18-2, NFB51-2 & NFB106-2) and 7 PSB strains (PSB7-2, PSB16-2, PSB64-7, PSB98-1, PSB109-1, PSB110-2 & PSB115-5) were selected. These potential strains will be tested for non-pathogenicity over silkworm and used to prepare biofertilizer after field evaluation.

DIETARY FEED STRUCTURES THE MICROBIOME OF GOLDEN SILK MOTH, *ANTHERAEA ASSAMENSIS* HELFER

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ABSTRACT

Animal guts are known to harbour diversity of microbial life. By adopting a symbiotic lifestyle microbes are known to provide evolutionary advantage to an animal by aiding for digestion, detoxification, providing resistance to pathogens, modulating reproductive behaviour etc. Structure and variations of gut community have been reported for model silkworm, *Bombyx mori*. Similar approaches of comprehensive characterization employing parallel sequencing has not been reported for the golden silk moth, *A. assamensis*. Here, comprehensive characterization of the gut community in *A. assamensis* is being reported and the structure, pattern and variation on feeding with different dietary host plants (*Persea bombycina, Litsea monopetala, Litsea salicifolia*) is discussed. Post filtering, denoising and removing PCR artifacts, a total of 1363 Amplicon Sequence Variants (ASV) was detected using DADA2 across all the sequenced samples. Principal coordinate analysis (PCoA) could explain 82.4% of variation and clustered the samples according to the dietary feed plants (adonis, r2 = 0.513, p = 0.001). The early instar stages (2^{nd} and 3^{rd}) significantly differed in communities than the late instars. Faith phylogenetic diversity was significantly different between *P. bombycina* and *L. monopetala* (p = 0.0256, F = 3.616) and no significant differences were observed with *L. salicifolia*. Taxonomic classification with IDTAXA against SILVA database revealed predominant community in the gut of muga silkworm were from *Methylobacterium-Methylorubrum, Tyzzerella, Sphingomonas*.

Keywords: silk moth; *Antheraea assamensis*, muga, silk, gut microbiome, diversity.

COMPARATIVE ANALYSIS OF WHOLE MITOCHONDRIAL GENOME OF ANTHERAEA SILKWORMS (LEPIDOPTERA: SATURNIIDAE)

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ABSTRACT

Antheraea mylitta popularly known as tasar silkworm is an economically important silk moth distributed in different geographical locations and habitats in tropical India. There are at least 44 identified eco-races which are morphologically and ethologically different in their primary food plant specificity. Tasar cocoons are reported to be the largest among all the silk-producing insects in the world. The complete mitogenomes are important resources for the phylogenomic studies as it provides alternative ways to resolve the phylogenies where rDNA-based methods would not be able to provide clear relationships among the closely related species. The present study decodes the complete mitochondrial genome of *A. mylitta* by utilizing the available whole genome sequence at the NCBI-SRA database and comparing it with the other available lepidopteran mitogenomes. The *A. mylitta* mitogenome is a circular double-stranded molecule of 15,354 bp (A+T content ~80.4%) typically found in insects. It contains 37 genes comprising of 13 protein-coding genes (PCG), 22 tRNA and 2 rRNA genes along with a 337bp long control region. *A. mylitta* shares similarity with a majority of lepidopterans particularly Saturniids in several characteristics such as genome organization and content, PCG size and structure, AT/GC skewness and tRNA structure. The phylogenic tree inferred from mitogenome of 16 different species suggests close relationships between *A. mylitta* and *A. frithi*. The comparative sequence homology of control region also showed higher similarity to *A. frithi* (95.0%) and lower similarity with distant organisms such as *Bombyx mori*. A highly conserved sequence block present in the control region of *A. mylitta* can be utilized as a marker for inferring species level molecular phylogeny along with other popular mitochondrial markers such as cytochrome oxidase subunit-1 and 16S rRNA genes.

Keywords: *Antheraea mylitta*, mitogenome, comparative genomics.

TRENDS IN NUCLEUS SEED COCOON PRESERVATION LOSS IN TROPICAL TASAR SILKWORM (*ANTHERAEA MYLITTA* D.) AND ITS IMPACT ON BASIC TASAR SILKWORM SEED PRODUCTION

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ABSTRACT

The Indian tropical tasar silkworm, *Antheraea mylitta* Drury (Lepidoptera: Saturniidae) is one of the commercially exploited non-mulberry silkworms for production of tasar silk, mostly in Central and North Indian States. It has a unique feature of pupal diapause so as to avoid unfavorable environmental conditions like harsh summer, non-availability of feed etc. Temperature, relative humidity and photoperiod regulate the diapause and onset of rains directly influences the emergence of tasar silk moth. The diapause period ranges from 6-7 months (210-225 days) from January to May (Trivoltine stock) and November to June (Bivoltine stock). During this long phase of pupal diapause, the nucleus seed cocoons are preserved in different types of grainage houses *viz.*, composite grainage/pucca grainage, mudwall grainage, tubular structure grainage and green shade net grainage house for seed production. Nucleus seed cocoons preserved during this period face extreme temperature ranging from 8-48°C and relative humidity of 30-85 % which directly effect on pupal development, in unseasonal and erratic moth emergence causing cocoon loss in varied proportions, besides loss due to infestation by yellow fly and uzi fly and damage by rats, squirrel and monkeys. In spite of selection pressure, nucleus seed cocoon preservation loss due to above factors directly impact the recovery of disease free laying (DFL) during basic seed grainage. In the present study, cocoon preservation loss in various Basic Seed Multiplication & Training Centres (BSM&TCs) of Central Silk Board during the period 2017-18 to 2021-22 due to various factors was studied in different tasar states. While overall nucleus seed cocoon preservation loss varied between 11.84% to 19.15% during the study period, it was maximum in the state of Andhra Pradesh (35.71%) and lowest in Bihar (7.17%). In the year 2021-22 preserved lot, average loss due to erratic emergence (EE) and pupal death (PD) throughout the units was 5.39% and 5.90% in BV lot whereas it was 5.59% and 3.81% in TV lot. Highest average loss due to respective parameter's was observed in Andhra Pradesh (BV lot- 2.60% EE, 54.75% PD and TV lot- 17.45% EE, 5.32% PD) which might be due to

uneven rain spells/cyclones and the lowest was recorded in Telangana (BV lot-3.69% EE, 4.72% PD and TV lot-0.67% EE, 0.5% PD) due to intervention of green shade net preservation technique. Further, better grainage performance with cocoon:dfl (4.6:1) was observed under green shade net grainage conditions, as they are closer to nature and the said model merits further promotion as ideal system of nucleus seed cocoon preservation for quality seed production. Also, technical management of abiotic and biotic factors besides adhering to brushing schedule improves crop performance, so as to minimize the preservation loss and maximize the tasar basic DFL production.

Keywords: Tropical tasar silkworm, pupa, diapause, grainage, preservation loss.

ANALYSIS OF GRAINAGE PERFORMANCE IN RELATION TO COCOON NUMBER IN TROPICAL TASAR SILKWORM

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ABSTRACT

DFL (disease-free-laying) production is an art and scientific approach of cocoon selection and their processing under grainage system. Mating behavior in relation to population density is prime factor to determine the reproductive behavior and recovery of dfls in tasar silkworm, *Antheraea mylitta* Drury (Lepidoptera: Saturniidae). The secondary data had maintained at Basic Tasar Silkworm Seed Organisation (BTSSO), Bilaspur on the number of cocoons processed and dfls prepared for the year 2016-17 to 2019-20 was used for regression analysis. Sample size for bivoltine (BV) 1st and 2nd grainages was 104 and 100 and number of cocoons ranged from 9900 to 598496 and 1113 to 770412, respectively. Similarly, Trivoltine (TV) 1st, 2nd and 3rd grainage sample size was 44, 35 and 49 and cocoon numbers ranged from 6400 to 211444, 3125 to 270520 and 8150 to 390830, respectively. Regression analysis output: ANOVA indicated that the cocoon processed and dfls recovery was statistically significant (Significance F was <0.05) in all the grainages (R^2 = 0.85 in 1st BV; R^2 = 0.70 in 1st TV; R^2 = 0.93 in 2nd BV; R^2 = 0.92 in 2nd TV and R^2 = 0.88 in 3rd TV). Residual plot analysis revealed that there was a linear relationship between cocoon number and dfls recovery, where increase in cocoon numbers was reflected in a reduction in Cocoon:DFLs ratio in all the grainages. Higher the cocoon numbers may helps in maintenance of favorable sex ratio throughout the grainage period and ultimately ensures recovery of gravid moths (fit for DFL production) during grainage process. The linear regression equation derived for 1st BV, 1st TV, 2nd BV, 2nd TV and 3rd TV was y=0.277*x-7110.44, y=0.269*x-2056.64, y=0.296*x-5011.21, y= 0.32*x+39.48 and y= 0.28x -156.07, respectively. The respective race and crop wise equations may be used for real time quantification of dfls recovery from the cocoons processed under the grainage.

Keywords: *Antheraea mylitta*, bivoltine, cocoon:DFLs ratio, sex ratio, trivoltine.

DE NOVO GENOME SEQUENCING AND COMPARATIVE GENOMICS OF TASAR SILKWORM *ANTHERAEA MYLITTA* REVEALED CONSTRUCTIVE INFORMATION

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ABSTRACT

Tasar silkworm *Antheraea mylitta* is economically important sericigenous insect. In the present study *de novo* whole genome sequencing and comparative genomics linked rigorous swot has been performed to utilise this information in future breeding programme. As the Daba ecorace is most commercialized ecotypes for tasar silk production, therefore, it was selected as the donor of genomic DNA. Outline of the *de novo* whole genome sequencing using hybrid platform (Illumina & PacBio) revealed following key information: Assembled Genome Size-707,757,747 bps. Genome Coverage-184.6 X; Total Scaffolds- 20,891 N50 Scaffolds- 5,182,261bps Total contig- 33,698 N50 contig- 136,984 bps Finished Genome- 97.50%. Subsequently, top hits of BLAST search (evalue 1e-5) between *A. mylitta* and *A. yamamai* was also conducted. The 86.27% (22,039/25,544) of *A. mylitta* proteins resembled with *A. yamamai*. Transcriptomics analysis of silk gland and ovary of *A. mylitta* has been also conducted which revealed gene expression pattern linked to silk gland development and egg production. Comparative genome mapping (*A. mylitta among A. yamamai* and *B. mori*) results indicated that *A. mylitta* is more closely related to *A. yamamai.* The whole genome sequencing of *A. mylitta* using Illumina and PacBio sequencing platform will help to study the molecular basis of different qualitative and quantitative traits of *A. mylitta*. In addition, researchers can use this sequence as a reference genome to identify the locations of genes, coding regions of genome to determine the function of various genes and its prospective utility in breeding programme. Unravelling of genes responsible for productive traits of tasar silkworm *A. mylitta* using functional genomics approach will provide detailed information to focus on tasar silkworm productivity enhancement in future.

Keywords: *Antheraea mylitta,* breeding programme, Tasar silk, genome sequencing.

IMPACT OF CONSUMPTION OF TASAR HOST PLANT LEAVES OF DIFFERENT STATUS ON THE VOLTINISM OF *ANTHERAEA MYLITTA D*

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ABSTRACT

The growth and development of the silkworm and economic characters of cocoons produced by them are greatly influenced by the nutrient content of the leaves. Lower the voltinism more is the silk content in cocoon shell. Both, racial character and survival percentage are influenced by type of food consumed by tasar silkworm larva. The nutrient content of leaves to which tasar silkworm larva consumes as food is one of the contributing factors in influencing its voltinism. An investigation was carried out to know the effect of consumption of leaves of primary tasar host plants of varied status by tasar silkworm *Antheraea mylitta* on its voltinism. An endemic wild eco-race Sarihan of Santhal Paragana of Jharkhand and Jamui district of Bihar which lies between latitude of 24º 30′ 00″ N to 24º 55′ 12″ N and longitude of 86º 13′ 12″ E to 87º 30′ 00″ E was studied for leaves of its host plants and voltinism. Major and micro nutrient contents in leaf of primary tasar host plant, *Shorea robusta*, *Terminalia arjuna* and *Terminalia tomentosa* were estimated for N by using Kel –plus nitrogen estimation system and P, K, Cu, Fe, Mn and Zn by di- acid digestion method using flame photometer, spectrophotometer and atomic absorption spectrophotometer respectively. On the basis of chemical analysis of leaf samples of different status and different primary tasar host plants, it was inferred that survivability and voltinism of this eco-races of tasar depends on the suitable range of nutrient content in leaf consumed by the silkworm. Higher content of N, Fe Mn and Zn in host plant leaves were found supportive for less voltinism and more silk content.

Keywords: voltinism**,** nutrient content, *Shorea robusta, Terminalia arjuna*, *Terminalia tomentosa*.

ERI SILKWORM REARING FOR ADDRESSING YOUTH UNEMPLOYMENT AND RURAL DEVELOPMENT: LESSONS FROM ETHIOPIA

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ABSTRACT

We report on lessons learnt in the implementation and adaptive management of a commercial sericulture development project in Ethiopia. To support the government's efforts in tackling the youth unemployment challenge, the International Centre of Insect Physiology and Ecology *(icipe)*, in partnership with the Mastercard Foundation (MCF), implemented the Young Entrepreneurs in Silk and Honey (YESH) project between 2016 and 2021. The partnership set out to create job opportunities for 2,500 youth (65% young women) by establishing sericulture farming businesses, providing holistic sericulture and entrepreneurship training, and linking youth to financial and market service providers. The beneficiary youth were recruited based on interest, education, age and gender criteria. Sericulture business starter kits were then provided, followed by guidance to start complementary side-line income generating activities, such as vegetable farming, multipurpose tree nurseries, value addition to primary products, and marketing. Progress monitoring surveys and independent mid-term as well as endline evaluations of the project revealed that, apart from skills and knowledge gained during targeted training workshops, local availability of Eri silkworm seed, reliable supplies of feed (castor leaves), timely delivery of micro-finance services and availability of alternative market outlets for cocoons were noted as essential for business success of the youth enterprises, and for sustaining interest of the beneficiary youth in this new venture. Establishment of local cocoon collection and drying facilities (electric ovens) was hampered by inadequate access to electric power supply. Weak economic activity was associated with limitations in group cohesion, as social loafing discouraged collective efforts. On the other hand, individual businesses established in private backyards, especially by experienced women silkworm rearing farmers, proved more productive than that of group enterprises.

The final project evaluation also revealed that over 85% of youth partners take pride in what they do in their enterprises; believe the project provided them with the opportunity

for dignified work; and felt their job in their enterprise offers them decent working conditions. Around 55% of direct beneficiary youths believed that the silk production business created decent economic opportunities for them and their families. As a result, the sub-sector has become a source of income and livelihoods support to the rural youths and their families. The average annual income of targeted youths has grown dramatically from the baseline. Likewise, common household item ownership of youths and their families increased by 82% as compared to the baseline. Livestock ownership by youth partners and their families increased by 47% from baseline indicating that silk farming has increased asset ownership by the targeted young men and women. The proportion of youths with advanced silkworm management skills (basic and advanced skills) also grew from zero at baseline to 78% at end-line indicating that youths have developed the skills needed to manage silkworm rearing and silk production activities effectively. The skill and knowledge gained by the youth partners has laid foundations to changing of the livelihood of people in their villages.

In conclusion, silk farming has created dignified and fulfilling job opportunities and helped youth and their households to increase their income and improve their livelihood. Youth households were also able to diversify their sources of livelihood, which used to be largely dependent on crop production. Indeed, many youth households in the project intervention sites have made silkworm rearing as their primary source of livelihood.

These lessons informed design of its scale-up in the More Young Entrepreneurs in Silk and Honey (MOYESH) programme across four regional states in the country where diverse and suitable agro-ecologies favors the promotion of Mulberry silkworm (*Bombyx mori*) and Eri silkworm (*Samia cynthia ricini*) production, although all the current smallholder silk production in the country utilizes Eri silkworms.

Currently, International Centre of Insect Physiology and Ecology (*icipe*) is playing a central role in sericulture development in Africa including Ethiopia.

Keywords: Ethiopia, Eri silkworm, sericulture, rural development, youth unemployment

EVALUATION OF ANTIFEEDANT PROPERTIES OF INDIGENOUS BOTANICAL EXTRACTS AGAINST PREDATORY BUGS OF TASAR SILKWORM *ANTHERAEA MYLITTA* (D)

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Tasar silk is produced by the wild silkworms *Antheraea mylitta* (Lepidoptera: Saturniidae) and are being semi-domesticated and are reared outdoor. Due to outdoor rearing tasarsilkworms are subjected to severe attack by predators, parasitoides and diseases that reduce total silk production. Among the predators two species of predatory bugs stink bug (*Eucanthecona furcellata*) and reduviid bug (*Sycanus collaris*) are major constraints for silkworm rearing and known to cause severe damage to tasar silkworms with estimated crop loss of 20-40%. Contrastingly they are beneficial in agriculture and forest ecosystem as they predate on crop pests. With this background in the present study we tried to explore the antifeedant effect of indigenous botanical extracts against these two important predators of tasar silkworm. In the study solvent extracts of six botanicals including Eucalyptus, Neem, Lantana, Agava, Lemon grass and *Vitex negundo* were screened for their antifeedant potential against predatory bugs of tasar silkworm. Solvent extracts namely hexane and methanol of all six botanicals were tested using filter paper no-choice assay method. Bioassay results of stink bug revealed that among the methanol extracts eucalyptus found superior by recording low larval consumption of 28.00% with highest time taken (59.20 mins) to initiate the feeding. Next better extract was lantana with 48.00% larval consumption and time taken to initiate the feeding was 56.20 mins. Apart from these two extracts remaining extracts found less effective by recording comparatively higher larval consumption. However some of the treatments like lemon grass (57.80 mins) and neem seed (51.60 mins) extracts recorded more time to initiate the feeding but they found least effective after certain time period. Among the hexane extracts none of the extracts found effective, though eucalyptus extract found moderately effective by recording 48% larval consumption with 27.80 mins to initiate the feeding. Apart from this neem (60.00 mins) and agava (50.00 mins) recorded more time to initiate the feeding but when larval consumption is considered they found less effective.

Similar experimentation was also carried out against reduviid bug and it has been observed that neem seed extract found effective in both hexane and methanol solvents with 20% and 30% larval consumption respectively. Time taken to initiate the feeding (62.00 mins) was also high among all the extracts. Except neem seed extracts all other extracts both in methanol and hexane solvents found moderate to least effective with more larval consumption and less time taken to initiate the feeding. Our study provides empirical data on scope of using botanical extracts for non-destructive method of predator's management in tasar sericulture.

WILD SILKS TRACES IN EUROPE: CIRCULATIONS, USAGES AND ACCLIMATIONS FROM ANTIQUITY TO THE PRESENT DAY

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ABSTRACT

Archaeological finds show a long-lasting use in Human industries and activities of various species belonging primarily to the Saturniidae family but also to the Lasiocampidae and Notodontidae families, i.e. species qualified as 'wild' by silk specialists. While Asia – notably China, India, Japan, Thailand, and Korea – is well known for its wild silk moths industries, Europe seems less resourceful from this perspective. Nevertheless, from the Roman Period, it proves to have been a steady destination for wild silks textiles and fibres made in Asia, and much later a hub for acclimation attempts. In this poster, we shall review some samples gathered from a selected bibliography or studied by our project, WILDSILKS, MATERIAL & CULTURE, focusing on the longue durée – since Antiquity to the present day. We aim to highlight the main issues these samples raise for the history and anthropology of silks in Europe besides the prevalent *Bombyx mori* L.

