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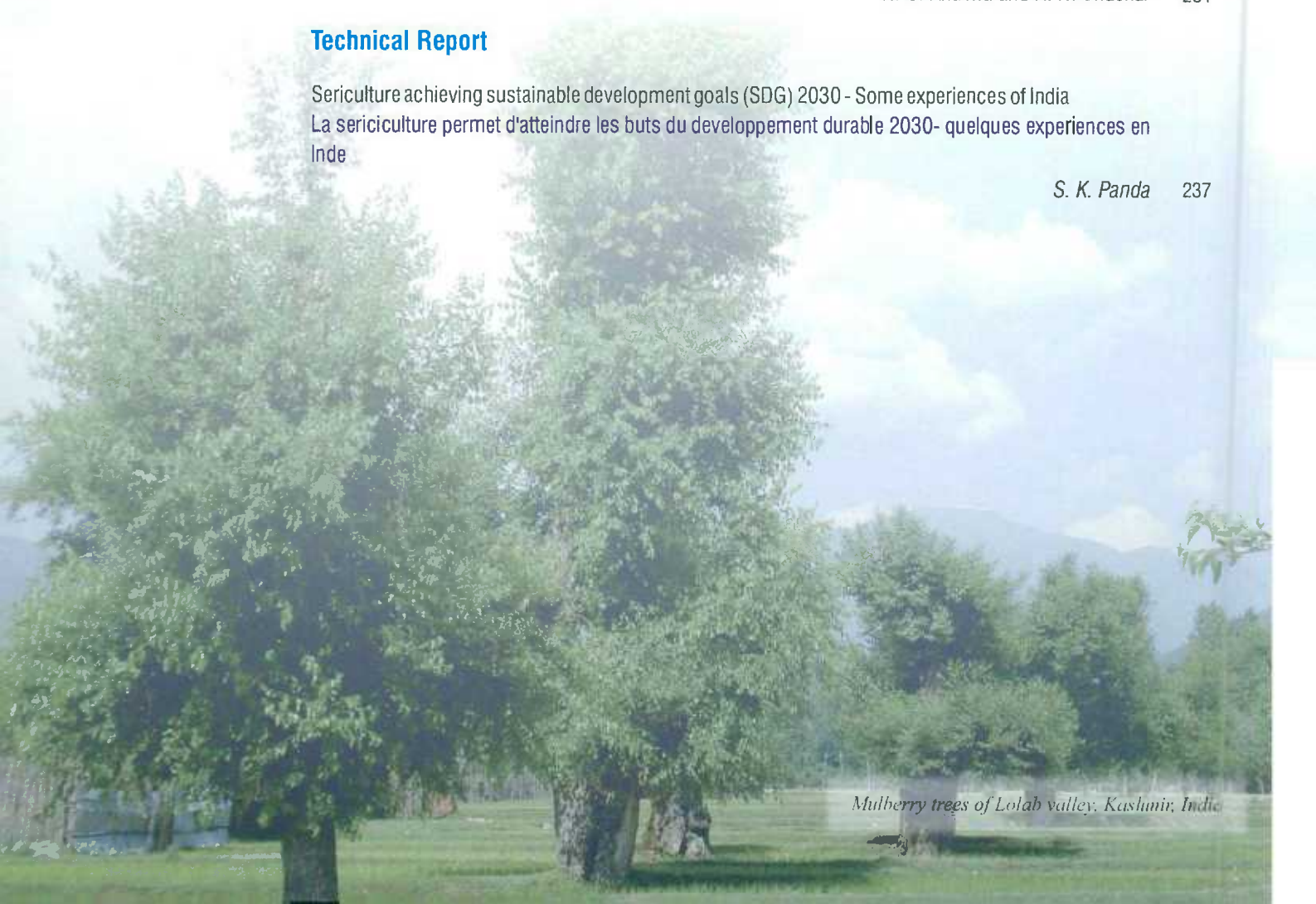
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GENETIC IMPROVEMENT OF MULBERRY IN INDIA: CHALLENGES AND PROSPECTS