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MOLECULAR LANDSCAPE OF *ANTHERAEA PROYLEI* NUCLEOPOLYHEDROVIRUS (ANPRNPV) INFECTING OAK TASAR SILKWORM

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ABSTRACT

Temperate oak tasar silkworm *Antheraea proylei* are frequently infested by tiger band disease caused by *A. proylei* nucleopolyhedrovirus (AnprNPV). The disease is characterised by dark tiger- like strips across the body of the silkworm, causing an increased mortality and yielding to poor seed cocoon recovery. Transmission electron micrographs of AnprNPV showed single rod-shaped and circular occlusion derived virus (ODV). The virus displays a higher copy number in the fat body tissue and is also able to spread and multiply in various development stages such as egg, larvae, pupa and moth of infected *A. proylei silkworm*. . Cross-infectivity studies of the AnprNPV among the silkworm species (*Antheraea pernyi*, *A. frithi*, *Samia ricini*) and other lepidopteran insects (*Phalera raya*, *Hablaea peura, Pieris canidia*and *P. brassicae*) showed the host range of this virus which was restricted to the silkworm clade. The virus follows a transovum vertical transmission route where the hatched larvae laid by the infected mother moths were found to contain virus. The surface of eggs is identified to be the potential source of infection since, the poorly washed eggs displayed the presence of virus on the outer surface whereas was absent in the inner contents of the surface washed eggs. Hence a surface disinfection method with 0.2% sodium hypochlorite has been devised from this study that can prevent the occurrence and spread of this virus. Similarly, a PCR as well as a qRT- PCR method has been developed for detection of the virus during early stages of infection in *A. proylei* silkworms.

Keywords: viral disease, oak silkworm, vertical transmission, egg surface, disinfection

SECTION 4:

BACOLOGY OF SILKWORMS / SILKWORMS IN RESEARCH

Domaine

Silkworms as a biological model, genetics, physiology, biochemistry, genetic-engineering, molecular biology, developmental biology, and genomics

Chairperson

Dr. Shuichiro TOMITA

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1990. 10. National Institute of Sericultural and Entomological Sciences (NISES)
2000. 6. Department of Zoology, University of Washington, Seattle, WA
2002. 9. National Institute of Agrobiological Sciences (NIAS)
2016. 4. Leader, Silk Research Unit, Institute of Agrobiological Sciences (NIAS), National Agriculture and Food Research Organization (NARO)
2019. 4. Professor, University of Tsukuba (concurrent appointment)
2021. 4. Leader, Silkworm Research Group, NIAS NARO

Research Interest:

Embryonic and post embryonic development of the silkworm, *Bombyx mori*, especially in evolutionary context. I've been focusing on development and evolution of abdominal prolegs in Lepidoptera in comparison with other orders that also develop larval prolegs such as Hymenoptera and Mecoptera. Although it has long been believed that abdominal prolegs are homologous to thoracic legs (true legs), apparent morphological differences suggest they are not equivalent and I'm trying to understand how lepidopteran prolegs has been evolved by revealing underlying molecular mechanisms for proleg development and disappearance.

Recent research project:

During 2014-2019 I have been acted as the leader of two national projects to develop risk assessment and rearing practice of transgenic silkworms and processing technologies for recombinant cocoons and silks. At the end, these projects enabled commercial rearing of a transgenic silkworm race in sericultural farms for the first time in the world in Japan. Currently three transgenic races are available for sericultural farms.

LEAD PAPER:

GENOME-WIDE ASSOCIATION MAPPING FOR ECONOMIC TRAITS OF SILKWORM, *BOMBYX MORI* L.,

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In silkworm, most of the economically important traits are quantitative in nature and therefore it is difficult to study due to the complex nature of their inheritance. The MAS methods could promote breeding result, but a molecular genetic map or a QTL map was necessary for construction in silkworm for improvement programme.To support these programs, genome-wide genetic markers are required. In this context, SNP markers are now the markers of choice and it has been the most useful molecular marker in genome mapping, association studies and diversity analysis because of their abundance and automated high-throughput genotyping, and the most cost effective genetic markers currently available.

Though, QTLs governing the trait by linkage analysis has been quite useful, but QTLs identified are not effective across diverse genetic background. Alternatively, association genetics studies are becoming an important methodology to identify QTLs and to find molecular markers associated with complex traits. Association mapping seeks to identify specific functional variants (loci, alleles) linked to phenotypic differences in a trait to facilitate detection of trait causing DNA sequence polymorphisms and selection of genotypes that closely resemble the phenotype. Further till now no comprehensive attempt has been made to genotype rich diversity of Indian silkworm breeds in such a way to identify each of them. NGS technologies have made it easier to develop methodologies to generate SNPs that can identify strains and can be used to select contrasting parents in breeding programs.

This study aimed to detect SNP variation in diverse set of silkworm breeds (including indigenous, exotic, elite and commercially exploited) by Genotyping by sequencing (GBS). The SNP information would enable for association or linkage analysis of traits of commercial interest in silkworm and to identify QTLs that are associated with traits of commercial interest thereby use in silkworm improvement programme.

Accordingly 100 diverse silkworm genotypes (60 bivoltine & 40 multivoltine), were subjected for phenotyping for five-qualitative traits and ten-quantitative traits.. Data thus obtained were subjected to ANOVA, frequency distribution and hierarchical clustering. Analysis of variance revealed significant variation among the genotypes for the characters studied. Pupation (survival) ranged from 55 - 97%, cocoon weight (0.850 - 1.752g), shell weight (0.099 - 0.389g), thermotolerance (10 - 87%), NPV tolerance (6 - 80%), filament length (252 - 863m), reelability (70 - 88%), raw silk (7 - 13%), neatness (75 -90) and evenness (70 – 85) were observed among the genotypes signifying the wide variability**,**

Further the genotypes were genotyped using genotyping-by-sequencing (GBS) and sequencing results revealed a total of 266915 SNPs with 865 indels, 2826 alleles with multiallelic sites whereas 1964 were with multiallelic SNP sites. After filtering for a minimum read depth of five, and minor allele frequency of 0.05, 23,254 high quality SNPs were selected to determine marker-trait associations (MTA). Linkage Disequilibrium (LD) analysis revealed LD decay to be seen at around 0.45 Mb genetic distance for the dataset.

Trait specific QTLs are identified and are positioned in different chromosomes. QTL for survival character was observed in 4 chromosomes (no. 17,16,10,24), Yield (wt), in 6 chromosomes (3,1,4,10,7,18), cocoon weight in 7 chromosomes (10,4,1,9,17,22), shell weight in 3 chromosomes (10,17,19), thermo tolerance in 5 chromosoes (7, 8,2,22,27), filament length in 5 chromosomes (7,13,16,17,19), reelability in 5 chromosomes (2,7,11,17,19) and evenness was observed in chromosome numbers 9,10,1,12,17. Further significant marker trait association was identified few important characters such as shell weight (WC-051360.1), cocoon weight (NW-021618427.1), filament length (NW-023678039.1), yield/10000 larvae (Wt-kg) (WC-051360.1) and thermo-tolerance (WC-051365.1).

This study helped to identify SNP markers (QTLs) associated with important traits in silkworm, *Bombyx mori* that have potential for marker-assisted selection towards silkworm crop improvement.

TRANSCRIPTOME ANALYSIS OF SILKWORM, *BOMBYX MORI*, DURING BMDNV1, BMIFV AND BMNPV INFECTION

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ABSTRACT

Bombyx mori Densonucleosis virus (BmDNV1), Bombyx mori Infectious flacherie virus (BmIFV) and Bombyx mori nuclear polyhedrosis virus (BmNPV) infection to silkworms causes major sericulture crop loss. Silkworm tolerant to BmNPV and BmIFV are controlled by multi-genes. Major dominant genes and minor effector genes responsible for diseases tolerance towards BmNPV and BmIFV still largely remains unknown. To identify the major dominant and minor effector genes that control resistance towards BmNPV and BmIFV, PAM117 breed were reared and inoculated individually with BmDNV1, BmIFV and BmNPV inoculums at 10-2, 2x106, 10-2 respectively, immediately after second moult. The midgut samples of 3rd day 5th age silkworm larvae were collected, pooled and subjected to mRNA Transcriptome. Uninoculated PAM117 silkworms were considered as control. Sequencing were performed on illumina sequencer and resulted in 7.0, 8.7, 9.5 and 6.0 Gb raw data for Control, DNV1, IFV and NPV infected samples, respectively. Read mapping to the reference Bombyx mori genome resulted in 89.5%, 90.4%, and 84.5% overall alignment rate for Control, DNV1, IFV and NPV infected samples, respectively. The gene expression quantification analysis yielded 52.2%, 46.6%, 46,1% assigned sequences. 527 genes upregulated and 3815 genes were downregulated for DNV1 inoculated sample, whereas 720 genes upregulated and 1468 genes were downregulated for IFV inoculated sample. Gene expression data showed significant upregulation of Toll and IMD pathway and downregulation of Endocytosis and Hippo pathway for DNV1 inoculated sample, whereas DNA replication pathway was upregulated and Toll and IMD pathway was downregulated for IFV inoculated sample.

Keywords: Bombyx mori, Densonucleosis virus, Infectious flacherie virus, Nuclear polyhedrosis virus, Transcriptome, Toll and IMD pathway

EXPRESSION PROFILING OF TRP GENES FOR DETERMINATION OF THERMO SENSITIVITY AND HUMIDITY TOLERANCE IN SILKWORM, *BOMBYX MORI* L.

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ABSTRACT

The challenges of facing rise in temperature and humidity is inevitable for insects and other animals as growing climate change effects pose an imminent survival threats. Insects have an exceptional sensory system, which helps adaptation to fluctuating temperatures from summer heat to winter cold. Molecular players such as heat shock proteins (hsps) have long been studied extensively in silkworm, but they are not the only ones which play major role. To understand the internal nature and rhythm of insects, genes involved in abiotic stress association were studied in the present investigation; particularly the role of Transient Receptor Potential (TRP) channel genes viz.,pyrexia, painless, time and period. Fifth instar silkworm larvae exposed to high temperature and high humidity at simulated conditions (36°C & 85% RH) were collected and the control silkworms were reared at optimum temperature. DNA was isolated to identify variants in TRP genes and RNA expression profiling from brain tissues from day 3 to spinning were established. SNPs in pyrexia gene were identified revealing up-regulation in 5th instar larvae. The upregulation of TRP genes possibly aids the silkworm to withstand high abiotic stress at late larval stages. It is hypothesized that TRP genes play a major role in perceiving heat and humidity sensation and also might other abiotic factors. These genes could be used as molecular biomarker for utilization in marker-assisted silkworm breeding programmes for abiotic stress tolerance in mulberry silkworms.

Keywords: Transient receptor potential, Bombyx mori, abiotic stress, pyrexia, SNP, expression profile

GENETIC STRATEGIES FOR THE DEVELOPMENT OF HERMOTOLERANT BIVOLTINE SILKWORM BREEDS OF *BOMBYX MORI* L.

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ABSTRACT

The tropical climate in India is suitable for sericulture however has its effects during summer season and at higher temperature leads to crop losses especially among the bivoltines. Under such circumstances, it is important to develop the thermal tolerance in some of the better performing silkworm varieties. To assess thermal tolerance, an experimental scheme for breeding and transcriptomic analysis was designed with a temperature of 34 ± 1ºC and relative humidity of 50 ± 5 % from brushing to spinning for analysis of specific heat shock proteins (HSPs), in identifying potential bivoltine silkworm strains specific for thermotolerance, a total number of 14 bivoltine breeds, APS12, APS50, APS8, APJ1, APJ2, APDR105, APS45, APS27, AC9, AP71, APS9, HTO5, HTO2 and HTP5 with diverse genetic makeup from the Germplasm Bank of Andhra Pradesh State Sericulture Research and Development Institute. Based on different parameter such as, the survival rate, larval weight, cocoon yield by number and weight, pupation, single Cocoon shell weight and shell ratio, the eight bivoltine strains APS50, HTP5, APS45, APS27, AC9, APDR105, APS9 and HTO2 were identified to be potential for thermo-tolerance.

RNA-seq analysis was performed on these breeds to study differentially expressed genes which showed up and down regulation was mapped for heat shock proteins with respect to the identified breeds. A total of 10 heat shock proteins 20.8, 70kDa cognate 5 like, 25.4, 19.9, 70A1, 21.4, 90kDa, 1, 70 kDa protein cognate, 12.2 and its variation across the breeds. The expression pattern of the Heat shock proteins among the breeds and their correlation with negative and positive fold change values were examined. The potential breeds which have thermal tolerance were recognized using the above study. Thus, APS9, HTO2, APS45 and APDR105 ranked the best for thermotolerance from the analysis of heat shock protein data as well as transcriptomic expression data.

Key words: Bombyx mori L., Thermo-tolerance, Heat shock proteins, transcriptomics.

EXPLORATION OF ROLE OF POLYAMINES IN GROWTH AND DEVELOPMENT OF *BOMBYX MORI*

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ABSTRACT

Sericulture industry is an integral part of Indian economy. An understanding of the molecules that regulate Bombyx mori development is important in producing quality silk. Polyamines are essential for survival of all living organisms. They play important roles in growth and development. Exogenous feeding of polyamine, spermidine enhanced silk production, improved silk quality and helped in growth of the larvae. Spermidine feeding changed the profile of gut microbiome and resulted in increase of beneficial bacteria. Feeding of larvae with difluoromethyl ornithine monohydrochloride (DFMO), an inhibitor of ornithine decarboxylase activity led to significant reduction of putrescine and spermidine levels with many developmental defects at the pupal and moth stages. At cellular level, reduced polyamine levels led to increased oxidative stress, decreased cell viability and significant drop in nutritional efficiency. Results of the above studies showed polyamines as key regulators of the development of Bombyx mori.

Key Words: Polyamines, Bombyx mori, Development, Spermidine

MOLECULAR MARKERS FROM PHILIPPINE-REARED *BOMBYX MORI* L. THROUGH GENOTYPING BY SEQUENCING (GBS)

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ABSTRACT

Bombyx mori silkworm is an economically important insect because of the silk it produces. Several silkworm strains were introduced to the Philippines as F1 hybrids decades ago from Japan, Korea and other silk-producing countries. From these hybrids, parental pure lines were established through backcrossing, segregation, and selection until uniformity of the desired traits was achieved.

Philippine-reared silkworms have diverse characteristics as observed from their eggs, larval markings, cocoon quality, and moths. The study collected silkworm larvae from three (3) sericulture facilities across the Philippines, specifically in Benguet, La Union, and Misamis Oriental. These samples were then subjected to genotyping by sequencing (GBS), a method that utilizes restriction enzymes to reduce genome complexity for the identification of single nucleotide polymorphisms (SNPs). These SNPs can be utilized as molecular markers for the identification and differentiation of the Philippine-reared silkworm strains included in the study.

Genomic DNA was extracted from silkworm larvae for library preparation, which involved restriction enzyme digestion and addition of barcode adapters. Next generation sequencing was then conducted using the Illumina NextSeq 500. The resulting sequences were then processed and analyzed following the GB-Easy pipeline to identify SNPs present in each strain. Results showed that DMMMSU A had the highest number of strain-specific loci (6,923) while strain B251 had the lowest (1,618). Identified SNPs

were located across the genome, such as in genes involved in metabolism, development, cell transport, and silk production. Subsequent validation of the presence of these SNPs is being conducted in additional silkworm individuals through the amplification and sequencing of regions where the SNPs are located. This is to confirm whether the SNPs are present across a larger population of individuals belonging to the corresponding silkworm strains.

SECTION 5:

POST-COCOON TECHNOLOGY

Domaine

Reeling, cocoon preservation, silk quality, gradation, weaving, products diversification.

Chairperson

Dr. Sukanya Chumchuen

MEET THE CHAIRPERSON

DR. SUKUNYA CHUMCHUEN

EXPERIENCE

2011- present: Working on sericulture production

EDUCATION

Bachelor of Science:
Ramkhumheng University, 2014 Thailand.

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LEAD PAPER:

DEVELOPMENT OF SILK YOGA MATS FORM RECYCLED SILK YARN AND THEIR EVALUATION

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ABSTRACT

Yoga is a means to relax mind and body and connect back to nature. While yoga is gaining popularity, yoga mats made of natural materials are disappearing from the market due to influx of cheaper synthetic mats. Synthetic mats create a physical barrier between man and nature, diluting the very purpose of yoga. They often have poor durability and are disposed off creating an environmental hazard, as they do not biodegrade within a reasonable time. Hence, the need for yoga mats made from natural materials like cotton, jute, hemp, straw and silk. Amongst the natural materials, silk is unique because it is a protein fibre and most compatible with the skin. It is soft, smooth and hygroscopic. However, silk is scarce and expensive and a yoga mat made of silk would be a luxury item, unaffordable to the common man. Hence, we made yoga mats from 500 Tex recycled silk yarn developed recently from discarded silk material waste and selvedge waste. The yarn was coloured using natural dyes. The mats were woven on handlooms with cotton yarn in the warp and recycled silk yarn in the weft, with different constructions. Ten desirable characteristics for yoga mats were identified and the mats were evaluated for compliance. Laboratory tests were supported by actual field trials. The quality was compared vis-à-vis 100% cotton yoga mat of the same construction and also non-woven (needle punched) yoga mat made from silk waste. The many advantages of recycled silk yoga mats, including promoting the concept of recycling, are discussed in detail.

Introduction:

Yoga and meditation were practiced even in the early stages of civilization in India. Ancient yogis practiced directly on the ground, on raised platforms or on animal skin especially deer skin. Tiger skin was mostly used by Royal families for meditation. Animal skin provides the warmth needed for the energy to raise up. It also protects from cold. When animal skins were no longer available, woollen mats (Kamblis produced locally by the shepherd community), handmade / hand woven mats of cotton,

jute, straw, coir etc., sourced locally became popular. These eco-friendly accessories were produced using sustainable materials and methods. However, of late these natural products are slowly disappearing from the market due to influx of cheaper imported synthetic mats made from foam, PVC, PVU, etc., which usually contain harmful ingredient such as phthalates. They use up huge amounts of energy during their manufacturing process. When disposed off they have virtually zero biodegradability. They generate highly toxic substances if burnt and thus become highly hazardous to the environment. Synthetic mats create a physical barrier between man and nature, diluting the very purpose of yoga. They are non-absorbent and tend to become slippery when wet with sweat. Sweaty mats breed microorganisms and soil easily. Hence, it if a necessity to go back to locally made natural fibre yoga mats which are good for the ecology as well as economy. Amongst the natural materials, silk is unique because it is a protein fibre and most compatible with the skin (anti-allergic/ skin friendly). It's hygroscopicity makes it absorbent and regulate body temperature. The hydrophilicity of silk fibres makes it absorbent. The smooth surface contour of silk filaments make it easy to clean as dust/dirt will be released easily when vacuumed or washed in water. Thus silk is an ideal natural material for yoga mats. However, reeled silk is scarce and expensive and usually reserved for luxury items. Hence yoga mats were made from silk waste by the needle punch technique. These mats did not provide the necessary grip while performing yoga involving movement of the feet. Also, virgin silk waste is also expensive. Therefore, we developed coarse recycled silk yarn from discarded silk material waste and selvedge waste and used it as weft to weave yoga mats with cotton warp. The details are discussed in the following paragraphs.

Recycled silk yarn making process:

India is the largest consumer of silk in the world and 70 to 80% of the silk is used for making *sarees* and *dothis*, the traditional garments. Each year a sizeable amount of silk fabrics is discarded as waste. The discarded material is collected and segregated according to utility and colour. The material meant for making recycled yarn is cut into strips of about 6 cm and any non-silk material is removed manually. It is then subjected to wash treatment in which it is boiled in a liquor containing soap and a discharging agent. The discharged silk waste material is passed through an opening machine which has a spiked roller, to tear open the fabric and separate out the interwoven yarns. Three to four runs are necessary for maximum individualization of the fibres. The process is depicted briefly in Figure 1.

Fig.1. Conversion of fabric to fibre- in brief

The tensile strength and elongation of the recovered fibres is very low and hence it was mixed with fibres recovered from selvedge waste (weaving waste) in the ratio 50:50. The characteristics of the recovered silk fibres is shown in Table 1.

Table 1. Characteristics of silk fibres extracted from discarded material and selvedge waste

#	Test parameter	Unit	Discarded material	Selvedge waste
1	Fibre bundle strength (IS 3675 :1966)	gf/tex	25.5	43.4
2	Elongation (IS 3675 :1966)	%	10	20
3	Fibre length (ASTM D5103 - 07(2018))	cm	6.2	4.7
4	Range (ASTM D5103 - 07(2018))	cm	1.5 to 12	3.5 to 5.5
5	Purity (AATCC-20A-2018)	%	99	99
6	Whiteness Index (Datacolor-650)	CIE	20	30
7	Yellowness Index (Datacolor-650)	CIE	18	10

The SEM image of fibres (Fig. 2) recovered from discarded material show fibrillation (splitting of the fibre, which can result in a dull appearance and impair tensile properties of the fibre.

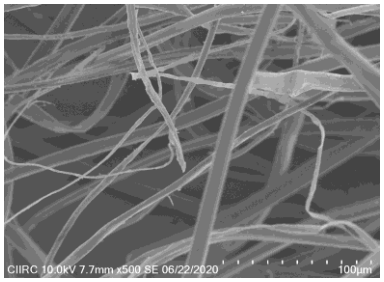

Figure 2. SEM image of silk fibres recovered from discarded silk material

A minimal processing sequence was used for spinning the yarn which included opening, web formation, carding, doubling and roving followed by hank winding and bundling. The process of spinning the yarn is depicted briefly in Figure 3.

Fig.3. Spinning process of recycled silk yarn

The characteristics of the yarn were evaluated and shown in Table 2.

Table 2. Characteristics of recycled silk yarn

Characteristics	Test method	Results
Purity (% Silk)	AATCC-20A-2018	98
Linear density (Tex)	ASTM D 1907:2012R	540
CV (%)		13.9
Twist (TPM)	IS 832 (Part 2):2011 / ISO 17202 : 2002	118
CV (%)		5.4
Breaking load (kg)	IS 1670:1991: 2017R	5.97
CV (%)		9.8
Tenacity (g/den)		1.19
Elongation (%)		8.8
CV (%)		8.9
Whiteness Index	CIE measured on Data Colour 650 Spectrophotometer	23.6
Yellowness Index		14.8

The recycled silk yarn is dull, coarse and slubby, it is weaker and less elastic compared to similar yarns made from virgin silk fibres. On the other hand, they are very soft and suitable for weaving on handlooms, as weft. They are the least expensive pure silk yarns in the market.

Development of yoga mats:

Non-woven yoga mats were initially developed from silk waste by needle punch technique. (Figure 4). They were dyed using safe and fast colours, cut to required dimensions and steam pressed. These mats were not suitable for performing yoga that involved movement as it did not provide the necessary grip to the feet. Also, the mats shed loose fibres easily.

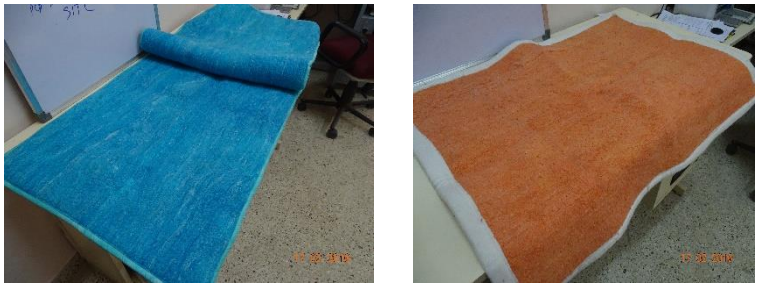

Fig. 4 Non-woven yoga and meditation mats developed from silk waste

Hence it was decided to develop woven yoga mats from recycled silk yarn, The interlacing of the warp and weft yarns in plain woven structures gives the fabric a grainy

surface, which can provide necessary grip. Moreover, the recycled silk yarn is not smooth as the virgin spun silk /reeled silk yarn.

The recycled silk yarn was dyed with safe dyes including natural dyes – madder and pomegranate. Pirn winding was done on a simple hand operated appliance. Weaving was carried out on pit loom using cotton warp. The weaving process is depicted briefly in Figure 5.

Fig.5. Weaning and testing the yoga mats

Two variants in construction were tried .viz., two ply weft and single weft. The construction particulars are given in Table 3. They are compared with a cotton yoga mat of same construction woven on the same loom.

Table 3. Construction particulars of yoga mats.

	Particulars	**Cotton X Cotton**	**Cotton X Silk (2 ply)**	**Cotton X Silk (single)**
1	Weight (kg)	1.2	1.3	1.3
2	Length (m)	1.8	1.9	1.9
3	Width (m)	0.76	0.74	0.74
4	Fabric mass (g/m^2)	850	922	906
5	Warp threads per dm (3as1)	32	32	32
6	Weft threads per dm (2as1)	85-105	44-54	92-96

7	Warp count (Ne)	2/8.2s	2/8.9s	2/8.5
8	Weft count (Ne)	1.54	1.18	1.18
9	Weight of Warp (%)	14.3	14.2	15.0
10	Weight of Weft (%)	85.7	85.8	85.0

Compared to two plies in the weft, the mats woven with a single ply appeared more uniform and neater. Hence it was decided to weave the yoga mats with single ply yarn only, though the time and effort required to weave two plies are less compared to single ply.

The yoga mats were woven as per the above particulars and evaluated for some of the performance characteristics. The results are at Table 4.

. **Table 4. Performance characteristics of yoga mats.**

	Particulars	**Units**	**Cotton X Cotton**	**Cotton X Silk)**
1	**Tensile strength (ISO 13934-1 : 1999)**			
i)	Breaking load -Warp	kg	36.1	40
ii)	Elongation -Warp	%	8.35	10.6
iii)	Breaking load-Weft	kg	110	132.9
iv)	Elongation -Weft	%	35.5	28.5
2	**Dimensional strability (IS 3561:1989)**			
i)	Shrinkage -Warp	%	0	1.53
ii)	Shrinkage - Weft	%	2	2
3	**Compressability (BS 4098: 2009)**			
i)	Mean thickness	mm	2.4	2.5
ii)	Avg. thickness recovery	%	85	86
iii)	Avg. compression recovery	%	56.7	55.3
4	**Thickness loss after dynamic loading (BS/ISO 2094: 1999)**			
i)	TL after 50 cycles (%)	%	81.9	88.4
ii)	TL after 100 cycles(%)	%	78.4	84.4
iii)	TL after 200 cycles(%)	%	75.8	81.2
iv)	TL after 1000 cycles(%)	%	70.3	73.2
5	**Wear and Abrasion Resistance test (IWS-TM-283)**			
i)	Rate of weight loss /1000 cycles	mg	**20.72**	25.8
6	**Flammability BS 4790:1987 Method 1 (Hot metal nut method)**			
i)	Greatest radius of affected area	mm	35	20
ii)	Flame extinction time	s	40	27
iii)	Duration of afterglow	s	9	8

It may be noted from the above table that the silk yoga mats are better in some characteristics like strength, flammability and thickness recovery whereas cotton mats are slightly better in case of thickness loss after dynamic loading.

Subjective evaluation of recycled silk yoga mats:

Five yoga mats were evaluated at Swamy Vivekananda Yoga Anusandhana Samsthana (S-VYASA) at Anekal, deemed to be University. Yoga Guru and the students performed yoga on these mats for a period of 3 weeks. Their feedback on the yoga mats is as below:

1. The yoga mats are very light and easy to carry, spread, fold and store.
2. They give adequate support to the body while performing yoga.
3. They are absorbent, unlike synthetic mats.
4. They do not cause itch / allergy.
5. It has a strong "feel good" factor because it uses natural, eco-friendly, biodegradable and recycled fibres and is made in a very sustainable manner.
6. There is better increase in energy levels in the body after performing yoga on natural fibre mats (as per *Shashtra*) and this can be evaluated for silk mats also.
7. Like cotton yoga mats they can slip on very smooth floors. But they do not slip on carpeted floors used in mass yoga. A light rubber backing will prevent slippage.

Based on the suggestions of the University, yoga mats were developed in three sizes – large, medium and small (for children). A striped rubber backing was provided to make the mat non-slippery. (Figure). The mats are washable (Hand wash) and they dry quickly. A marking along the centre and another about half a metre from one edge was provided which will help in positioning properly on the mats and identifying the head and feet ends on the mat. Mats of different designs, patterns, colours, sizes and thickness were woven (Figure 6). With the flexibility in manufacturing, they have potential market in eco-conscious stores selling exclusively recycled, organic, natural products which are gaining popularity worldwide.

Conclusion

The increase in consumerism worldwide has resulted in generation of large quantities of textile waste most of which is disposed off in landfills, burnt or dumped in water bodies. This is a big hazard to the environment. One of the best methods of managing this waste is through recycling as much of the material as possible. Benefits of recycling include reduced waste and pollution, resource efficiency, increased jobs and increased revenue leading to sustainable development. The recycled silk yoga mats are durable and good for yoga practice. They promote the concept of recycling as much as the concept of using natural material in place of synthetic materials. The "queen of

textiles" is a favourite and much sought-after fibre can surely be the brand ambassador for the environment.

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EXPLORATION OF ROLE OF POLYAMINES IN GROWTH AND DEVELOPMENT OF *BOMBYX MORI*

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ABSTRACT

Sericulture industry is an integral part of Indian economy. An understanding of the molecules that regulate *Bombyx mori* development is important in producing quality silk. Polyamines are essential for survival of all living organisms. They play important roles in growth and development. Exogenous feeding of polyamine, spermidine enhanced silk production, improved silk quality and helped in growth of the larvae. Spermidine feeding changed the profile of gut microbiome and resulted in increase of beneficial bacteria. Feeding of larvae with difluoromethyl ornithine monohydrochloride (DFMO), an inhibitor of ornithine decarboxylase activity led to significant reduction of putrescine and spermidine levels with many developmental defects at the pupal and moth stages. At cellular level, reduced polyamine levels led to increased oxidative stress, decreased cell viability and significant drop in nutritional efficiency. Results of the above studies showed polyamines as key regulators of the development of *Bombyx mori*.

Keywords: polyamines, *Bombyx mori*, development, spermidine.

DEVELOPMENT OF AN APPARATUS TO ESTIMATE THE REELABILITY OF MULBERRY COCOONS

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ABSTRACT

In silk reeling industry raw silk productivity and quality are based on quality of cocoons, reeling process parameters, human skill and quality of water used. The commercial quality parameters like shell ratio, defective cocoon and reliability percentage determine 80 percent in the overall achievement of quality and productivity. Reliability parameter significantly depends on cocoon rearing and spinning conditions. Water dissolved sericin peak was found in spectral range of 260-280 nm. Sericin dissolution and reliability is having perfect positive correlation and based on this, an apparatus to estimate the reliability of the cocoons in prescribe time frame has been developed. Apparatus consists of LED for light source, a quartz rectangle for sample holder, notch filter, photodiode sensor, processor and interfaced with PC. Testing sample preparation components like integrated weighing, liquid dispenser, demineralizer and water bath were developed. The correlation coefficient (R-Sq) of 97.68% (MV cocoons) and 97.45 % (BV hybrid cocoons) was observed.

Keywords: cocoons, reelability, apparatus, correlation coefficient.

STUDIES ON IMPROVING THE CREASE RECOVERY OF SOFT SILK FABRICS BY FABRIC GEOMETRY

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ABSTRACT

Silk fabrics world over are known for their unique functional and aesthetic properties. Silk has unique advantages such as strength, soft feel, lustre and niche appeal. Soft silk fabrics extensively used for Sarees and apparels. In spite of its popularity, the soft silk variety has a major problem of poor crease recovery. It is one of the important properties and this can be improved by fabric geometry as well as by chemical finishing. Many studies have been conducted to improve the crease recovery property by the chemical finishing. Generally, the chemical finishes tend to affect some of the inherent characteristics of soft silk like softness and lustre. Hence, improving the crease recovery of the soft silk fabric without impairing the inherent quality is of paramount importance which can be carried out by the process of fabric engineering. From the interaction with industry, it was learnt that, when the crease recovery is improved through fabric structure such varieties of silk fabric shall create a huge market potential. In this present study to improve the crease recovery of soft silk fabric by changing the fabric geometric parameters like warp density, weft density and weft denier while keeping the warp denier constant. In this study the major findings related to geometrical parameters towards improve crease recoveries are: Warp & weft denier 33 & 70, warp & weft density per inch 200 & 90, GSM- around 56 having the maximum crease recovery angle of 246° in comparison to the commercial fabric having the crease recovery angle of 197°. This product is being propagated in industries through stakeholders.

Keywords: comfort properties, crease recovery angle, GSM, fabric engineering, soft silk, tensile property, warp & weft denier, water vapour permeability, etc.

STUDIES ON MORPHOLOGY AND STRUCTURE OF LONG PASSAGE IN SILK REELING AND DEVELOPMENTS OF GADGETS FOR RETRO-FITTING IN REELING MACHINES

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ABSTRACT

The quality and grade of raw silk is determined by various factors like Cocoon quality, Reeling Machines, process parameters, water, reeling speed etc. The presence of natural gum/Sericin in Silk fibres always play key role in quality of raw Silk in deciding the winding breaks, Cohesion etc. due to gum spots prevalence in raw silk. The use of long passage technique in Italian basin/ Back-end Reeling (Indirect reeling on to1.5 m diameter Re-reeling swift rather than 0.68 m diameter small reels) influences less breakage in winding and better Cohesion orientation, resulting in relatively better grade raw silk production. This system of reeling is still in vogue in Siddlaghatta cluster in Karnataka state, India where the infamous "Table" reeling, or back-end or Italian basin is popularly done even today in spite of the better technological availability in the form of MRM &ARM. The Handloom weavers still prefer the "Table/Back-end" silk particularly for warp purpose. In this background, we initiated a study on long passage in silk reeling. As per this, the morphological changes in the raw silk reeled both in Multi end Reeling and Italian basin silk was first studied using SEM. Interestingly the SEM photographs showed some distinct variation wherein Italian basin silk depict better uniformity with less serrations than multi-end silk. Encouraged by this probe, we initiated some retro-fitting mechanisms to study the effect. While designing the retro-fitting gadgets with long passage effect, suitable consideration were given without disturbing existing system of silk reeling but with adequate design aspects so that the retro-fitting becomes feasible and user friendly to achieve same or higher production This showed interesting results as long passage in silk reeling has definite advantages. Normally the passage length was 2 m approximately in multi-end/automatic reeling. The Italian basin/Back-end reeling having 4 m long passage showed better quality on the test done in SEM and Digital microscope analysis etc.

Keywords: reeling, long passage, gadgets, morphology, SEM, retro-fitting, ISA.

SECTION 6:

ECONOMY, MANAGEMENT AND MARKETING IN SERICULTURE

About/Foreword

Silk markets, prices, trading, economic analysis, situation, and statistics in silk producing countries; marketing and silk promotion; import/exports.

Chairperson

Mr. Adeel SARVIZARGAR

MEET THE CHAIRPERSON

Alina S. Rusu (biologist and psychologist) has received her PhD title in Natural Sciences in 2004 at Animal Behavior Department, University of Zürich, Switzerland. Her research interests are interdisciplinary ones, combining ideas and models from animal life with knowledge about human emotions and behavior. After her PhD, she had successfully applied for a Reintegration Grant for Young Researchers funded by the Romanian National Council for Research in Higher Education (2005-2007). Since 2007 to present, she was the director of several research grants funded by national and international agencies. Over the last ten years, Alina S. Rusu has published around 60 papers, chapters, books and conference proceedings in the fields of applied animal behavior, positive human animal interactions, evolutionary psychology and, recently, in the area of applied educational sciences (Service-Learning and interdisciplinary curriculum development). In 2017, she was awarded a Fulbright Senior Scholarship at Rutgers University, The State University of New Jersey, US. She is currently one of the Fulbright Ambassadors in the Romanian academic environment. Dr. Rusu has received her habilitation title in Psychology domain in 2013 and in the Sciences of Education domain in 2019 (Doctoral School "Education, Reflection, Development", UBB). Since 2013 to 2019, she was in charge with the coordination of the academic postgraduate training program "Animal Assisted Therapy and Activities for Persons with Special Needs" UBB-USAMV CN (in collaboration with members of the Faculty of Veterinary Medicine, USAMV Cluj-Napoca). Alina Rusu is a board member of the European Association of Service-Learning in Higher Education and one of the contributor experts of the platform International Center of Anthrozoology.

LEAD PAPER:

THE FALLOUT OF HIGG INDEX ON SILK AND THE WAY FORWARD

by

Dileep Kumar R, Programme Coordinator, International Sericultural Commission

1. Introduction

Sustainable Apparel Coalition (SAC), a USA based global initiative has introduced a sustainability index namely 'Higg Index' for products and services, including silk. This index portray silk as an unsustainable fiber based on fabricated and unsubstantiated information and data. ISC has undertaken a detailed investigation on the formulation of Higg Index and found out major flaws which revealed the deliberate and malicious attempt of SAC to defame the centuries old richness and heritage of silk. Realizing this dangerous ploy, ISC has embarked into a series of actions intending to withdraw the Higg Index from public space. Apart from these actions, ISC would like to collaborate with agencies associated with silk industry to initiate similar actions against SAC and also to develop global sustainability standards for silk that truly reflect the production process across regions. The evolved sustainability standards shall be made available for public use after validation by ISO and PEFCR authorities.

2. Sustainability Standards

Sustainable production is the creation of goods and services using processes and systems that are, non-polluting, conserving energy and natural resources, economically viable, safe and healthy for workers, communities, and consumers. In many countries, the consumer's choices are increasingly inclined to sustainable products, more particularly the textile materials. Consequently, production of many textile commodities is in the path of change with the aim of following environmentally sustainable production processes.

The sustainability standards of products and services are evolved by undertaking Life Cycle Assessment (LCA) studies. Life Cycle Assessment is a structured, internationally standardized method for quantifying the emissions, resources consumed and environmental and health impacts that are associated with goods and services. LCAs take into account the product 's full life cycle: from the extraction of resources, production, use and recycling to the disposal of the remaining waste. Life Cycle Assessment (LCA) consists of 4 phases: 1) Goal and Scope definition, 2) Life Cycle Inventory (LCI), 3) Life Cycle Impact Assessment (LCIA), 4) Life Cycle Interpretation (LCI). Since the early 1990s, numerous LCA methodologies have been developed. The existence of several different methodologies has sometimes created unnecessary confusion partly due to differing results, depending on the methodology chosen. Consequently, ISO stepped into the scenario and developed guidelines for Life Cycle Assessment through ISO 14040: 2006 and 14044: 2006. Although this measure brought

some standardization to a general framework, but they did not provide a technically-detailed standardisation.

The United Nations Environment Programme and the Society of Environmental Toxicology and Chemistry (UNEPSETAC) Life Cycle Initiative aided further developments towards consensus and a recommended best practice, and this work has since been complemented by the activities of many other organisations, such as the United States Environmental Protection Agency (US EPA) and the European Commission. The European Commission has brought out a detailed guideline on LCA study through the Product Environment Foot Print Category Rules (PEFCR), which is widely accepted in the world. The major impact categories assessed under the LCA study are:

1) Climate change,
2) Ozone depletion,
3) Human toxicity,
4) Respiratory inorganics/particulate matter,
5) Ionising radiation,
6) Photochemical ozone formation,
7) Acidification,
8) Eutrophication,
9) Ecotoxicity,
10) Land use,
11) Resource depletion, and
12) Water use.

2.1 Areas of contention

Although the PEFCR guidelines are greatly harmonized in developing sustainability standards, we found that the one-size-fits-all PEF method of accounting for all product categories is flawed for the natural textile category. A level playing field is not possible with a rating scheme that does not reward the attributes of natural fibres and does not penalise key environmental impacts of fossil fuel-based fibres. The PEF Method's failure to consider and account for renewability at the start-of-life, biodegradability at end-of-life and to completely overlook microplastic pollution will mislead well intentioned consumers. The contribution of natural fibres for achieving the Sustainable Development Goals (SDGs) of United Nations are not incorporated in the PEF methodologies, which is a great injustice to millions of rural and downtrodden people finding their livelihood in the sector. Without improvement, the PEF method will cause significant collateral damage to all-natural fibre industries, including silk.

Apart from the above, we find that some of the private global initiatives are developing sustainability standards by creating methodologies and criteria suiting to their vested interests. These fake indexes are creating considerable damages to the natural textile fibre industry. The classic example is the "Higg Index", created by Sustainable Apparel Coalition (SAC), a USA based global initiative, a front agency for promoting the synthetic products.