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ABSTRACT

Mulberry (*Morus* spp.), belonging to the order, Rosales and family, Moraceae, has received much attention because of its economic and medicinal value, as well as its role in ecological conservation. It is a perennial tree having high heterozygosity due to out breeding reproductive system. In India, mulberry is mainly cultivated for its leaf to rear the silk producing caterpillar, *Bombyx mori* L. Considerable efforts have been made to improve the yield and quality of mulberry leaf through both conventional breeding and modern biotechnological methods. A number of varieties were developed in India during the last 40 years through conventional breeding. Authorization of mulberry varieties through All India Coordinated Experiment is a relatively new concept in India and so far, 18 mulberry varieties have been authorized for commercial use under this system, based on their suitability to different agro-climatic conditions. The newly authorized mulberry varieties under ideal cultural and climatic conditions have leaf yield potential of 55-60 Mt/ha/yr. In addition to the above, several mulberry varieties have been developed for different agro-climatic regions with specific requirements. Conventional breeding method has contributed much to the sericulture industry, though it is tedious, labour intensive and time taking, as it takes more than 15-20 years to develop a variety. Nonetheless, need is felt to bring down the time required for developing a variety and also to develop varieties with specific traits, using modern biotechnological methods. Molecular marker technology has to be adopted at a faster pace for comprehensive characterization of the genetic resources, precise selection of parents and their offsprings. Transgenesis is another area which is being used for the genetic improvement of mulberry. Using genetic engineering, transgenic mulberry tolerant to drought has been developed. Tissue culture has also been used effectively for rapid and efficient screening of germplasm for stress tolerance. This paper enumerates the problems, challenges and constraints faced and achievements obtained in the field of mulberry breeding along with an account on recent advances made in the areas of biotechnology and molecular biology to enable mulberry breeders to tackle specific problems more systematically and effectively.

Key words: Breeding, mulberry, sericulture.

INTRODUCTION

Mulberry (*Morus* spp.; family: Moraceae) is one of the economically important trees that is being grown widely in Asian countries including China, India, Bangladesh, Korea, Thailand and Pakistan where sericulture is one of the important sources of employment for the rural folks. As mulberry leaf is the sole feed available for the

silkworm, *Bombyx mori* L., it becomes one of the vital components of sericulture industry in the world. Additionally, mulberry provides a number of benefits to the mankind in the form of fruits and medicines (Chang *et al.*, 2011; Sharma *et al.*, 2013). Being a perennial tree crop with a crop cycle of over 50 years, mulberry helps conserve soil and water and enhances biodiversity by providing shelter to shade loving plants, and food to birds

and small animals. It is believed that mulberry has originated in the Northern hemisphere, particularly in the Himalayan foothills, and later spread into the tropics of Southern hemisphere (Benavides *et al.*, 1994; Hou, 1994). Today, it is present in all regions between 50°N Lat. and 10°S Lat. (Yokoyama, 1962), from sea level to altitudes as high as 4000 m (Machii *et al.*, 1999), including Asia, Europe, North and South America and Africa.

The taxonomy of mulberry is highly complicated due to the presence of large number of natural hybrids. Nonetheless, according to the widely accepted classification of Koidzumi (1917), the genus *Morus* is divided into two sections, the *Dolichostylae* (long style) and the *Macromorus* (short style), and each section is again divided into two groups, namely Papillosae and Pubescentae, based on the nature of stigmatic hairs. A total of 24 species and one subspecies were recognized in this classification (Table 1). Out of these species, a few, such as *M. alba*, *M. indica*, *M. bombycis*, *M. latifolia* and *M. multicaulis* are being used in sericulture while others are left unutilized because of the less palatability of the leaf. Cytologically, mulberry exists in different ploidy levels ranging from diploids (2x, 2n=28), triploids (3x, 3n=42; *M. bombycis*), tetraploids (4x, 4n=56; *M. laevigata*, *M. cathayana* and *M. boninensis*), hexaploids (6x, 6n=84; *M. serrata* and *M. tiliaefolia*), octaploids (8x, 8n=112; *M. cathayana*) to docosaploids (22x, 22n=308; *M. nigra*) (Basavaiah *et al.*, 1989). Presence of natural haploid (*M. notabilis*) with 14 chromosomes was also reported (Maode *et al.*, 1996).