3. About SAC and Higg Index

The Sustainable Apparel Coalition (SAC) is the apparel, footwear, and textile industry's leading alliance for sustainable production. The SAC develops the "Higg Index", a suite of tools that standardizes value chain sustainability measurement for all industry participants. Higg Index is evolved through a core set of five tools that together assess the social and environmental performance of the value chain and the environmental impacts of products. The SAC has developed their own methodologies by cherry picking certain provisions contained in ISO and PEFCR that are suitable to them and avoiding most of the guidelines which are core to the environmental category assessments.

Many leading global manufacturers, retailers, brands, academics, NGOs, etc. are members of SAC like; Walmart, Amazon, Patagonia, Jokey, Levis, Puma, AEO, ASICS, Disney, JC Penny, Ralph Lauren, Vera Braddy, Aditya Birla, Arvind, Gildan, ISKO, Texon, VITAS, etc. We could not independently verify about the geniuses of these companies' membership, which nevertheless shall be investigated in the coming days. However, we found that the SAC fraudulently built up their credibility in public space by planting false information in the most widely watched web portal; Wikipedia, that the United States Government Environmental Protection Agency is a member of their alliance. We have checked the genuineness of this information and found that to be wrong. Such information is available in many websites, which we believe are deliberately planted to bring credibility into their unfair practice. Our investigations found out that the major chunk of the funding to SAC are emanating from the oil producing giants like; Shell, Reliance, etc., who are more interested in promoting the synthetic apparels at the cost of other products.

The SAC developed the "Higg Index" as a single score by aggregating the results of 5 impact categories. The Higg Index score has been developed for many products, even though it was not requested from many sectors. These scores are freely available in their web portal for public viewing. The Higg Index score on few of the popular textile products are given below:

#	fibre	Higg Index Score
A	**Natural Fibbers**	
1	Silk	**1086**
2	Alpaca	**320**
3	Conventional Cotton	**101**
4	Wool	**78**
B	**Synthetic Fibres**	
5	Nylon	**48**
6	Polyester	**36**
-=7	**Elastane**	**35**

In simple terms, the Higg Index indicates that silk is 30 times worse than polyester in terms of the environmental sustainability factors. This is nothing but belittling the fact that silk is an environmentally sustainable product, the sustainable existence of which can be traced back to more than 5000 years. As a fallout of the Higg Index, the Global Fashion Agenda has already advised its members to reduce the use of natural fibres by 30%.

The SAC has developed and published the above indexes without consulting the respective stakeholders including ISC, the only inter-governmental agency for silk, nor any of the silk producing and consuming countries and any of the experts in the field. The extensive use of Higg Index by the synthetic manufactures, who are also SAC members, for promoting their products is creating considerable harm to the silk sector, wherein about 22 million people from the rural area are finding their livelihood.

4. Major flaws of Higg Index

We have undertaken a detailed investigation on the development of Higg Index and found serious flaws on a number of areas, the details of which are briefly summarised as below:

a) As per the globally accepted methodologies, the LCA study must be undertaken under the Cradle to Grave or Cradle to Cradle approach to derive data pertaining to sustainability based impact categories. However, the Higg Index has been developed based on "Cradle to Gate" approach, thereby avoiding certain critical impact assessment categories intrinsically favouring natural fibre sector, including silk sector. Further, on a deeper study on this issue it is revealed that the use and disposal phase of the value chain activities are highly disadvantageous to the synthetic products compared to natural products. SAC, thus concealed the negative aspects of synthetic fibres by adopting cradle to gate LCA which ultimately resulted in portraying silk as the worst textile fibre. It is also pertinent to add here that the microplastic pollution that occurs during the use phase of synthetic dress products can create serious health issues to living organism. This serious issue has also not been accounted for the impact assessment.

b) Many aspects of Sustainable Development Goals (SDGs); like employment generation, women empowerment, environmentally sustainable production process, poverty alleviation, etc., are intrinsically associated with the silk industry. But these factors are not accounted for determining the Higg Index.

c) There is serious lapse on the data quality assurance as mandated under the ISO and PEFCR for evolving the Higg Index. ISC have been informed by the SAC that they have adopted the study results of Astudillo et. al. (2014) of Oxford University on Indian silk industry which contribute 18% weightage to the index. But the authors themselves informed ISC that their study was meant to throw light on issues associated with silk production, and was based on one specific scenario, real, realistic but also specific. They further stated that for the Higgs Index, their study result was taken out of context by - apparently - being used as a generic pattern of sericulture. As such it is totally misunderstanding, and thus misrepresenting. They are also not aware of the fact that their study report has used by a commercial data base provider and later by SAC for developing Higg Index, which has economic and other benefits. The authors also recommended that a specific LCA study must be taken up for silk by taking into account of silk industry's contributions to Sustainable Development Goals (SDG) of UN and other innate properties of silk as a bio-fibre. It may also to be noted that the data used for the purpose are sourced of a 2006 study, which is not only unrelated but also outdated.

   For the 82% weightage on the index, the LCA data on Chinese industry should have to be adopted. The SAC claimed that they have obtained this data from the paper published by Huo Y (2017). But ISC found that there are no LCA studies by this author nor any LCA study so far undertaken on Chinese silk industry. SAC has not provided us a copy of Huo Y (2017) report, inspite of ISC's specific request. Hence, it is conclusively proven that SAC has fabricated 82% of the data pertains to China, the major silk producer of the world, for deriving the Higg Index.

d) As per the ISO and PEFCR guidelines, the study results, if at all undertaken under the Cradle to Gate approach, shall be used for internal consumption only and hence never to be disclosed in public space. It was also explicitly made clear that such half-baked outcomes shall not be used for comparison among the products. However, the SAC deliberately flouted this rule by allowing its members to compare silk and synthetic products, thereby severely damaging the image of silk among the consumers.

e) For deriving the Higg Index scores of different products, the basic premise of sourcing representative data truly reflecting the production bases have not been followed. For example, the results of a study undertaken among 100 farmers in a remote area of Tamilnadu province of Indian State have been used to extrapolate the data of silk for the entire country. In case of synthetic products, which has the major production base in Asia, data modelled by a high-end factory in Europe has been used for developing the Higg Index of synthetic textile products. It is ironical that both these products are compared to determine their environmental sustainability, which is highly unfair.

f) There are more than 12 impact assessment categories, as detailed at Para 2, for arriving the environmental sustainability of the products. However, the SAC resorted in cherry picking 5 categories alone, of which two of the categories have only moderate impact on the final result. Thus, the Higg Index do not truly reflect the sustainability of the products under assessment.

g) The ISO and PEFCR guidelines do not subscribe for aggregating the scores of impact assessment categories as such figures shall be highly misleading and do not help in resolving contentious issues. However, the Higg Index resorted in arriving aggregated score for the products, including silk, which is once again proved to be a highly unfair practice adopted by SAC.

h) As per the Higg Index methodology, a Data Submitter should submit the data in due process to calculate the Higg Index score. In case of calculating Higg Index for silk, no one from the silk sector ever submitted the Data, nor did they approve to publish the Higg score. Apparently, the authors of study report have not submitted the data for seeking the Higg Index score. It appears that the Higg Index score was developed with the specific purpose of comparing and promoting synthetic products for certain influential members of SAC thereby degrading the value of silk. This is a serious breach of all the existing guidelines.

i) The PEFCR and ISO standards provisioned innate space for consultation with respective stakeholders before finalizing the LCA study results. But we are constrained to note that the SAC has not consulted with the stakeholders involved in silk industry, and not even with the authors, whose LCA study report have been used for developing the Higg Index. There are no experts on silk in the Advisory Council of SAC nor in the entire "Involved Parties" list of Higg Index to validate the score for silk. It is also of great concern that the SAC has never consulted the ISC, the only governmental agency for silk, for deriving the Higg MSI.

j) The SAC refused to share information on arriving the Higg Index, although ISO guidelines (ISO14044 2006) provided specific provision under 5.1.2 to share such details under "third party reports". There is no transparency in all the dealings of the SAC.

5. Actions initiated by ISC

Since the second half of 2020, the ISC was in touch with many industry partners and experts to investigate and assess the fallouts of Higg Index on silk industry. Our studies have concluded that the existence of such sustainability score has the potential to severely dent the image of silk and resultantly the demand for silk in the global market could be significantly reduced. The signs of such repercussions are beginning to be noticed as the Global Fashion Agenda has already advised its members to reduce the use of silk by 30%. We have thus initiated a series of actions against the Higg Index and also decided to create the sustainability data base of silk, that truly reflect the nature of the industry across the production bases. Our actions are summarised as below:

a) We have contested the use of Higg Index for silk based on the above facts and requested SAC to suspend the Index till an independent LCA study is undertaken to derive credible sustainability data pertains to silk that are truly reflecting the production practice adopted in different countries. However, the SAC has refused to accept our proposal to suspend the index nor to undertake an authentic study on arriving the sustainability criteria of silk. Consequently, ISC has given a strong warning to SAC that further display of the Higg index on silk in public domain would attract punitive actions for safeguarding the interest of silk.

b) Since no action was taken by SAC to suspend the Higg Index, ISC launched an official complaint with Federal Trade Commission (FTC), USA on 23rd March 2021, as the FTC is the responsible body for regulating the activities of such firms located in USA. FTC has already responded to our complaint by informing that the issue is being examined in detail for consideration. We expect a strong action from FTC due to the simple reason that such actions amount to "Greenwashing", which is considered as a reprehensible act as per the environmental guidelines of US government. Greenwashing is termed as an unsubstantiated claim to deceive consumers into believing that a company's products/actions are environmentally friendly.

c) At present, the existing standards of International Organization for Standardization (ISO) for LCA studies (ISO14040 and 14044) are meant for all products and services, irrespective of natural or manmade materials. Hence, ISC requested ISO to develop separate LCA standards for natural fibres, including silk. We have also requested all ISC Member Countries to write ISO on similar lines. We have been following up the matter with ISO regularly.

d) We have been in touch with other international agencies dealing with wool, alpaca, leather, cotton, flax, etc., to object the use of Higg Index for their products, and initiate similar action as in the case of silk. Many of these agencies have already written to FTC and ISO and the process is going on.

e) We have been campaigning with "Apparel Insider", a UK based magazine about the ill effects of Higg Index. Further, efforts are on by promoting the advantages of silk by writing articles in international magazines, like the recent article entitled "Silk and the importance of SDGs" appeared in the January 2021 issue of Apparel Insider. There are many articles appearing in international magazines and online forums on the ill effects of Higg Index.

f) The aggressive actions of ISC to protect the interest of silk has been attracting the attention of similar international agencies for natural fibres all across the world. Consequently, ISC has collaborated with International Wool Textile Organization (IWTO) and created a a global initiative namely "Natural Fibre Coalition". The main intention at present for creating this coalition is to campaign with the EU for including special qualities of natural fibres in the Product Environment Footprint (PEF) methodologies of EU. IWTO states that the PEF methodologies fails to consider and account for renewability at the start of life, bio-degradability at the end of life and completely overlooked microplastic pollution of synthetic products. ISC also found that many of the Sustainable Development Goals (SDGs) of UN are innately associated with silk industry, the criteria of which need to be incorporated in PEF methodologies and Category Rules (PEFCR). Considering the enormous importance of this issue, ISC has now become part of the "**Natural Fibre Coalition**".

   Under the Coalition a separate "Make the Label Count" has been launched to influence the EU law makers and other important policy makers for providing a sustainable for natural including silk in the PEF. Other campaigns in press. Electronic, and social media platforms have been quiet successful, which is continuing.

6. The way forward

ISC and ISU has decided to work jointly for evolving a mechanism for suspending the Higg Index in the instant case and further to develop standardized sustainability data for silk at global level. As a response to our efforts, ISU launched the Joint Initiative on Global Silk Sustainability and Green Consumption, which is going to show our commitment against Higg Index and decide the future steps for silk sustainability, and maintain the international image of silk. In this regard, the following actions were initiated:

1) Take all possible steps to expose the flaws of "Higg Index" in the global arena.

2) Campaigning with ISO for creating separate LCA standards for natural fibres/products as the provisions contained in the existing LCA standards; ISO14040 and 14044 are not able to account the innate qualities of natural products.

3) So far, no credible LCA study on silk or silk products was undertaken that truly reflect the production base and by following the prescribed guidelines of the ISO and PEFCR. Hence, it is critically important to create credible and standardized

LCA data on silk for public use. China and India being the largest producers of silk in the world (98%), a global LCA study has been launched collaborative actions by ISC, ISU, Indian government and Chinese government.

The LCA study is being undertaken by a global study group comprising scientists and experts with a common agenda of action. The study results would be used for arriving the global sustainability data for silk. This data would be made available to the international forum after validation by ISO and other environmental agencies in UNEP-SETAC, EU, etc. Participation of few selected experts, technocrats, policy planners, etc., from all over the world would be sourced for providing inputs to the study.

4) The LCA study would reveal the hot spots in the silk value chain activities. This knowledge would facilitate the countries to undertake research to modify the package of practise to ensure that the silk production process is not solely based on the productivity parameters but by considering the environmental sustainability and other socio-economic factors.

COUNTRY REPORT – INDIA

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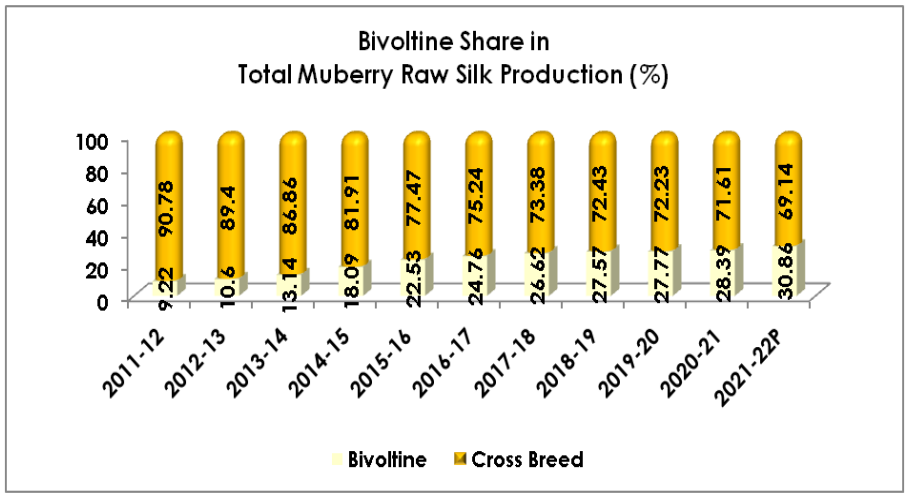
Introduction

Silk has a long history and tradition of production, consumption and trade through its own weaves and textures in India. Silk carries an important place in the life and culture of Indians and no auspicious ritual is complete without silk. India is the second largest silk producer and the largest silk consuming country in the world. Owing to the high employment potential, low capital requisite and remunerative nature sericulture and silk industry plays a major role in providing livelihood opportunities for millions of people and socio-economic upliftment for large portion of poor tribal farmers of India. The sericulture related activities ensure the livelihood security for over 1.20 million families stretch 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 *viz*., mulberry, tropical tasar, oak tasar, eri and muga and the raw silk production in the country during 2021-22 was 34,923 MT.

Growth in Mulberry Silk Production

Mulberry is the major silk produced in the country, which accounts for about 74% of total silk production during 2021-22. The major mulberry silk production comes from southern region of India, wherein sericulture is practiced throughout the year.



The mulberry area increased from 1,81,089 ha in 2011-12 to 2,45,185 ha in 2021-22 at a compound annual growth rate of 2.79% (Table l). During the same period, mulberry raw silk production increased from 18,272 MT to 25,853 MT at a growth rate of 3.21% 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 0.68% per annum during the period between 2011-12 and 2021-22.

Table 1: Mulberry Area & Production in India (2011-22)

Years	Mulberry Area (ha)	Raw Silk Production (MT)		
		Bivoltine	Cross Breed	Total
2011-12	181089	1685	16587	18272
2012-13	186015	1984	16731	18715
2013-14	203023	2559	16917	19476
2014-15	219819	3870	17520	21390
2015-16	208947	4613	15865	20478
2016-17	216810	5266	16007	21273
2017-18	223926	5874	16192	22066
2018-19	235001	6987	18357	25344
2019-20	239967	7009	18230	25239
2020-21	237578	6783	17113	23896
2021-22^{P}	245185	7978	17875	25853
CAGR*(%)	2.79	15.18	0.68	3.21

Note: CAGR: Compound Annual Growth Rate &
P: Provisional

Bivoltine silk, which is reeled from bivoltine hybrid cocoons, is better than the silk produced by the crossbreeds in terms of quality and productivity. Therefore, the Government of India has been providing ample opportunities to the farmers for production of the bivoltine silk to improve the quality and productivity of the silk. The new bivoltine silkworm hybrids and silkworm rearing practices and reeling packages evolved by the R&D institutes and the Japan International Cooperation Agency (JICA) assisted projects have helped to accelerate the growth of mulberry silk production in the country. Since then, the bivoltine silk production has been growing in the country at an incredible rate of 15.18% per annum during the period.

The fast pace of growth in bivoltine silk production as compared to crossbreed resulted in steep increase in the share of bivoltine silk production in total mulberry silk production from mere 3.69% in 1995-96 to whopping 15% in 2021-22. 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 field on trees (natural forests and perennial plantations), the non-mulberry silks (tasar, eri and muga) are known as *Vanya* silks in India. *Vanya* silk production assumes a major significance in India due to involvement of tribal's in a substantial number in different stages of production. The *Vanya* silk production has grown substantially in India owing to huge production potential arising out of wide congenial biodiversity for *Vanya* silkworms, eco-friendly nature, 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 (2011-22)

Years	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
2019-20	3136	7204	241	10581
2020-21	2689	6946	239	9874
2021-22^{P}	1456	7359	255	9070
CAGR (%)	-0.80	8.27	6.60	5.98

Note: CAGR: Compound Annual Growth Rate & P: Provisional

The forest based tasar silk is prominently produced in Central and Eastern regions of India. The North-Eastern states are known for the production of eri and muga silks. The tasar silk production slightly down from 1,590 MT in 2011-12 to 1,456 MT in 2021-22 registering a growth rate of -0.80% per annum (Table 2); whereas, eri silk production recorded an annual growth of 8.27% to increase from 3,027 MT in 2011-12 to 7,359 MT in 2021-22. Muga silk grew at a rate of 5.98% during last decade.

Growth in Overall Silk Production

The silk production in the country grew from 23,060 MT in 2011-12 to 34,923 MT in 2021-22 at an annual compound growth rate of 3.85% (Table 3). The mulberry

silk production in the country grew at 3.21% per annum during the period. On the other hand, the non-mulberry silks registered higher growth rate of -0.80 by tasar, 8.27% by eri and 6.60% 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 74% in 2021-22.

Table 3: Total Silk Production in India (2011-22)

Years	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
2019-20	25239	10581	35820	70.46	29.54
2020-21	23896	9874	33770	70.76	29.24
2021-22^{P}	25853	9070	34923	74.03	25.97
CAGR(%)	3.21	5.98	3.85		

Note: CAGR: Compound Annual Growth Rate & P: Provisional

Growth in Silk Consumption

The raw silk demand has been growing in the country at 2.30% per annum from 28,743 MT in 2011-12 to 36,901 MT in 2021-22 (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 2021-22 increased to 95% and the share of the

imported silk fell down to 5%. It is expected that the country would become self-sufficient in raw silk production by2025.

Table 4: Raw Silk Production, Import & Availability in India (2011-22)

Years	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
2019-20	35468	3315	39135
2020-21	33770	1804	35574
2021-22^{P}	34923	1978	36901
CAGR(%)	3.85	-9.15	2.30

Note: CAGR: Compound Annual Growth Rate & P: Provisional

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, gloves, 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 silkworm and its host plant mulberry(sericin, pupae, moths, silkworm excreta, silk fiber waste and mulberry leaves, fruits and roots) for therapeutic use (anti-diabetic, anti-viral, hypoglycaemic, anti-bacterial and antivirus products), cosmetics (skin and hair products), animal food (feed for poultry, fishes, cattle etc.) and foodstuff for human consumption (oil, juice, marmalade, wine, fruit distillate, vinegar, dried fruit powder and natural colouring agents).

COUNTRY REPORT

SERICULTURE IN THAILAND

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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 silkworm varieties in Thailand (Fig.1).