Mulberry breeding in India

Mulberry breeding in India has mainly been targeting to develop mulberry varieties capable of producing higher quantity of superior quality leaf for silkworm rearing. Since mulberry leaf productivity is a multifactorial trait that depends on a number of quantitative traits such as plant height, number of branches, nodal length, leaf size and weight, total biomass *etc.* (Vijayan *et al.*, 1997; Tikader *et al.*, 2009), efforts were made to improve each

Table 1: Mulberry species recognized by Koidzumi (1917)

Sl. No.	Species	Sl. No.	Species
1	<i>M. bombycis</i> Koidz.	13	<i>M. latifolia</i> Poir.
2	<i>M. alba</i> L.	14	<i>M. acidosa</i> Griff.
3	<i>M. indica</i> L.	15	<i>M. rotundiloba</i> Koidz.
4	<i>M. kagayamae</i> Koidz.	16	<i>M. notabilis</i> C. K. Schn.
5	<i>M. boninensis</i> Koidz.	17	<i>M. nigriformis</i> Koidz.
6	<i>M. atropurpurea</i> Roxb.	18	<i>M. serrata</i> Roxb.
7	<i>M. laevigata</i> Wall.	19	<i>M. nigra</i> L.
8	<i>M. formosensis</i> Hotta	20	<i>M. rubra</i> L.
9	<i>M. mesozygia</i> Stapf.	21	<i>M. celtidifolia</i> Kunth
10	<i>M. cathayana</i> Hemsl.	22	<i>M. tiliaefolia</i> Makino
11	<i>M. microphylla</i> Bickl.	23	<i>M. macroura</i> Miq.
12	<i>M. rabica</i> Koidz.	24	<i>M. multicaulis</i> Perr.

of these characters. Traditionally, cultivar development in mulberry is centered on exploration and collections of local ecotypes and cultivars, screening them in field trials for performance and geographic adaptation, and then releasing the best accession as a new cultivar (Datta, 2000).

Since mulberry is a cross-pollinated perennial plant with long juvenile period, traditional breeding methodologies mostly relied on the production of F₁ hybrid cultivars (Das, 1984). F₁ hybrids are obtained either through controlled crossing or by collecting open pollinated seeds from selected female parents. The seedlings are subjected to intensive selection pressure and the best ones are selected through a multi-level screening and selection process (Figure 1) which include testing them in primary yield trial, final yield trial and multi-locational yield trial (Vijayan, 2010). Using these breeding methods, a few improved mulberry varieties have been evolved and authorized for commercial exploitation (Table 2) and also a few others released to cultivate in specific areas (Table 3). Thus, the breeding efforts made during the last half a century have resulted in the production of a number of varieties that could increase the leaf yield from 8-10 Mt/ha/yr in cultivars viz., Kajli to 44-45 Mt/ha/yr in S-1635 in West Bengal and 30-35 Mt.