Native variety Hybrid variety Chinese x Japanese

Figure 1. Type of silkworm varieties in Thailand

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 biovoltine 166 varieties and polyvoltine 95 varieties[1].

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 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 biovoltine and polyvoltine are 166 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

[1] Source: Office of Sericulture Conservation and Standard Conformity Assessment data on August 15, 2022

leave yields are based on its variety. For example, the varieties of as per farmer practice, the given yields are about 320 – 400 kg/hectare/year. Nevertheless, some farmer still uses the native varieties (such as Noi, Ta Dam, and Khun-Pai varieties provide 320 – 400 kg/hectare/year. The Queen Sirikit Department of Sericulture introduced mulberry varieties such as Buriram 60, Sakolnakhon 85, Sakolnakhon and Srisaket 84 (Fig.2) to replace the farmer's low yielding varieties. These 4 varieties could provide 693, 545, 400 and 278 kg/hectare/year. 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 August 15, 2022

KhunPai

Sisaket84

Buriram60


Sakonnakhon


Sakonnakhon85


Chiangmai

Figure 2. Mulberry varieties

Sericulture situation

Sericulture in Thailand, there are approximately 83,950 farmers of sericulture with area of mulberry field is about 9,959 hectares[2]. The table 2 below indicates the sericulture farmer and mulberry plantation area found that the current mulberry area decreased compare with the year in 2020 due to COVID-19 situation affects domestic and international markets and some 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 2012 – 2021

Year	Sericulture farmer	Mulberry plantation (hectares)
2012	-	-
2013	107,435	10,000
2014	73,874	7,838
2015	82,071	7,553
2016	-	-
2017	85,578	7,234

2 The Queen Sirikit Department of Sericulture data on September 30,2021

2018	87,369	7,085
2019	81,497	6,723
2020	85,437	11,021
2021	83,950	9,959

Source: The Queen Sirikit Department of Sericulture, TAMIS and research data 2012 - 2021

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 2021, raw silk yarn production in Thailand was decrease 503 tons compare with the year in 2020 (520 tons) (Table 3).

Table 3: Raw silk production for the last ten years 2012 – 2021

Year	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Raw silk (Tons)	655	680	692	698	712	448	403	700	520	503

Situation of raw silk and spun silk

Table 4: Import and Export of raw silk and spun silk for the last ten years 2012 – 2021

Year	Import		Export	
	Qty (Tons)	**Value (US$)**	**Qty (Tons)**	**Value (US$)**
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	472	7,940,284	292	5,342,463
2020	300	3,599,714	195	3,511,513
2021	273	4,226,354	393	7,637,719

Source: Thai Customs Department, data 2012 - December 31, 2021

AFRO SILK COMPANY LDT.

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Afro silk company is a sub company under Iran Argo industrial group and it specialises in production of raw silk and it is based in Gomba – kisozi (Uganda) Afro silk company ltd has set up the first large scale silk production project of its kind in East Africa, with over 10 million mulberry trees aid 22 million silk worms being reared, at a single rearing monthly.

Afro silk company Limited in conjunction with the UGANDA silk producer's association, ministry of agriculture, Department of Entomology and in the ministry of science, Technology and Innovation from 2011with the aim of the expansion of silk production in UGANDA, we have invested in the project by testing and developing different mulberry trees according to the excellent climate of Uganda, which is temperate not cold and not hot at 18°C -28°C.

we have managed to put up the largest plantation worldwide over 10 million mulberry trees in one farm which are able to feed 1000 boxes of silk worms monthly and a rearing facility for over 22 million silk worms per month. The Aim of AFRO SILK-company Limited to support out grower silk farmers to join the programme by supplying mulberry stems, the best breed of the silk worm eggs and buying cocoon from the farmers. AFRO silk company ltd. We proud that we have, The largest mulberry farm for silkworm production in Africa. Uganda's special weather conditions have made us able to grow and produce silkworms in twelve months of the year. Currently, only mulberry plants are used for raring, but in the future research plans, the use of other plants such as cassava and castor will be used for the raring of Eri silk.

ROLE OF ISC FOR THE DEVELOPMENT OF SERICULTURE & SILK INDUSTRY IN THE WORLD

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ABSTRACT

Sericulture and Silk Industry is considered as an ideal tool for rural development and poverty alleviation. Its potential for employment generation and women empowerment is noteworthy. Since 1870, International Sericultural Commission (ISC), an inter-governmental organization, has been engaged in the development of sericulture and silk industry across the globe. ISC has been providing a global platform for dissemination of scientific and technical advancements among the silk fraternity. ISC has instituted the Prestigious Louis Pasteur Award for recognizing outstanding contribution of individuals for the global development of silk industry. During the year 2019, ISC has introduced another award namely, "Excellence in Sericulture Science (ESS)" in four categories of sericulture science for recognising breakthrough works in silk sector.

ISC publishes "Sericologia" the scientific journal devoted for sericulture science, which is widely popular among the researchers, technocrats, and silk stakeholders. The digital version of the journal since 1948 is freely available now. At present, there are 21 member countries and 30 associate members in ISC. The volunteer expert program is an innovative program to freely provide scientific, technical and managerial services to the sericultural developing countries. ISC provides scholarships for empowering sericulture researchers in specific areas of silk industry. Under the capacity building program, which is the integral part of ISC activities and initiated during 2015, 147 students from 25 countries have trained. ISC is coordinating the sericulture developmental activities in different silk producing and consuming countries armed with the much-needed technical expertise in all the sectoral areas. Facilitating research collaborations among the countries and institutes are also part of the regular activities of ISC.

In order to estimate the impact Covid-19 on silk industry, ISC has undertaken a global study and brought the findings in the form of book; "Impact of Covid-19 on the global silk industry and the way forward". The 15-point plan of actions elaborated in the book would provide new direction for the sustainable development of sericulture and silk industry. ISC is making serious objections on the introduction of Higg Index developed by Sustainable Apparel Coalition (SAC), that portrays silk as the least

sustainable fiber. The matter has been brought to the notice of EU, UN and USA with the immediate aim of suspending the index. Further, ISC has established collaboration with International Silk Union (ISU), China for developing global sustainable standards by undertaking LCA study on silk. We have also initiated to develop a global coalition namely "Natural Fiber Coalition" in association with IWTO and other agencies related to natural fiber industry to campaign with EU for including the innate qualities of silk and other natural fibers in the PEF methodology of EU. ISC is in the process of bringing out a coffee table book on "Silk products of the world" to document the legacy of silk since 3rd Millennium BCE.

Key Words: PEF Methodologies, Higg Index, LCA, MSI, Member Countries, SAC

AN EXPERIENCE SHARING ON MEGHALAYA EXPERIENCE OF BRANDING AND MARKETING OF RYNDIA – THE VERSATILE ERI SILK, AN HEIRLOOM OF THE PEOPLE OF MEGHALAYA, NORTHEAST INDIA

"ROOTED IN NATURE, CONNECTED TO CULTURE"

Frederick Roy Kharkongor, IAS

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ABSTRACT

Eri silk, or 'Ryndia, Meghalaya's hand woven, hand-crafted organic fabric, indigenous to the state is spun from 'Takli' a traditional spindle and is culturally distinctive. 15900 families are directly involved in Eri handloom and 16000 families in Eri Sericulture farming activities. Derived from 'Rynda' the castor plant, Ryndia is the only domesticated silk produced in India, processed without killing the pupae inside. It advocates co-existence & harmony between man and nature. It is famous the world over, as 'Ahimsa Silk' (Peace Silk) or the fabric of peace. Total Eri Plantation area in the state is 9336 acres. The state produces 918 MT of Eri and is only the second largest producer of raw silk in North Eastern India. In essence, at each step of the value chain, from farm to fibre, fibre to fabric, production process is anchored by women, creating a 'virtuous cycle'. It is warm in winter, cool in summer, durable & 100% naturally dyed with natural ingredients sourced from plants and plant parts, such as turmeric, onion skin and plant-based mordants, justifying its claim for eco-labelling, being ethically sourced and organically produced. Multiple weaves, motifs and weaving techniques are linked with this traditional fabric which includes Thohriawstem, Khmat pattern and Khneng embroidery. The State's Textile Department has initiated measures to promote, safeguard and elevate Ryndia. The outcomes are steadily resulting in strengthening women empowerment, checking cocoon out-flow, boosting pre-cocoon and post-cocoon sector linkages, disseminating latest technologies, infusion of best CSB practises in Silk worm rearing, reeling, spinning, weaving, processing and marketing with qualitative and quantitative improvement in silk production per unit area. Value addition, conversion of silk cocoon into yarn and product diversification is being enhanced. Development of improved designs, aligned to market trends and contemporary taste is also being explored. Clarity of branding philosophy, focussed on connection to nature–Eco-friendly and organic production. Heritage, culture & Tradition leveraged, interwoven with traditional weaving techniques, blended with contemporary look. Brand elevation, from cottage industry to fashion and lifestyle concept. Recognizable & impactful Logo, a

catchy tagline – 'From Thread to trend', compelling brand video, weaver's music video, social media platforms, building interactive and dynamic content to engage, connect & build a dynamic online repository. Dedicated Eri Corner, launched for un-ventured opportunities in refashioning these traditional fabrics as luxury products. Tangible outcomes include official Declaration of States First Eri Silk Village at Umden, which is the weaving epicentre on 12th of February 2021, revolving around 7282 Sericulture farmers & 6000 active weavers, augmenting rearing houses, Eri food plants, cocoon bank, Eri private graineurs, modern Eri spinning unit-Sailum (thread from the hills). The recognition inspires weavers and spinners to transform Meghalaya into a big player in the Silk Industry, particularly the niche silk sector, highlighting the singular sensitive treatment in the production of fabric. with its pronounced pro-life approach, making the silk unique and sustainable, in both process and product. Design Innovation Resource Centre(DIRC) set up**,** as one-stop centre for seri inputs, doubt clarification, problem resolution, for weavers, dyers, researchers. It is aimed at facilitating an interactive platform for artisans, weavers, industry and design students, through professional display areas & specialized labs, resource centre and design activities, through technology demonstration & skill enhancement, new & contemporary design infusion, product diversification, subsidized raw materials access, brand building, marketing assistance, & e-commerce platform promotion in the second phase. The management is envisaged by handpicked/lead/elite farmers or any non-profit organization, seri-societies for the benefit, of cluster farmers and Eri Seri-culturist.

Key Words: Peace Silk, Sustainable, Heritage Craft, Naturally Dyed, Women Centric, from Thread to Trend, Silk Village, ethically sourced, organically produced.

IMPACT OF SILK SAMAGRA SCHEME – TOOL FOR OVERALL DEVELOPMENT OF SERICULTURE IN INDIA

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ABSTRACT

Sericulture development schemes/projects have been given high priority by the Indian Government considering its contribution to the national agenda of rural development and poverty alleviation. Silk Samagra scheme, which was earlier known as the "Integrated scheme for development of silk industry" was recasted with appropriate modifications enabling to meet the emerging challenges witnessed in the Indian silk industry. The prime focus has been identified to transform the country as Atma-Nirbhar (Self Reliant) in the production of high quality bivoltine silk. Although various programmes were implemented in the past to increase the raw silk production, the impact was minimal due to the absence of advanced technologies and innovation. Considering this critical issue, the Central Silk Board had conceived and implemented the "Silk Samagra Scheme" during the financial year of 2017-18 onwards for the systematic development of Indian silk industry. Silk Samagra Scheme contains four components; a) Research & Development, training, transfer of technology and IT initiative, b) Seed organisation, c) Coordination and market development and d)Quality certification systems & brand promotion & technology upgradation. All these componentsare closely interlinked with prime focus on the comprehensive and sustained development of silk industry.

Silk Samagra scheme mainly focused on research and development aiming to produce high quality bivoltine silk from 3A grade and above. Resultantly, there was a paradigm shift in the promotion of bivoltine sericulture by accelerating improvements in the areas of research, extension, seed production, cocoon production, marketing, credit facilitation, policy options and increased participation of stakeholders in decision making process/areas. The R & D interventions, particularly to inculcate region specific improved mulberry varieties, breed and appropriate technologies have created a quantifiable impact at farmers level. These measures ultimately attributed for enhancing the production, productivity and quality of silk. Resultantly, the Bivoltine silk production in the country has reached to 7978 MTs in 2021-22 with a significant increase of 51.50% over the XII plan (2012-17) period production of 5266 MTs. The bivoltine breeds and packages of practices developed by the research

institutes are found to be increasingly suitable and stable in the Indian tropical climatic conditions. The Institutes have been focussing on tropicalization of temperate sericulture to build robustness under stress conditions like high temperature, variations in humidity and disease occurrences. Because of the production of large quantities of uniform quality bivoltine cocoons, entrepreneurs are beginning to install Automatic Reeling Machines(ARMs) to produce import substitute silk that are essentially required for the power loom sector. Due to this, there was drastic reduction of import of silk from 7300 MTs during 2009-10 to 1978 MTs during 2021-22, which resulted in foreign currency savings. The eco-friendly Vanya Silk production has also reached to 9070 MTs at the end of 2021-22, which heralded increased demand for organic Indian silks in the global market. With the successful implementation of Silk Samagra programme by Central Silk Board the following quantifiable achievement could be made in the field level.

a) Improvement in mulberry productivity from 50 MT/ha/Yr during 2005-06 to 65 MT/ha/Yr during 2021-22 and cocoon productivity from 48 Kg/100 dfls during 2005-06 to 70 Kg/100 dfls during 2021-22.
b) Raw silk productivity improved from 98 Kg/ha (2016-17) to 108.5 Kg/ha (2021-22).

In the background of the successful implementation of Silk Samagra programme by Central Silk Board, the Govt. of India set the following targets in silk sector by the end of 2025-26.

- Production of 12250 MT import substitute Bivoltine silk.
- Production of 46500 MT Raw silk.
- Raw silk productivity 115.50 Kg/ha.

ANALYSIS OF THE ENERGY BALANCE IN THE *MORUS ALBA*-*BOMBYX MORI* SYSTEM IN CUBA'S SERICULTURE

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ABSTRACT

The National Sericulture Project in Havana, started in 2011 to establish silkworm (*Bombyx mori*) rearing at a large scale in order to generate products to be used in the cosmetic, biomedical, biotechnological and pharmaceutical industries. The feeding of *Bombyx mori* L. exclusively depends on mulberry (*Morus alba* L.), so turning this system into a sustainable one for its development in the country requires an efficient use of the energy mainly based on the energy input-output relationships, on having mulberry cultivars of a high photosynthetic efficiency, on increasing agroecológica practices and introducing other agricultural activities to diversify the intensive mulberry production system. The analysis of the energy balance used the software Energía 3.01, designed to estimate the energy of agroecosystems. The management of the area was characterized by identifying conventional agroecological practices developed on it. The results of estimating the energy efficiency indicate a mean efficiency for a specialized system depending on very few external outputs. These results were compared to 2019 the energy balance made in 2017. The introduction of new productive activities leading to increased energy efficiency and the generation of new products with a favorable impact on the environment and on the energy balance of the system, were proposed.

Keywords: *Bombyx mori*, *Morus alba*, Agroecology, Energy Balance

IMPACT OF JICA PROJECTS FOR THE BIVOLTINE SERICULTURE DEVELOPMENT IN INDIA

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ABSTRACT

Sericulture development projects have been given a high priority in India as the sericulture is an ideal tool for rural development and employment generation. Attempt to produce quality bivoltine raw silk was initiated through various projects; Karnataka Sericulture Development Project supported by the World Bank in 1981, followed by National Sericulture Project (NSP) in 1989 with financial support from the World Bank and the Swiss Development Agency. Although, the NSP was one of the most important projects for developing the Indian sericulture, aimed primarily at introduction, development and promotion of bivoltine sericulture, but in absence of appropriate technologies and breed, the bivoltine production could not reach to the desired level. Under this situation, the Government of India with the support from Japanese International Cooperation Agency, Govt. of Japan had implemented 3 phases of JICA projects for the periods from 1991 to 2007.

The Bivoltine Sericulture Technology Development Project (BSTD) (Phase-1) had come out with a comprehensive Bivoltine Sericulture Technology package like improved mulberry varieties (V1 & S 36), new silkworm hybrids (CSR2 X CSR4, CSR4 X CSR2, CSR4 X CSR5, CSR18 X CSR19),suitable rearing and mounting methods, disease management & control measures, the improved techniques of seed production, seed preservation, processing and incubation, standard method of cocoon drying, cocoon quality testing, cocoon storage, cocoon cooking and reeling techniques suited to Indian Conditions. The Project for Promotion and Popularizing of the Bivoltine Sericulture Technology (PPPBST), the 2nd phase of the Project was known as Technology Verification and demonstration of the Bivoltine Sericulture Technologies evolved during first phase of the project with the selected 142 farmers from Karnataka, Tamil Nadu and Andhra Pradesh. The project also supported for human resource development in the field of Bivoltine sericulture and skill development technicians and farmers. Both the projects had come out with a comprehensive Bivoltine Sericulture Technology package suited to Indian conditions. The 3rd phase of JICA Project; "Project for Strengthening Extension System for Bivoltine Sericulture (PEBS)" covering 3698 farmers had evolved a model for bivoltine expansion system to sustain the bivoltine production and to meet the growing need of import substitute silk in the country.

With the successful implementation of JICA programmes, Central Silk board has standardized the Bivoltine Sericulture Technology suiting to the Indian conditions, which are now popularly known as JICA Technologies. Consequently, the Govt. of India had given emphasis on production of Bivoltine Silk through field dissemination of newly evolved technologies to meet the ever-increasing demand of Bivoltine silk in Indian market and thus reduce import to a bare minimum. The bivoltine production which was 1800 MT in XI Plan had reached to 8000 MT by 2021, which is a remarkable achievement. Now the Govt. of India is focusing to produce 20000 MT of bivoltine silk by 2030 enabling the country to become self-reliant on producing internationally graded silk. The root cause of all these developments were the successful implementation of the JICA projects.

Key Words: Bivoltine, JICA, Silkworm Hybrid, BSTD, PPPBST, Sericulture Technology

ENTERPRISE OPPORTUNITIES IN MULBERRY SILKWORM SEED SECTOR IN INDIA

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ABSTRACT

India is poised to grow exponentially in raw silk production in the current decade in a bid to bring down the import of raw silk in the next two years and becoming self-reliant. The country has set an ambitious target of 60000 MT raw silk by the turn of this decade with a share of mulberry silk as high as 42300 MT. While China has been consistently de-growing during the past 5 years in raw silk production at a whopping annual rate of (-) 20.69 % (170000 MT in 2015; 53359 MT in 2020), Indian story is encouraging at a five year CAGR of 3.43 %. India is positioned to grow at a rate of 11.29 % in bivoltine raw silk production and at 1.86 %, in cross breed mulberry raw silk production. This opens up substantial opportunities for micro-enterprise development in the country in silk sector in general and silkworm seed sector in particular. Three verticals such as the anchor-vertical in silkworm egg production, the backward-linkage-vertical in seed cocoon generation and the forward-linkage-vertical in large scale young silkworm rearing are on offer. The viable enterprise possibilities are examined in the light of the end- to-end value chain of mulberry silk and the prominent place the silkworm seed sector occupies in it. These enterprise possibilities are also aligned with at least six most prominent and universal sustainable development goals (SDGs) as proclaimed by the United Nations that point to the theme 'leave no one behind' in the development process. The present business size of bivoltine and CB seed cocoon generation is *ca.* INR. 1990 million which would reach INR. 4810 million by 2030. For the number of farmer-entrepreneurs who hold at least 4 acres of mulberry garden to generate bivoltine seed cocoons and who hold at least 2 acres of mulberry garden for multivoltine seed cocoons from the current level of 1550 will grow to 1927 by 2030. The cost-benefit ratio in seed cocoon production enterprise works out to be 1:1.44. The business size of silkworm seed production at present is about INR. 2.45 billion which would grow to about INR. 7 billion. The number of entrepreneurs with an average production capacity of one million DFLs per annum, would be around 600. The cost - benefit ratio of seed production works out to be 1:1.45 in the case of bivoltine and 1:1.30 in the case of cross breed seed. Likewise, the present business size of silkworm chawki rearing is INR. 12.50 billion with a potential to reach INR. 35 billion by 2030. The cost

benefit ratio in this case works out be 1:1.64. This will open up the opportunity to entrepreneurs in excess of 10000. The enterprise opportunities in seed sector are promising with consistent and attractive cash flow. The cost economics of the silkworm seed sector enterprises, the importance of enabling environment in realizing the potential and the tangible and intangible essentials required for establishment and running the enterprises are discussed.