Table 2: Mulberry varieties authorized for commercial use in India

Variety	Region / Zone	Parentage	Cultivation condition
G4	Southern Zone	<i>M. multicaulis</i> x S-13	Irrigated
C2038	Eastern Zone	CF1 x C763	Irrigated
Tr-23	Hilly areas of Eastern Zone	T25 x S162	Rainfed
Vishala	All India	Clonal selection from farmers' field	Irrigated
S1635	All India	OPH from CSRS-1	Irrigated
V1	South Zone	S30 x Ber-C776 (Black cherry x <i>M. Multicaulis</i>)	Irrigated
Anantha	South Zone	Selection from RFS-135 (OPH of K2)	Irrigated
DD (Viswa)	South Zone	Clonal selection	Irrigated
S13	South Zone	Mixed pollen progeny (K2 OPH)	Irrigated
S34	South Zone	S30 x Ber-C776	Rainfed
S36	South Zone	EMS induced mutant of B'local	Rainfed
S1	Eastern Zone	OPH from Mandalaya (<i>M. alba</i>)	All conditions
S799	Central India	OPH from local variety	Irrigated
BC ₅ 59	Hilly area	Berhampore local x Kosan	Rainfed
S146	Hilly area	OPH	Rainfed
Tr-10	Hilly area	T25 x S162	Rainfed
Chak Majra	Northern Zone	Local selection	Rainfed
Chinese white	Northern Zone	Clonal selection	Rainfed

Table 3: Mulberry varieties developed to meet the requirement of specific regions in India

Variety	Progenitor	Pedigree	Recommended area
C2020	CSRTI, Berhampore	CW x S1532	Water logged areas
C2017	CSRTI, Berhampore	Hosur local x S162	Irrigated
C1730	CSRTI, Berhampore	T25 x S-162	Moisture stressed
G2	CSRTI, Mysuru	<i>M. multicaulis</i> x S-34	Irrigated soil (chawki garden)
AR12	CSRTI, Mysuru	OPH-K2	Alkaline affected
RC1	CSRTI, Mysuru	Punjab local x Kosan	Resource constraints
Suvarna-1	KSSRDI, Thalaghattapura	M-5 x Mysore local	Southern red soil regions
PPR-1	CSRTI, Pampore	Gosheorami x China white	Temperate region

ha / yr in Kanva-2 to 65-70 Mt/ ha/yr in V-1 in southern states (Jalaja *et al.*, 1994).

Need of mulberry varieties with higher yield potential and greater plasticity

The recent economic and industrial boom and

consequent urbanization has affected sericulture dearly. Additionally, the global warming and sharp climatic changes due to phenomena, such as El Nino, demand development of mulberry varieties with high resilience for sustainable sericulture. As per the planning commission, India has 15 well demarcated agro-climatic zones (Alagh *et al.*, 1989). It is a known factor that varieties developed

under particular climatic conditions may not perform well in other regions and conditions. Therefore, to suit to each of these divergent regions, varieties with varying adaptability and potentiality have to be developed to make sericulture a sustainable occupation in India.

Genetic resources and their significance

Genetic resources are the raw materials that breeders use for developing new varieties and it consists of diverse types of collections such as primitive cultivars, natural hybrids, wild and weedy relatives, wild species, obsolete varieties, elite lines, breeding lines, mutants and polyploids and systematically developed inter specific and intergeneric hybrids (Haussmann *et al.*, 2004). Central Sericultural Germplasm Resources Centre (CSGRC), Hosur, Tamil Nadu is the main repository of mulberry genetic resources in India where it maintains 1269 accessions *viz.*, 999 indigenous and 270 exotic accessions belonging to 16 different *Morus* species collected from 27 countries (Table 4). These genetic resources have been well characterized using important morphological, physiological, biochemical and anatomical characters and it is found that among the well recognized 16 *Morus* species, a few wild species *viz.*, *M. laevigata* and *M. serrata* with excellent agronomical properties along with genes for resistance to salt, drought and cold *etc.*, are available (Tikader and Dandin, 2005). Among these accessions, a few are from extreme cold regions of Ladakh, Meghalaya, Arunachal Pradesh and Himachal Pradesh (Rao *et al.*, 2005) and another set is from extreme dry hot arid region of Rajasthan, Uttar Pradesh, Madhya Pradesh and Bihar (Rao *et al.*, 2011), yet another set is from coastal areas, such as Andaman and Nicobar Island, Tamil Nadu, Andhra Pradesh and Kerala. The genetic resources are being conserved in four different ways, such as *in situ* conservation, *ex situ* conservation, *in vitro* conservation and DNA banking. The merits and demerits of these techniques are described in Table 5.

Characterization of mulberry germplasm

Characterization of mulberry genetic resources is the process by which mulberry accessions are identified or differentiated from other accessions through a set of

Table 4: Country-wise mulberry germplasm accessions being maintained at CSGRC Hosur

Country	No. of accessions
Afghanistan	2
Australia	2
Bangladesh	5
China	53
Cyprus	1
Egypt	3
France	32
Hungary	1
India	999
Indonesia	6
Italy	7
Japan	70
Myanmar	7
Pakistan	8
Papua New Guinea	1
Paraguay	4
Philippines	1
Portugal	1
Russia	1
South Korea	6
Spain	2
Thailand	11
Turkey	1
USA	2
Venezuela	1
Vietnam	3
Zimbabwe	11
Unidentified	28
Total	1269

characters that are highly heritable, easily observable and environmentally less influenced. In the traditional method of characterization, a list of morphological characters is used for describing and distinguishing an accession. However, most of the morphological characters vary greatly depending upon the developmental stage,

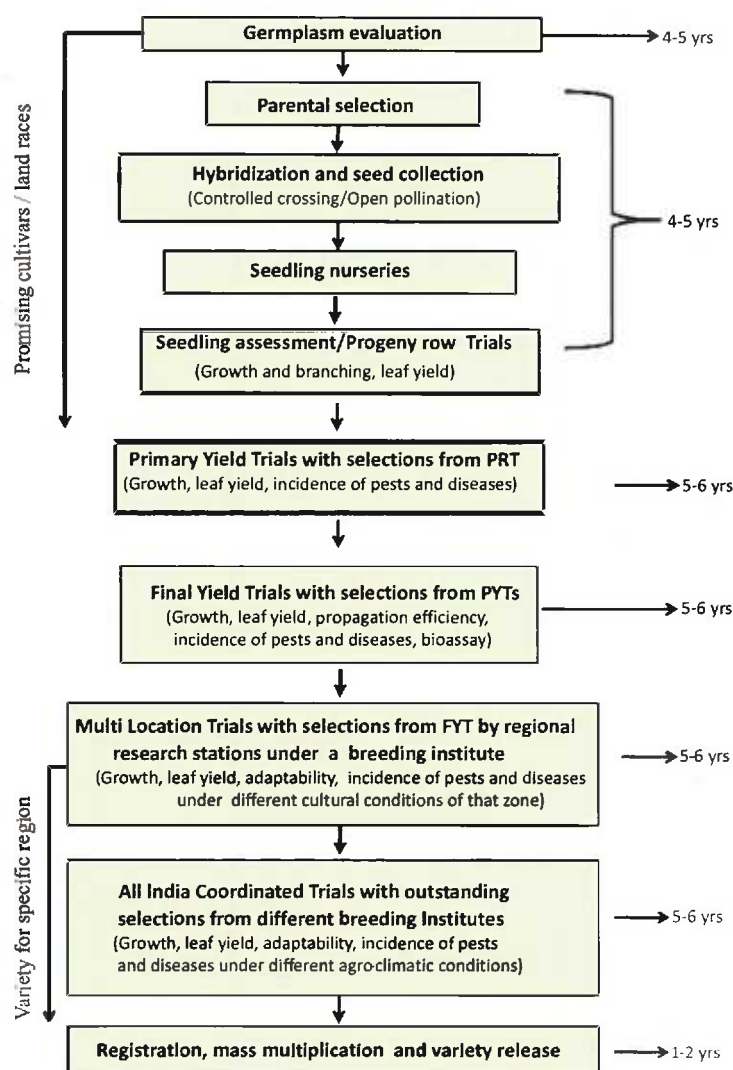


Figure 1: General breeding strategy in mulberry

environmental conditions and the intuition of the researcher (Vijayan *et al.*, 2009 b). Because most of the morphological traits are quantitative in nature, the perception and categorization may vary with persons. With the advancement of molecular biology, DNA markers have been used for genetic characterization of mulberry germplasm using Random Amplified Polymorphic DNA (RAPD), inter simple sequence repeats (ISSR), Simple sequence repeat (SSR) and Amplified Fragment Length Polymorphism (AFLP) (Sharma *et al.*, 2000; Srivastava *et al.*, 2004; Vijayan,

2004, 2010; Vijayan *et al.*, 2004, 2005, 2006 a, b). Characterization with stable and robust markers have helped not only in identifying duplicates but also in utilizing the germplasm effectively and efficiently in crop improvement program through selection of appropriate parents.