Key words: Bivoltine, business size, cost-benefit ratio, cross breed, enterprise opportunity.

PROMOTION OF PRIVATE PARTICIPATION IN SILKWORM SEED SECTOR TO BOOST RAW SILK PRODUCTION IN INDIA TO ACHIEVE PROJECTED GROWTH

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ABSTRACT

The share of the public sector in Agriculture seed production in the country reduced from 42.72 % in 2017-18 to 35.54 % in 2020-21, and this highlighting the rising role of private sector in India's seed sector. Private participation is a key tool for rapid economic development of any country, and it facilitates greater efficiency and innovation in the production and promotes rapid economic development. it is estimated that if this model popularizes widely in sericulture, industry will obtain big push in terms of finance, technology, efficiency in production and delivery of products, which will reduce the cost of silk production that leads to increase in the exports of raw silk and finished products of silk. The government wants to enhance production of raw silk through vertical and horizontal expansion of mulberry as well as non-mulberry sericulture. It aims to develop a vibrant and sustainable farmer base by overall improvement in production, productivity and output quality through expansion.

In sericulture sector the Silkworm Seed Production Centres under CSB as wells as state Govt. located across the length and breadth of the country, play a significant role in the production of silkworm seed and its distribution. It is a matter of great pride to state that CSB shoulders the major responsibility of meeting about 65-70% of the country's requirement of bivoltine hybrid DFLs, hundred percentage of nucleus and major share of basic seed in mulberry and Vanya sector. The success story mainly lies in the product quality, greater acceptance of the brand and the trust reposed in the organization by the end user.

As per the vision 2030 plan of Central Silk Board the projected raw silk production in all sectors would be about 60 thousand MT and would be recorded a growth rate of 53.76% during next 9 years and mulberry raw silk would be a major share (70.3%) out of the total raw silk production and for achieving the projected target, 9673 lakhs of silkworm seed would be required for all the sectors. As we discussed the Govt sector in central as well as state is mainly concentrating nucleus and some share of basic

seed production and major share (94%) of silkworm would be expected from private partners. Central Silk Board has planned various programs and schemes in this line and Silk samagra-2 also focused on promotion of seed production in private sector through assistance for development of ASR concept for quality seed cocoon production and promotion of private seed producers and establishment of cold storages for preservation of bivoltine seed. In addition to this CSB will provide technological handholding and skill development in seed production under Central Seed Act and also regularly being supported technically time to time. The success of a seed production centre lies in the generation of quality parental seed cocoons at required regular intervals and it forms the backward linkage for production of commercial silkworm eggs. The support of extension workers in supervision of the seed crop rearings is highly essential. In addition to this share of silkworm egg production of private partners has to be increased by large-scale support to egg producers and seed cocoon producers by joint efforts of private players and Govt agencies.

Keywords: Private participation, seed production and registered seed producers

MILESTONES IN SERICULTURE AND SILK INDUSTRY DEVELOPMENT CATALYZING ECONOMIC GROWTH ACHIEVED IN INDIA OVER LAST TWO CENTURIES – A CHRONOLOGICAL ILLUSTRATION OF TECHNOLOGICAL AND INFRASTRUCTURAL INITIATIVES

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ABSTRACT

Sericulture in India is an age-old practice dating back to 5th A.D as per known records. Another theory points out use of some wild silks in Harappa as per archaeological references during Indus Valley civilization. Although sericulture was practiced in the Himalayan Mountain belts from Kashmir, Tibet leading up to Bengal as per silk exports of Bengal traced to Europe under Royal Dynasties of Murshidabad; yet, the scalable and phenomenal growth can be attributed to 250 years of development in the South Indian states.

India would have not been the second largest producer of silk, had it not ventured sericulture as a community rearing activity, patronized by the Tippu dynasty. This was followed well by equally supporting measures taken by the Maharajas of Mysore, The Diwans, the Colonial British Rulers, the post-independence Central & State Governments of the Republic of India in shaping bold policy measures in terms of technological interference, creation of required infrastructure.

There are a good number of milestone achievements by India during the last 250 years like introduction of mulberry cultivation and Bombyx mori silkworm rearing from the saplings and seed collected from Bengal, reeling machines from Italy to Karnataka, popularizing community rearing in Mysore area, creation of seed network and related training in India and Japan, infrastructure creation of cocoon markets Parent (P) basic seed farms, grainages, Silk exchanges, KSIC, KSMB, World Bank / SDC/ India Funding under KSP 1 & 2, NSP, CDP, Silk Samagra, CSR silkworm hybrids, Chawki rearing Enterprises, adopted seed rearers, Shoot rearing,, MRM, ARM, etc.

In the present paper, an attempt has been made to document this vast and diversified achievement in a chronological manner to illustrate the history of development of sericulture in India against the contemporary challenges. This was done with the help of government records, archaeology and historical literature, which will certainly form as a valid document to devise systematic approach for further development. There are discussesions about challenges faced by the upcoming sericulture countries and the precautions, measures that need to be taken by them. The economics of silkworm rearing, reeling, pherpheral approach in sericulture, etc., have been analyzed to promote enterprise development in Technical and managerial aspects. India presents an example of Model Leader into an era of economic growth through holistic approach in sericulture development for adoption by the new countries.

Key words: Milestones, Chronology, Economics, Management, History, KSP, NSP, CDP, CSR hybrid, ARM

ROLE OF EXTENSION COMMUNICATION PROGRAMMES (ECP) AND CLUSTER PROMOTION PROGRAMME (CPP) IN IMPROVING BIVOLTINE SILK PRODUCTION IN SOUTHERN INDIA

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ABSTRACT

Central Sericultural Research and Training Institute (CSRTI), Mysore is the pioneer research and development Institute of Sericulture under Central silk board in India and played a vital role in promotion of mulberry sericulture in India for the past 60 years. The technology developed from this Institute is validated through different Regional Sericultural Research Stations and Research Extension Centres situated in Southern India through Transfer of Technology (TOT) programmes like on station trials (OST) and On farm trials (OFT). After the completion of validation, the technologies are disseminated through different Extension Communication Programmes (ECP) viz., Sericulture farmer's workshop cum Exhibition, Farmers Field Day, Awareness programme Technology demonstration / Enlightenment programmes, Workshop / Seminars & Conferences and also through training programmes. During the period 2017-2022 , 4951 events under different ECPs were conducted in 26 Mega sericulture clusters of South India and sensitized 3.14 lakh farmers and thereby achieved average 97.99 % of total bivoltine raw silk production target with 24580 Metric Tonnes (MT) of silk (3905.3 MT(2017-18), 4781.2 MT (2018-19),5054.5 MT (2019-20),5006.6 MT (2020-21)and 5832.8 MT(2021-22) and also 88994.0 acres of New Mulberry plantation were taken up by 62990 farmers.

PROYECTO SEDA: A SERICULTURE DEVELOPMENT PROPOSAL ORIENTED TO AGROECOLOGY, GENRE, CLIMATE CHANGE AND LOCAL VALUE GENERATION

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ABSTRACT

Introduction. This work focusses on a the develop of a research and extension regional scale consortium. The main objective was to strength Latin-American and Caribbean sericulture sector. It works was oriented on sericulture agroecological transition, Climate Change mitigation, local labour generation and genre development.

Sericulture has been a traditional farm activity in Latin America, with cocoon production oriented to raw silk global market. Brazil was the major supplier, but actually it presents a drastic decline due to inconvenient relative prices, rural emigration and environmental issues, mainly pesticide contamination associates with soya crops and long drought periods, associated with Climate Change.

The rest of countries, through public-private actions, were implementing different diversification strategies, which included productive integration and local artisanal value. Although the number of sericulturists was reduced, stability and greater capture of final value by farmers was observed. (Pescio *et al*, 2012). Among the major regional problems, were identified restrictions to proper *Bombyx mori* and *Morus sp* breeding material; support to implementation of agroecological (organic) practices and Climate Change mitigation strategies.

Development and objective. The Silk Project (Europe Aid / 150248 / DH / ACT / ALC) it's an international cooperation consortium between eleven institutions, from six countries of Latin-America and three european countries. It´s part of the Triangular Cooperation ADELANTE Program and financed through the Regional Mechanism for Cooperation of the European Commission. The major objective was to develop support actions for sericulture sector, oriented to local value creation and women's labour. From the productive perspective, it focuses on agroecological approach and incorporation of Climate Change mitigation practices. Among the proposed actions, its highlights strengthening of extension services, technological development and farmers training.

It includes scale-up production of key inputs, as mulberry saplings and silkworms hibrids eggs. One of the key elements it was a direct subsidy fund for farmers.

Results. Among the major results, new varieties of mulberry are in development and a silkworm egg production facility was builded. The farmer`s found financed 41 experiences for a total of 417,937 €. There were 3,659 direct beneficiaries, of which 2,373 are women (64%). The investments were directed to improvements in mulberry fields and rearing houses, clean technologies and small-scale reeling equipment. Due to COVID19 crisis, the projects will be fully executed in 2022. At the end of the process, an improvement in the quality of life of stakeholders its expected.

SERICULTURE IN CUBA: SCIENTIFIC ADVANCES AND CHALLENGES

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ABSTRACT

Cuba's National Sericulture Project was started in 2011, in order to develop products from the silkworm cocoon for the biopharmaceutic, biotechnological and cosmetic industries. The Project has developed its scientific basis in the course of these years, as well as the scaling of silkworm rearing in three stages. This paper shows results and implemented methodologies in the period 2011-2021. The results of the efficiency rate for the Integrated System Morus alba-Bombyx mori with an agroecological approach, are also presented. The main products derived from the silkworm cocoons so far, have been silk thread, sericin hydrolyzed and fibroin nanoparticles. The main challenges of the Project are focused on the incorporation, evaluation and development of new breeds of *Bombyx mori* L.; eggs production; the expansion to production scale through an integrated rearing management, all these based on a circular economy, as well as the attainment and development of new products from the silkworm cocoon.

Key words: *Bombyx mori*, rearing, energy balance, cocoon byproducts.

INCOME AND EMPLOYMENT GENERATION OF WOMEN IN ERICULTURE: A STUDY OF BODOLAND TERRITORIAL REGION, ASSAM

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ABSTRACT

Sericulture is an agro-based small scale industry. It involves rearing of silkworms for the production of raw silk. The major activities of sericulture comprise of food plant cultivation to rearing of silkworm, production of cocoons, reeling and weaving. Since, sericulture has been one of the leading economic activities in Bodoland Territorial Region (BTR) of Assam and mainly women are involved in this profession therefore it was important to study the role of sericulture and its impact on the life of women in the region. The study was undertaken with the objectives to analyse the socio-economic condition of women in ericulture, income and employment generation using simple statistical tools. Primary data were collected from 128 households from eight villages spread over in 4 districts of Assam in the year 2021. The study reveals that ericulture played a great role in the economic uplift of BPL households by way of income and employment generation. Eri activity is observed to be mostly carried out by the tribal women belonging to BPL households. Mostly middle-aged women without having any formal education are engaged in these activities. It is witnessed that income generated from ericulture activities have contributed greatly to the total income of the family obtained from various sources. About 45 percent of women in the study area got actively employed for more than 300 days in a year due to ericulture activities.

Keywords: Sericulture, Ericulture, Women, Socio-economic, Employment, Income

REVITALIZATION OF THE SILK INDUSTRY IN KEY AREAS IN THE PHILIPPINES THROUGH THE PHILIPPINE SILK ROAD PROGRAM

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BSTRACT

Silk from *Bombyx mori* L thrives as a distinct textile-fiber material for the local handloom woven fabric weavers in the Philippines. Woven with pineapple leaf filament fibers on the filling or just with its own, it has been fashioned by Philippine's premier designers in creating a gala masterpiece for the top-tier population of the Philippines' social class. The small national demand of 10 tons of raw silk a year is hardly supplied, at 10% on average, annually. Securing the silkworm germplasm for more than 40 decades and its progressive efforts on silk development have been the chief contribution of DOST-PTRI to the Philippine silk industry. Historically, the early efforts in the Provinces of Misamis Oriental and Benguet, respectively bannered silk that pivoted from the initial sericulture experimental stations to becoming Technology Centers, eventually opening the gateways for mulberry propagations and silkworm rearing to flourish in many rural communities in Northern Mindanao and the Cordilleras. The Philippine government's right-sizing in 2008 affected many line agencies and research institutes including the silk production works of the DOST-PTRI. Ten years hence, the Institute's Philippine Silk Program thru Science and Technology revitalized silk production activities in the Provinces of Misamis Oriental, Bukidnon, Benguet, Kalinga, and Apayao and once again caused the widespread and collaborative efforts of technology promotions and knowledge transfer with and among partners on the ground. Silk processing lines, known to be the bottleneck in the completion of the Philippine silk value chain were established and became available in strategic regional areas in the Cordilleras in Luzon, Western Visayas, and Northern Mindanao, serving as the hub that connects all pockets of silk cocoon productions within and surrounding the respective

regions. Three (3) Philippine Silk Summits have been annually staged which provided the avenue for conversations, sharing, and exchange of data and best practices among the silk stakeholders even amidst the global health crisis. By silk value chain integration approach, the DOST-PTRI ensures the capability and competence of the Philippine silkworm germplasm and the availability of new community-based silk processing facilities as government interventions that are critically fundamental to supporting the development of the local silk industry. The progress, albeit slow, is a calculated move guaranteeing the successful integration of each domain in the value chain while ensuring inclusivity of key players of the government and non-government sectors and the groundwork in the rural communities. All the collective efforts are aimed to carry off the goal to make Philippine silk an indispensable material source for the local fashion, and the creative industry and to satisfy the mandate for a minimum 5% composition of silk in the Philippine Tropical Fabric (PTF) in government personnel's uniforms.

SECTION 7:

SERICULTURE IN NON-TEXTILE INDUSTRY

Domaine

The silkworms and mulberries for medicals, pharmaceuticals, food, biotechnology, biomaterials.

Chairperson

Dr. Tsunenori KAMEDA

MEET THE CHAIRPERSON

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The National Agriculture and Food Research Organization (NARO) is Japan's largest national research institute for agricultural research, including sericulture. At NARO, research on the advanced utilization of silkworms and research on the creation and evaluation of silk materials are divided into two independent groups to improve the efficiency of research. As the leader of the latter, Silk Materials Research group, I am passionate about research and development of silk biomaterials, high-strength silk materials, functional silk materials, so on. I target not only *B. mori* silkworm silk, but also other insect silk, such as the silk produced by hornets and bagworms. I have made many pioneering achievements especially in the study of hornet silk. Products for nail care made from hornet silk are already on the market in Japan. I am also a professor at Tsukuba University and Kumamoto University and am making efforts to train young silk researchers. For seven years until 2021, I was the leader of an international project to promote sericulture in Kenya. The goal of this project was to build silkworm rearing facility and silk reeling facility for sericulture research in Kenya with Japanese assistance, and to introduce Japanese sericulture technology to Kenya. This great goal has been successfully achieved.

LEAD PAPER:

SILK AS NON-TEXTILE MATERIALS

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ABSTRACT

In recent years, many attentions have been focused on the use of silk for non-textile industries by taking advantage of its excellent environmental affinity, biocompatibility, or molding processability. However, these attentions have not been started recently. In Japan in the 1930s and 1950s, active researches and developments were once carried out so that silk can be used as a variety of materials necessary for daily life and industry besides textiles (Takabayashi *et al.*, *J. Silk Sci. Tech Jpn*, **21**, 49 (2013)). Not only for hats, umbrellas, interiors, but also for sports goods such as tennis and badminton rackets (strings of rackets), and even industrial gears and fishing nets were made of silk. It can be said that pioneering research on the use of silk as a non-textile material in Japan had already been carried out in that period. The reason why such textile silk materials were actively developed in this way was the background of the shortage of material supplies in Japan before and after World War II. It was tried to make up for this shortage of supplies by using silk as a material. As the well-known saying "Necessity is the mother of invention", the "necessity" of having to solve the material supply shortage became the driving force of the "invention" of the new silk material. Recently, global environmental problems may cause new supply shortages not only in Japan but all over the world. Since a strong demand for rapid changes to the society that does not rely on petroleum-derived materials to achieve decarbonization, and the supply of materials commensurate with that is not keeping up. Under these circumstances, interest in the use of silk materials is increasing again. Silk is eco-friendly. Recent silk research as a non-textile material has attracted attention on the following topics: (1) Novel processing into films, gels, nanofibers, nanoparticles, etc., (2) Add functions not found in silk or overcome the weaknesses of silk. In the processing, we consider that it is important to process while maintaining the high molecular weight that silk originally has. In terms of function addition, we have developed technologies such as transgenic technology, genome editing technology, and compounding technology with other polymers or peptides. The presentation will focus on our achievements on these topics.

IMMOBILIZATION AND VISUALIZATION OF FUNCTIONAL PEPTIDES ON SILK FIBROIN-BASED BIOMATERIALS

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ABSTRACT

Bombyx mori silk fibroin-based biomaterials show good biocompatibilities, and they are thought to be useful in the tissue engineering field. Heavy chains of silk fibroin contain highly repetitive crystalline regions and amorphous regions. The secondary structural changes of silk fibroin molecules to □-sheet structure are known to be induced by various stimulations, such as alcohol treatments, heating treatments, pH values and metal ion concentrations. Stimulation-induced structural changes of silk fibroin molecules are thought to contribute the immobilization efficiency of colocalized peptides to silk fibroin-based materials. In this study, our approach to develop functional silk fibroin-based biomaterials is the immobilization of functional peptides to silk fibroin molecules under treatment with alcohol aqueous solutions. Functional peptides containing GAGAGS sequence, one of repetitive sequence in crystalline regions of silk fibroin molecules, were synthesized and immobilized to crystalline regions of silk fibroin-based biomaterials. Analysis of immobilization efficiencies and visualizations of peptides were performed.

STUDIES & EXPERIMENTAL TRIALS ON CARBONIZATION OF SILK FIBROIN AND ITS USE FOR ELECTRONIC TEXTILE AND MANUFACTURING OF COMPOSITE MATERIALS

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ABSTRACT

Recent literature on carbonized silk shows some interesting trends and promising avenues for its products in divergent fields, proving once again the "versatility" of the 'wonder' silk fibre. Few interesting papers on carbonized silk fabric, CSFs, are by C. Wang et al , 2016 on' DOI: 10.1002/adma.201601572 on strain sensors; Hierarchically carbonized silk/ceramic composites by Daiqi Li et al 2021 ceramic precursors as "mullite" composites on https://doi.org/10.1016/j.composiiitesa.2020.106237; Animal silk derived amorphous carbon fibres by Ping Qi et al. Carbonized silk fibre mat on https://doi.org/10.1021/acssuschemeng.1c02857 etc Show evidently of these developments

Generally, carbon fibre, an *electrically conductive property proved fibre,* has literature for its use in *low flexibility, heavy weight, low shear stress-oriented applications*. Hence it cannot be made as a wearable fabric. Due to this limitation; carbonized silk fibre was thought of exploring its very good mechanical properties including its light weight. Silk can be converted into highly electrically conductive material by carbonizing it at very high temperature without impairing its intrinsic properties. The functional property of silk was exploited to develop different products in increasingly expanding Technical Textile applications. This has been successfully done by carbonization of silk fibroin used from mulberry *Bombyx Mori* and its electrical conductivity has been tested which shows good conductivity. In this background, we initiated experimental trials on carbonization of different silk fibres. As per this, we prepared different types of silk materials in the form of raw silk, degummed silk, twisted silk, and ionized silk of three varieties of silk like Mulberry, Tasar, and Eri. The carbonization trails were done using a laboratory model Lenton furnace and quartz tube etc by fine tuning different process parameters under inert gas atmosphere. The temperature gradient was attempted from 800^0C to 1300^{o}C.

We conducted testing for the tensile behavior, electrical conductivity using an ammeter and electrical light glowing circuit etc apart from EDAX and CHN analysis for carbon tests. The utility part of carbonized silk trails on different applications like composites, E-electro medium embedment, stretchable fabrics, electronic textiles, wearable strain sensors etc are being attempted which shows promising trends. The carbonized silk from different sources and methodologies will open up new avenues including Technical Textile oriented applications which are being taken by up as a Mission by Government sector in India.

Keywords: fibroin, degumming, furnace, quartz tubes, carbonization, inert gas, temperature gradient, composites-textiles, strain sensors, pyroproteins.

GREEN SYNTHESIS OF SILVER NANOPARTICLES IN AQUEOUS MEDIUM BY REDUCTION OF SILVER NITRATE BY USING EXCRETA OF *BOMBYX MORI* FOR MEDICAL APPLICATIONS IN WOUND, DENTISTRY HEALING AND DISEASE CONTROL DURING SILKWORM REARING

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ABSTRACT

Silver nano particles (AgNPs) are increasingly used in various fields due to its physical, chemical and biological properties. Silver has been known longer than the recorded history due to its medical and therapeutic benefits before the realization that microbes are agents for infections. In India, Silver has been an age-old traditional medicine material in Ayurveda, Siddha, Unani due to its compatibility to use as sutures colloids, lotions and ointments etc The benefits of silver are more than the risk factors. Biogenic syntheses of silver nano particles using plants and their pharmacological and other potential applications are gaining momentum owing to its assured rewards. In this background, the study was initiated to probe the influence of Mulberry silkworm excreta-oriented treatment.

The excreta of Bombyx Mori were collected from a local farmer' rearing house and it was washed thoroughly, steamed and dried at 60 degrees centigrade. Then the fully dried excreta were made into powder form with the help of a crusher. The powder was then boiled in de-ionized water with a material liquor ratio 2:30. Silver nano particles were synthesized by reducing the precursor silver nitrate 99.9% pure in aqueous medium with the help of excreta of Bombyx Mori. The 0.01 molar solution of silver nitrate was prepared in aqueous medium and used as precursor. The solution became dark reddish brown. Then the solution was filtered three times to get clean solution. This solution was used as reducing and capping agent. The silver nanoparticles synthesized were subjected for UV-Vis, SEM, DLS and XRD tests. The UV-Vis spectrum showed plasmas on resonance peak at 420nm. SEM and DLS study showed the presence of spherical size silver nano particle. The average size was found 60Nm which confirm the presence of AgNO3 as per XRD test. The colloidal solution of the silver nanoparticles was used for antibacterial tests. The zone inhibition test has shown high anti-bacterial properties of the above said nano particles. The sample prepared is under the process of dentistry investigations for invitro evaluation on anti-bacterial activity against S. mutans, S. sobrinus, L. acidophilus, in silcal evaluation of binding energy, invitro evaluation of effectiveness of compound in extracted wound healing and animal study with the help of a Medical Research Institution as per medical protocol guidelines. It is also being

explored the possibility of usage of aqueous AgNO3 solution for reducing secondary infections of Bombyx mori during silkworm rearing.

Keywords: silver nitrate, De-ionized water, litter, synthesis, precursor, aqueous, reducing and capping.

SERICIN IS A GIFT OF NATURE: ITS VALORIZATION

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ABSTRACT

Tasar cocoon cooking wastewater contains major silk waste proteins *i.e*. sericin, which is a valuable raw material for many industries including cosmetics, pharmaceuticals and textiles. Therefore, in the present study, an attempt has been made for the extraction and characterization of sericin from tasar silk industry wastewater for cosmeceutical purposes with an important impact on value addition. The surface morphology of extracted sericin was analyzed by SEM. Characterization of sericin was performed by SDS-PAGE, FTIR, CHNS, TGA and amino acid analyzer. Biological properties such as anti-tyrosinase, anti-elastase, antioxidant potential and moisture absorbing potential were also evaluated. Surface morphology by SEM showed a rough surface along with aggregation of small particles of size around 10µm. Both high and low molecular weight fractions were found in isolated peptides. FTIR spectra confirmed the presence of both secondary structures. Thermal properties were studied by TGA showing a 50% degradation temperature around 590^{o}C. Among 17 amino acids found in tasar sericin, serine, aspartic acid and glycine are predominantly present. Further, various biological properties were also observed in isolated sericin. The present study appears to be helpful in exploiting sericin as potential biomaterial in cosmeceutical and allied fields.

Keywords: *Antheraea mylitta*, biomaterial, wastewater, sericin, tasar silkworm.

A PHYSICO-CHEMICAL STUDY ON SOAP AND COSMETICS ENRICHED WITH SERICIN EXTRACTED FROM MULBERRY SILK COCOONS *BOMBYX MORI* L.

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ABSTRACT

Sericin is an abundant but underutilized waste/by-product of the silk industry. A protein extracted from the silk filament, it accounts for about 25% of total silk weight, the remaining being Fibroin. Often considered as a waste, sericin has many important properties like gelling, moisture absorption, antioxidant and, anti-bacterial. For decades, efforts have been made to utilize sericin to develop into value-added products in the fields like bio-medical, pharmaceutical, cosmetic, and food industries. The biocompatibility, biodegradability and wettability of sericin has facilitated development of cosmetic products also not limiting to skin, nails but for hair also. In Japan, special silkworm races producing high percentage of sericin were reared for studying the properties of sericin for cosmetic use. International market is already flooded with skin care products containing sericin. Realizing the scope, India is also keeping pace with the race. Patents are registered for the use of sericin in preparation of soaps and various skin care formulations. This study was taken up mainly as utilization of sericin can help in generating extra revenue for the stakeholders. Here, mulberry sericin has been standardized to use it as an active ingredient in formulation of bathing soap and few cosmetic products for skin care & hair care *viz*., body lotion, moisturizing cream and hair gel. The skin lotion/body lotion formulated has already passed its required laboratory tests successfully. The effect of mulberry sericin on product properties, stability and sensory parameters has also been studied. With its hygroscopic nature and easy water-solubility, sericin helps the skin to absorb the amino acid present in it. Small addition of sericin in soap and cosmetics can enhance the nutrition and elasticity of the skin. The results of the study also show that the addition of sericin has no negative effect on the skin. It clearly showed the potential of sericin to act as an active ingredient in soaps & cosmetics and thus opening up new vistas for the global cosmetic industry.

Keywords: amino acid, anti-aging, biocompatibility, biodegradability, hygroscopic nature.

POTENTIAL OF SERICIN PEPTIDES FROM *BOMBYX MORI* (NISTARI) AS DRUG DELIVERY MOLECULES: A COMPUTATIONAL ANALYSIS

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ABSTRACT

Sericin produced by *Bombyx mori*, isa globular protein which acts as an adhesive for keeping two fibroin filaments together. Fibroin and sericin are produced in posterior and middle region of silk gland, respectively. The presence of polar amino acids in sericin protein allows crosslinking with other compounds/materials. The present study envisages characterization of sericin protein extracted from *Bombyx mori* cocoons of Nistari breed, a land race of Eastern & Northeastern India. 15 polypeptides ranging between 8-200kDa were observed on SDS-PAGE. Two low molecular weight polypeptides (18 & 25kDa) analyzed by LC-MS/MS and *de novo* sequencing revealed the presence of peptides of Sericin 1, Sericin 1B, Sericin 2 & Sericin 3 along with seroins, serpins and few uncharacterized proteins. Seven peptides of sericin 1 were identified in 18kDa polypeptide; while four peptides in 25kDa polypeptide. These low molecular weight peptides of sericin 1 protein were analysed by I-TASSER for structure prediction and ligand binding sites. The predicted secondary structure of sericin 1 peptide suggested presence of alpha helix and coil. Sericin 1 peptide is serine rich and its predicted solvent solubility (0.498; pI is 6.150) indicated exposed polar amino acid residues and comprises of nine polar amino acids and three ligand binding sites with C-score 0.28. In addition, cell penetrating peptides (CPPs) were predicted in Sericin 1 by MLCPP 2.0 with high uptake efficiency probability of 0.56 and CPP probability of 0.86. Sericin 1 peptide properties based on computational analysis seem promising, which could be explored further as a potential drug delivery molecule.

Keywords: *Bombyx mori*, sericin, peptides, LC-MS/MS, protein *de novo* sequencing, drug delivery

COMPOSITION OF NUTRIENTS AND BIOACTIVE COMPOUNDS IN THE PUPAE OF SILKWORM, *BOMBYX MORI*

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ABSTRACT

The silkworm, *Bombyx mori* pupae, a major by-product of the silk reeling industry, has received a considerable attention in recent years due to the presence of a variety essential nutrients and bioactive compounds. Hence, this study performed a comprehensive analysis of macromolecules, nutrients, anti-nutrients and bioactive compounds in mulberry silkworm pupae using standard protocols, ICP-MS, LC-MS and GC-MS techniques. The crude protein content in dried pupae ranged from 51-55% and contains all the essential amino acids. The proteomic analysis of silkworm pupae by LC-MS/MS detected a total of 5,882 proteins, which are novel uncharacterized, as well as enzymes, storage, membrane, nuclear and mitochondrial proteins, hundreds of these novel proteins could have therapeutic and nutritional value to humans and animals. Lipid content of dried pupae ranged from 25 to 32% and contains 11 kinds of fatty acids with higher levels of α-linolenic acid. Desirable levels of inorganic elements have detected N (~10%), P (~1%), K (2-3%), Ca (0.5-1%), Mg (0.3-0.5%), while Cu, Zn, Fe and Mn are trace amount of pupae and heavy metals such as Pb, Cd, Cr, Ni, As and Co are below the permissible range. Sugar profiling revealed the presence of 15 different sugar molecules, with sorbitol as the main component known to promote digestion and oral health. Silkworm pupae also contain most of the water-soluble and fat-soluble vitamins, including vitamin-C, E, K, D, and vitamin B_{12} forms. Total of 18 different phenolic acid compounds found in pupae with a great deal of ferulic and cinnamic acids and all these compounds known to display several beneficial health effects. Moreover, 15 different flavonoids molecules have detected in pupae, of which luteolin, quercetin, myrcetin, catechin and epicatechin are having anti-cancer, anti-ageing and anti-diabetic properties. Comprehensive nutritional and bioactive molecules analysis of silkworm pupae revealed that the presence of high- value nutrients and bioactive compounds; these compounds have the potential to explore in pharmaceuticals, nutraceuticals, functional foods and feed additives.

PUPAE OF WILD SILKWORM *SATURNIA PYRI* - THIS IS A NEW AND VALUABLE FOOD ADDITIVE IN THE ENTIRE PARAMETER

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ABSTRACT

The article presents the results of the content of the chemical and biochemical composition of the pupa of the wild silkworm *Saturnia pyri* belonging to the family *Saturniidae*, species of Lepidoptera. The nutritional value of silkworm *Saturnia pyri* pupae was evaluated, which contained 51% dry matter, 52.50% crude protein, 27.89% fat, 10.50% chitin fibers, 2.5% ash, 27 macro-, and microelements, and 25 mg alpha tocopherols in 100 g oil. The X-ray fluorescence method was used to determine the content of mineral elements in the pupa of the silkworm *Saturnia pyri*. It was revealed that the pupa of this type of silkworm contains 25 elements, of which the relative amount of K, Mg, Na, Ca, Al is much higher than other elements.

Keywords: giant peacock moth, Aristotle's silkworm, mineral elements, proteins, fat, chitin fiber, ash, vitamin E.

PRODUCT DEVELOPMENT FROM MULBERRY FRUIT JUICE INTO FRUIT INSTANT BY FOAM-MAT DRYING

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ABSTRACT

This research was conducted to produce Mulberry Fruit Instant by Foam-mat Drying. The study of 15 type of foaming agents in cludeing Carboxy methyl cellulose (CMC), Glyceryl monostearate (GMS), Span 60, Methocel, Egg Albumin, CMC mixed with GMS, CMC mixed with Span 60, CMC mixed with Methocel, CMC mixed with Egg albumin, GMS mixed with Span 60, GMS mixed with Methocel, GMS mixed with Egg albumin, Span 60 mixed with Methocel, Span 60 mixed with Egg albumin and Methocel mixed with Egg albumin with the mixing ratio of two substance, which is 1:1 by weight, dissolving in water to receive the concentration of 1%. It was found that the optimal foaming agents is Methocel, the foam is stable and has good properties. Then study the volume of foaming agent and temperature for drying. The experiment was conducted using Factorial 3 x3 in CRD with 2 factors include volume of foaming agent (75, 100, 125%) and temperature (60, 70, 80 °C). It was found that the optimization for foam-mate drying is volume of foaming agent at 75% and temperature at 70°C. It was high productivity, shortest for soluble and good quality of powder. The Mulberry Fruit Instant prototype had water activity of 0.30 ± 0.01, moisture content of 2.79% ± 0.21, phenolic compound content of 203.70 ± 2.45mg/100g, anthocyanin content of 29.50±0.52mg/100g, In addition, Mulberry Fruit Instant had overall preference scores from “moderately like” (6.41 + 1.29)**.** Consumers were acceptance of product 79% and they will buy the product 70%. The product is safe for consumption from both pathogenic and food poisoning microorganisms and consistent with community standards. The predicted shelf life of the product at room temperature (25°C) was 92.58 days and unit cost were 497.50 Baths per box containing 10 packs of 25 g of product.

Keywords: mulberry fruit, mulberry juice, processing, foam-mate, product development.

MULBERRY LEAVES AS PRACTICAL ALTERNATIVE FOR IMPROVING THE QUALITY OF THE HUMAN LIFE

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ABSTRACT

As a new concept, mulberry leaves have been very important during COVID-19 pandemic, as an alternative for decreasing the severity of the SARS-CoV2 infection. The main investigations referred in literature about mulberry leaves for COVID-19 treating will be summarized. The mechanisms of action in human body proposed for mulberry leaves will be discussed. Also, the antiviral activities demonstrated *in vitro* assays will be summarized. The applications of mulberry leaves in Cuba during COVID-19 pandemic will be presented, as well as the variety of products consumed. The Cuban mulberry leaves registered products will be presented. Finally, the impact of mulberry leaves on diabetes mellitus and cardiovascular disorders will be discussed, as an effective alternative for improving the quality of the life around the world.

VALUE ADDITION TO SILK MOTH SCALES THROUGH EXTRACTION AND CHARACTERIZATION OF CHITIN AND CHITOSAN

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ABSTRACT

During the grainage activity in sericulture, the silkworm moth scales will be released into the grainage hall by the fluttering moths. The insect scales are a rich source of chitin. Hence, the scales collection and utilization of silk moth scales for extraction will be of prime importance. The present work aimed to extract chitin from silk moth scales using chemical and microbial methods. Further, chitin was converted into chitosan using chemicals and microbes. The obtained chitin and chitosan were characterized by using Scanning Electron Microscopy (SEM), X-Ray Diffraction studies (XRD), and Dynamic Light Scattering (DLS). Further, the antibacterial potential of the chitin/chitosan isolated from the scales was evaluated against *Bacillus thuringenesis* (silkworm pathogen). The results revealed strong antibacterial activity against test pathogen. The present study confirms that maximum recovery of chitin and chitosan was observed from the microbial method in comparison with the chemical method. The present work emphasizes the conversion of waste material (Silk moth scales) into biomedically and economically important products (Chitin/Chitosan). Further, confirmation of antibacterial activity of chitin/chitosan confirms silkworm scales can be a good source of antimicrobial compounds.

Keywords: silkmoth scales, chitin, byproduct utilization, XRD, SEM, DLS, antibacterial activity.

REPLACEMENT OF FISH MEAL WITH MULBERRY LEAF MEAL IN FRESHWATER ECONOMIC FISH FEED FORMULA

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ABSTRACT

Proximate analysis revealed that the mulberry leaf meal contained crude protein, fat, crude fiber, ash, and gross energy of 20.88%, 4.72%, 14.05%, 12.02% and 4 Kcal/g, respectively. The antioxidant activity of the mulberry leaf extract was evaluated using oxygen radical antioxidant capacity (ORAC). The extract exhibited the varied antioxidant activities of 83,351.3 µmol TE/g DW in ORAC. The minimum inhibitory concentration (MIC) of mulberry leaf ethanolic extracts against *Edwardsiella tarda*, *Aeromonas hydrophila*, and *Plesiomonas shigelloides* were 125, 500, and 500 mg/ml, respectively. The minimum bactericidal concentration (MBC) against *E. tarda* was 1,000 mg/ml. The appropriate replacement level of mulberry leaf meal was 25% and 100% for tilapia and catfish. For mulberry leaf meal fermented, it was successfully replaced fishmeal as 50% and 100% for tilapia and catfish, respectively. Based on these information, mulberry leaf can be useful for fish meal replacement.

Keywords: mulberry leaf, tilapia, striped catfish, replacement, fish meal.

SILK NANOPARTICLES: MORPHOLOGY CONTROL UNDER BULK AND MICROFLUIDIC MIXING REGIMES

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ABSTRACT

Silk is emerging as a promising material for medical applications, including anticancer nanomedicines. One challenge is to develop robust manufacturing protocols. The control of silk fibroin multiscale structure by shear processing is fundamental to the biopolymer function in the natural world anFbacd can be harnessed in nanoprecipitation. This work uses *B. mori* regenerated silk fibroin. We report the modulation of silk fibroin primary–tertiary self-assembly by varying factors which control shear and mixing during nanoprecipitation in semi-batch and micro-mixers. Under high shear regimes and bulk mixing conditions, the size and polydispersity index of assemblies decreased with mixing time, as stirring rate (800, 400 < 0 rpm) and feed addition height (3.5 < 0 cm) increased. Using the optimised conditions for low bulk mixing times, moving from low to high shear processing increased the extent of self-assembly (0.017 < 16.96 mL min-1) for 0.5, 2 and 3% w/v silk. Finally, in conditions of high shear and low mixing time, the feed concentration controlled the assembly shape, size, and polydispersity index in microfluidic (0.5, 3.0 < 2% w/v) and semi-batch format (3.0 < 0.5% w/v). Although the multiscale structure was varied with silk precursor concentration in high shear, fast bulk mixing, mixtures of spherical nanoparticles with nanofiber, lamellar and gel-like assemblies were formed. Due to the sufficiently low micro-mixing times in high shear, microfluidic format, the particle morphology was tuned from monodisperse, worm-like to spherical nanoparticles by increasing concentration from 0.5 to 3% w/v silk precursor. This comparative work provides new insight into morphology control of silk nanoparticles using silk concentration as a controllable input factor.

INCLUSION OF SILKWORM CHRYSALIS MEAL (*BOMBYX MORI L.*) IN DIETS FOR SLOW GROWING BROILERS

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ABSTRACT

The process of obtaining silk generates many by-products, including the chrysalis, a product of excellent nutritional composition, with a high content of protein, ether extract and gross energy, and with good nutritional potential for use in the diets for birds. The objective of the present work was to evaluate the effects of inclusion of silkworm chrysalis meal (*Bombyx mori L.*) in substitution of soybean meal in the diet for slow-growing chickens on performance variables. For that, an assay was carried out using 96 slow-growing chickens (Sasso Ruby N -XL44N strain) with 49 days of age (1543 g ± 35 g of average initial weight), raised in a rearing system in ecological basis and with access to grazing paddocks after 30 days of age. The present study was carried out in August 2020. The birds were evaluated for 21 consecutive days (49 - 70 days of life). The chickens were distributed in a completely randomized design consisting of four treatments and four replicates, containing 6 birds per experimental unit. The experimental diets were formulated to be isoenergetic (3250 kcal/kg) and isoprotein (17.47% CP), with increasing levels (0%, 25%, 50% and 75%) of inclusion of chrysalis flour replacing soybean meal (representing total inclusion levels of 0%, 6.88%, 13.76% and 20.64% of the natural matter), where the birds were evaluated regarding the parameters of average daily weight gain (ADWG), average daily feed intake (ADFI) and feed conversion (CA). The data obtained were submitted to analysis of variance. When a significant effect was found ($P \leq 0.05$), a Tukey test was used to discriminate the means with the use of Statistical Analysis System software. At the end of the production period, ADWG observed was 51.10 g, 48.00 g, 48.60 g and 46.90 g, and FC was 2.82; 2.99; 2.92; and 3.02, both for the inclusion levels of 0, 25, 50 and 75% of chrysalis flour, respectively.

Analyzing the data throughout the experimental period, no difference was identified in ADWG and ADFI, however an increase in FC was identified with 75% inclusion of chrysalis flour, with no differences being observed between the other treatments. We concluded that silkworm chrysalis meal can be used to replace up to 50% of soybean meal (13.76% of the total diet) in the feeding of slow-growing chickens (Sasso Ruby N – strain). XL44N), promoting good growth performance, however, higher levels of inclusion (75%) can lead to an increase in feed conversion. The use of this alternative food in the diet of birds can be financially viable according to the production system and costs of each country.

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SECTION 8:

SILK PROCESSING

Domaine

All the activities in silk processing, import, export, silk consumption, global demand, marketing, and promotion.

Chairperson

Dr. Subhas V Naik

MEET THE CHAIRPERSON

Dr. SUBHAS V. NAIK is a Textile Engineer and has completed Ph.D Degree in Textile Technology. He has worked for 25 years as a Scientist and 7 ½ years as Director, Central Silk Technological Research Institute, Central Silk Board, Ministry of Textiles Govt. of India Bengaluru. He has made significant contribution for the overall development of the silk industry in India including silk processing. He has addressed the issue of self-sufficiency, particularly in production of superior grade raw silk to achieve the VISION OF CSB.

Dr. Naik has carried out 65 Research projects in various capacities as Principal Investigator, Co-investigator and Project co-ordinator in post cocoon areas and the research outcome have significantly contributed for the development of silk industry in India, which includes 650 multiend reeling units and establishment of 146 automatic reeling units for production of superior grade raw silk. Further, he was instrumental in development and popularization of indigenous automatic reeling machinery package under make in India initiative. These efforts have resulted in achieving production of 3A to 4A grade silk from non-gradable silk. This has created significant impact on the livelihood of the stakeholders through enhancing income and socio-economic condition.

His research outputs on cocoon quality evaluation were quite useful for the breeders in developing new silkworm breeds.

Dr. Naik has contributed as a team member for development of Non-Mulberry (Eri, Tasar and Muga) sector by developing cooking technology and machineries for improving the productivity and quality and promoting Eri-wool blends.

Dr. Naik's contribution for silk weaving and silk wet processing for quality and productivity improvement is noteworthy. Further, he has also initiated research on application of silk for the non-textile purpose, in the field of nutraceutical, cosmetics, etc. He has taken leading role in upgradation of the industry with latest technologies and developing the human resources.

LEAD PAPER:

SILK PROCESSING - ADVANCED DEVELOPMENTS

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ABSTRACT

Silk is the most elegant textiles in the world with unparalleled grandeur, natural sheen and inherent affinity for dyes, high absorbance, light weight, soft touch, and high durability and known as the Queen of Textiles the world over. China, India, Uzbekistan, Brazil. Republic of Korea, Thailand, Japan, Vietnam, DPR Korea, Iran etc., are some of the major silk producing countries. Global Silk production is about 91765 MT (2020). India is the second largest producer of silk next to China. Silk is known for its variant colours and designs and wet processing plays a vital role in the marketing of silk. In the recent years, lot of technological developments have taken place both in yarn processing and fabric processing. The present trend in the world silk industry is to look for technologies which gives better quality, productivity with less labour/water/energy requirements. The present need of the industry is usage of the quality dye stuffs, chemicals, trained manpower, modern equipments and hygiene conditions. Acid dyes are dominated and followed by metal complex and reactive dyes. Conventional dyeing with oven heating is replaced with the tub / arm dyeing/pressurised dyeing machinery in case of yarn dyeing. Some of the recent advancements in silk dyeing are Dyeing silk with ultrasound, Application of plasma technology in dyeing, Supercritical carbon dioxide dyeing process, Air dyeing process, Foam dyeing technique and degumming with high temperature and pressure and in this field lot of further research is under progress. The main aim of these advance developments is to reduce / eliminate usage of water and the process chemicals, reduce the energy consumption and pollution and to improve the dyeing quality. In order to enhance the performance of the fabrics, various functional finishing treatment like stain guard/water repellence, antimicrobial, fire retardant and aroma finishing treatment etc., are given to the yarn/fabric, whereas there is scope for further research and improvement in the easy care finish of silk fabrics which is need of the hour. Silk printing is one of the very popular method of creation of designs and there are wide range of traditional and latest techniques used. Traditional printing techniques are retained due to uniqueness in their design art and passion, whereas latest

techniques have to be adopted due to techno-economic advantages. Of late, digital printing is gaining lot of popularity due to its versatility, productivity and quality. In order to broad base the usage of silk and cater to the need of the present demand, various new and diversified products need to be developed. There exists huge scope for using silk for non- textile applications particularly for the development of Sericin and Fibroin based products in the area of Nutraceuticals, Medical and Cosmetics. Silk being highly valued fibre, robust branding and purity /quality assurance system is essential to enhance the confidence of stake holder as well as consumers. Development of uniform universal raw silk testing and grading is essential in order to eliminate confusion in the industry due to different grading system. In order to globalise the silk trade it is essential to strengthen the E-Marketing and forecasting system. Silk being natural eco-friendly fibre with unique characteristics is used entirely for the production of high-quality textiles and hence has a great future.

DEVELOPMENT OF ENZYMATIC FINISHING PROCESS ON TASAR SILK FABRICS TO ENHANCE THE HANDLE PROPERTIES

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ABSTRACT

Tasar silk is known for its unique rustic appearance and niche appeal. Indian tropical tasar silk fabrics generally tend to have rough surface and poor dimensional stability, which is solemn problem for its large-scale application in silken apparels. Present work attempts to address the problem through application of enzymes on tasar silk fabrics as finishing agent, without affecting its colour. Serine protease enzyme readily available through biotechnology companies for textile sector has been used for developing finishing process on the tasar silk fabrics. Tropical × Tropical tasar and Tropical × Temperate tasar fabrics have been used for experimental purpose. The developed enzymatic biofinishing technology on tasar silk has shown significant improvement on lustre, soft feel and comfort properties of tasar fabric through an eco-friendly way, without affecting its strength and colour. Low stress mechanical properties of the untreated and treated fabrics were evaluated using Kawabata Evaluation System (KES). Test results reveal that significant improvement has been observed in the total hand value (THV) of tasar fabric after the enzyme treatment prompting its viability to be used for silk apparel applications.

Keywords: protease enzyme, tropical tasar, lustre, smoothness, fabric handle, shrinkage.

CHARACTERIZATION OF SILK MELANGE YARNS BY IMAGE PROCESSING TECHNIQUE

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ABSTRACT

Melange yarn is a blend of different colour fibres to develop fancy visual peppery effect in the yarn. Difference in the ratio of differently colour fibres blended during spinning process induces the unique melange effect in yarn. These melange yarns have advantages of unique fabric appearance and they can be used in casual wear, sportswear, shirts, business suits, socks and all sorts of cloth products, as well as bed linens, towels, decorative fabrics and other home fabric products. The current apparel trends and fashion developments identify melange yarns as a perfect choice for design promotions due to its unique patterns and colour flexibility. Although melange yarns are being used in textile and apparel sector, characterization of melange effect with respect to its visual effect has not been carried-out. Hence, in this article an attempt has been made to characterize the silk melange yarns through image processing technique. Silk melange yarns have been prepared by wrapping on yarn appearance boards and its high quality images have been captured using a high resolution digital camera. The HD images of the silk melange yarns were then processed (image processing) for colour contrast analyses using Image Colour Extract CoolPHP software. This image processing tool provides ratio of the prominent colours in the given image. Based on the colour percentage of the each colour in the images, Melange Effect Factor has been derived and calculated. Higher the Melange Effect Factor, higher is the visual melange effect obtainable in the fabric. This new method would be very useful for the textile sector to assess the melange yarns available in the field to identify and select the yarns based on Melange Effect Factor as per the needs of the applications.

ECO FRIENDLY DEGUMMING OF ERI SILK FIBRES

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ABSTRACT

Degumming of silk is a process which is performed to remove the sericinacious gum from silk fibres. Degumming is an essential process where about 15 % of sericin gum in eri silk is removed before subjecting eri silk fibres to spinning process. Degumming process facilitates the opening of the eri silk fibrous mass and thereby eases the spinning process. The customary practice adopted by silk industries for degumming is the soap-soda method. This soap-soda degumming method of sericin strip-off is not only harsh on silk fibres but also deteriorates silk fibres strength & elasticity due to uncontrolled alkalinity and also contributes significantly to the effluent load. A new method of degumming eri silk fibres by novel method in eri eco degumming machine with water without using any chemicals has been successfully developed at CSTRI, Central Silk Board, India. This novel approach enhances the productivity due to shorter processing time. Eri cocoons were degummed by this novel method and the results have been compared with different degumming methods *viz*. soap and soda, enzymatic methods. Fibres degummed with novel method at higher temperature of 140^0C for 30 minutes displayed fibrillations in the images signifying excessive degumming causing fibre damage. SEM images displayed best result in treatment samples degummed by novel method in eco eri degumming machine using soft water at temperature of 130℃ and duration of 30 minutes. This novel method of degumming in the Eco Eri Degumming machine at 130^0C for 30 minutes is aiding enhanced productivity in shorter processing time and also ensures uniform softening of eri silk shells. With this novel method, the degumming loss is 15.7%., while soap and soda degumming loss is 14.0% and enzymatic degumming loss is 13.6%. It is very clear from this study that, the novel method of eri silk degumming has the great advantage of totally avoiding the use of chemicals, achieves uniform and effective degumming and takes 1/3rd the duration compared to conventional soap and soda ash method. The SEM images clearly show that both soap and soda method and novel degumming method samples are smooth, show clearer fibre surface images without any depositions on them indicating efficient removal of sericin from eri silk fibres.

EFFECT OF EXTRACTION TECHNIQUE ON THE PROPERTIES OF SERICIN EXTRACTED FROM ORGANICALLY REARED *BOMBYX MORI* SILKWORM COCOONS

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ABSTRACT

The silk protein secreted by *Bombyx mori* silkworm has a core and sheath structure. The fibrous core fibroin is adhered with a globular gummy protein called sericin. Sericin is a by-product of silk processing industry and due to its important valuable properties, it has created niche applications in various unconventional sectors such as cosmetics, nutraceuticals and pharmaceuticals. Sericin is a macromolecular protein whose properties are greatly affected by the technique used for its extraction. Sericin can be extracted from raw silk using various methods. A clear understanding of the effect of extraction conditions on properties of silk sericin is essential with respect to different applications. The present study attempts to extract sericin from organically reared BV *Bombyx mori* cocoons using different methods namely, conventional soap soda method, High temperature high pressure technique, urea method, acid degradation method, alkali degradation method and enzymatic hydrolysis method. The extracted sericin has been studied for its rheological and physiochemical properties. Rheological and gelation studies of the sericin changes with the extraction method and are dependent on molecular weight of sericin. The results of the study show that different technique of extraction provides sericin with different molecular weight. Gelation time and viscosity of the sericin solution is dependent on its range of molecular weight. It is observed that sericin extraction process plays an important role on the characteristics of sericin and thus should be chosen based on the area of application.

SILKWORM *BOMBYX MORI* L. COCOON FINGER PUPPETS: NEW PEDAGOGICAL AID IN EDUCATION

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ABSTRACT

This paper explores and envisages the potential of the 'Silkworm cocoon' of *Bombyx mori* L. in edification. The Sericulture industry is banking on ~18-23 % of silk filament wrapped around each cocoon, leaving the inner shell (~80%) unutilized, which unwraps an enormous opportunity to explore this unique natural material for its qualities and abundance. Puppetry proved to be an efficient tool to improve communication, narrate concepts, increase students' enthusiasm and learning outcomes in education. The finger puppets are relatively modern, naive, and easy to implement among various puppetry types. Design being the strategical lever, Cocoon Finger Puppets (CFP) are designed to offer infinite possibilities across educational stages, aiding pedagogy. In earlier attempts, the cocoons have been employed in crafts, value-added products, and explorations of teaching science. Nevertheless, there is seldom any attempt to use cocoon as the 'primary resource' to design an approach comprehensive to education. We piloted a study, identified a niche, and demonstrated creating exciting CFP through Design Development (DD) process. That involved sourcing locally available cocoons and Designing CFP for extensive references. The DD complements the earlier attempts using Puppetry and advocates a 'material-centric' make and learn a framework to achieve Sustainable Development Goals (SDG) through education. The kinesthetic nature of finger puppetry would be ideal educational aid at foundational and primary teaching. Due to their ease and less effort, are preferent handcrafts among parents, children, and educators; however, making and using puppets are sporadic in educational practices. It would be an inventive learning method supporting mediating interactions at elementary schooling. It would also offer the authentic and experiential opportunity to improve educators' and students' skills, imagination, and collaboration across child-development stages by involving puppet-making and user activity. The cocoons being economical and nature friendly would complement the global efforts towards humankind's inclusive, democratic, and sustainable development goals in a post-industrial creative economy.

Keywords*: Bombyx mori L.*, cocoon crafts, SDGs, finger puppetry, make & learn, handmade-toys.

STUDIES ON EFFECT OF DIFFERENT YARN FINISHES ON COMFORT AND LOW STRESS MECHANICAL PROPERTIES OF LOOM FINISHED FABRICS

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ABSTRACT

In India about 65-70% of silk products produced on hand loom are loom finished fabrics. It is a well known fact that any finish given after fabric is woven leads to disturbance in its structural and also inherent properties. Hence, a finishing treatment was developed and given at yarn stage itself to impart desirable functional properties such as oil and water repellence and anti-microbial finish for the loom finished fabrics. In the present study, the silk yarns were degummed, dyed, and treated with chemicals to impart oil and water repellent (OWR), Antimicrobial (AM) properties, and their combination *i.e.*, OWR&AM. Different fabric samples were woven on handloom using treated yarns and control yarn (*sans* treating). All the samples were analysed for air permeability, water vapour permeation and wicking to address their comfort properties. The results showed that yarn finishes effectively enhanced the above parameters. Further, the low stress tensile, shear, bending, compression and surface properties were analysed using Kawabata evaluation system for fabrics (KES-F). The test results when compared with the control samples, revealed that any treatment imparted at the yarn stage influences most of the properties specifically indicating that yarn finished samples are softer, more elastic with better extensibility & drape, better recovery to bending and hence a better hand value.

Keywords: comfort properties, functional properties, loom finished fabrics, mechanical properties, yarn finish.

STUDIES ON IMPACT OF WET PROCESSING ON QUALITY OF MULBERRY SILK FABRIC

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ABSTRACT

During chemical wet processing of silk fabrics, each processing stage leads to addition of few new characteristics and loss of some prominent properties. An effort has been made in this paper to study the changes in the mechanical as well as low stress mechanical properties that occur during various stages of chemical processing of the silk fabrics. The study also reveals the scope of applying objective measurement technique to quantify the effects of wet finishing treatments on fabric mechanical properties. Raw silk fabrics have been subjected to degumming, bleaching, dyeing, printing and finishing processes as per the standard operating procedure. During each stage, the treated fabric is analysed for its general mechanical and low stress mechanical properties such as tensile, shear, bending and compression using *Kawabata* Evaluation System (KES-F). Results show that during degumming there is significant difference in weight loss which has directly influenced the overall fabric mechanical properties and also has significant influence in the feel of the silk fabric. Effect of dye -fibre interaction during dyeing on the mechanical properties has been interesting. Further, the effect of printing and the extent of loss of mechanical properties have been studied and finally the influence of finishing treatments which were given to enhance aesthetic appeal, functional performance have also been noted. Thus, the study has addressed all the aspects of processing and their overall influence on the quality of silk fabric.

Keywords: comfort properties, dye fibre interaction, finishing treatments, functional performance, mechanical properties.

DEVELOPMENT AND COMMERCIALIZATION OF INDIAN ERI SILK AND WOOL BLENDED YARN FOR WORSTED SUITING FABRICS

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ABSTRACT

Silk is a biodegradable, eco-friendly protein fibre that blends well with wool. Natural protein fibres like wool and silk provide UV protection and anti-carcinogenic properties, among other benefits. Both silk and wool are among the most skin-friendly fibres used in manufacturing suiting fabrics. Out of the many varieties of silk available, Mulberry silk, Eri silk, and Tasar silk are the most common varieties of silk used in the worsted industry. Compared to Mulberry silk at 10.5-11 microns and Tasar silk at 27-30 microns, Eri silk is 16-19 microns and more compatible blending with wool. The major consumption of wool falls primarily between 18.2 - 22.5 microns. The very fine micron of Mulberry silk makes it very difficult to spin with blended wool because of inherent ball formation or pilling problems in worsted systems. Mulberry silk is usually blended with cotton and spun in a short-staple system. Tasar is very coarse in microns and has a weaker dye affinity than Eri silk. The Eri silk cocoon and fibre are primarily white, are compatible with average wool microns used in the worsted industry and exhibit similar dye affinity to wool fibre. This reduces the dyeing time of Eri silk and wool blend compared to Tasar silk and wool blend for dark and extra dark shades. Mulberry silk cannot be blended with wool as it has very fine microns and will generate more neps during the process, causing the yarn to become more hairy. Based on the fineness of different silks, the products are designed accordingly to meet the hand feel and drape requirements for shirting, suiting, and other dress material in the woven and knit area. Thus, Mulberry silk (10.5-11 micron) filament and fibre are used primarily in women's Sarees, Shirts, Neckties, Pillow covers, and fine Curtain Cloth. Eri silk (16-19 micron) and its blended yarn products are used for various suiting fabrics and fillings for quilts. The Indian Tasar is used for a medium range of shawls, Khadi products which are hand spun and handwoven. We at Raymond spin 2/60 Nm yarn containing 52 % Eri Silk and 48 % 21-micron wool following the top dyed route of the worsted system for making suiting fabrics and its commercialization. In terms of fineness and imperfection, the yarn quality met the specified requirements and was superior to blends made from imported Tasar silk from China, whose micron ranges from 27 to 29. A wide variety of silk wool-blended worsted suiting fabrics with different patterns and colors having 200 to 225 GSM are regularly manufactured and sold in the Indian domestic market and overseas market.

Keywords: silk, wool, protein fibre, blending, worsted

GENERIC PROMOTION AND PRODUCT DIVERSIFICATION: A KEY FOR GROWTH OF GLOBAL SILK INDUSTRY: QUEST OF SILK MARK LABELLING OF SILK PRODUCTS IN INDIA

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ABSTRACT

In an era of eco-friendly textiles, consumer demand for natural-fiber based textile products is ever increasing. Silk fiber as a "Queen of textiles", scores the highest points in terms of functional, aesthetic, comfort, safety and ecological properties. However, growth prospects for production of silk puts pressure on cultivable land meant for food crops and labor-intensive cultural operations put limitations as labour cost is increasing in the sericultural nations. Hence, vertical expansion through enhanced productivity, income generation per unit of land and mechanization are most sought after aspects. Due to perpetual increase in the cost of silk products, the consumption of silk for traditional silk items, as was the practice in the past, is giving way to new generation consumer items with diversified products often utilizing silk-imitation synthetic fibres. It is therefore necessary to look at ways and means to address generic promotion of silk, design of newer products as per emerging market forces both domestically and international is the soul-searching strategies to be evolved by sericulture and silk industry-based nations for the growth prospects. In addition, the product integrity of pure-silk to reinforce confidence in genuine silk consumers is equally important for enlarging the silk users base in the market. This is all the more important due to mushrooming of manmade fibers glittering like silk but lacking sanctity of pure silk. Silk Mark labelling of products as prime fiber label of pure natural silk at premises gives an edge in enlarging the consumer base. Based on the experience of about two decades of implementation of Silk Mark labelling, a number of measures to plug the loopholes in the Silk Mark labelling schemes have been introduced. In this pursuit, some of the initiatives taken by India and our experiences especially in the pandemic period are described. It is a long journey to reach self sufficiency in satiating the consumer market, but the beginning has been made with substantial progress. With environmentally conscious consumers growing prime natural fiber family, natural silk gets its due share with newer generation and diversified product mix. It is hoped that as one of the driving factors among the three i.e.; vertical expansion to augment productivity and quality, product diversification and generic promotion through silk mark labelling as market access tool, initiatives by Silk Mark Organization of India would serve as growth promoter of silk Industry globally in general and in India in particular.

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