Conventional breeding and constraints

As stated elsewhere, traditional breeding methods have made it possible to develop a number of mulberry varieties

Table 5: Merits and demerits of different methods used for conserving the genetic resources of vegetatively propagated plants

<i>In situ</i>	<i>Ex situ</i>	<i>In vitro</i>	DNA banking
Apt for forest species and wild crop relatives.	Only option for the asexually reproducing plants.	Suitable for both sexually and asexually reproducing plants.	Suitable for both sexually and asexually reproducing plants.
Field oriented, laborious and expensive.	Field oriented, laborious and expensive.	Laboratory oriented, minimum space and less laborious.	Laboratory oriented, minimum space and less laborious.
Allows evolution to continue.	Evolution restricted.	No chance of evolution.	No chance of evolution.
Increases genetic diversity.	Less prone to genetic variability.	No genetic variation.	No genetic variation.
Vulnerable to disease and other natural calamities.	Vulnerable to disease and other natural calamities.	Well protected against disease and other natural calamities.	Well protected against disease and other natural calamities.
Strengthens the link between conservationists and local people who traditionally maintain the plant.	Minimum interactions.	No interactions.	No interactions.
Exchange of materials is difficult.	Exchange of materials possible but needs extra care.	Easy exchange of materials.	Easy exchange of materials.

Table 6: Transgenesis in mulberry for abiotic stress tolerance (adopted from Vijayan *et al.*, 2011)

Gene*	Expression profile	Reference
<i>WAP21</i>	Cold tolerance	Ukaji <i>et al.</i> (1999)
<i>COR</i>	Cold tolerance	Ukaji <i>et al.</i> (2001)
<i>AlaBib</i>	Salinity tolerance	Wang <i>et al.</i> (2003)
<i>OC</i>	Insect resistance	Wang <i>et al.</i> (2003)
<i>SHN 1</i>	Drought tolerance	Aharoni <i>et al.</i> (2004)
<i>HVA1</i>	Drought and salinity stress	Lal <i>et al.</i> (2008)
<i>bch</i>	Drought and salinity stress	Khurana (2010)
<i>NHX</i>	Drought and salinity stress	Khurana (2010)
<i>Osmotin</i>	Drought and salinity stress	Das <i>et al.</i> (2011)

**AlaBib*- Soyabean glycine gene; *bch*-L inhibitor 2-aminobicyclo-(2, 2, 1)-heptane-2-carboxylic acid; *COR*-cold on regulation; *HVA1*-*Hevea brasiliensis* abiotic stress gene; *NHX*- Na⁺/H⁺ exchanger; *OC*- osteocalcin; *Osmotin*-osmotic stress induced gene; *SHN 1*-schnurri from *Drosophila melanogaster*; *WAP21*- water allocation plan.

with better genetic potential to suit the need of specific regions and requirement like young age silkworm rearing *etc.* However, traditional breeding of mulberry has a number of constraints such as the high heterozygosity of the parental materials, little information on heritability and combining abilities, long juvenile period, excessive time requirement for variety development, genetic drag *etc.* To overcome these challenges and constraints, conventional breeding methods are to be complimented with modern molecular biological tools.

Modern technologies

Tissue culture for improvement

Tissue culture has been used extensively in mulberry for various purposes. Micro-propagation is adopted to propagate the hard to root mulberry genotypes (Figure 2), through culturing shoot tips and nodal segments of juvenile or adult shoots of current year growth with dormant axillary buds (Bhau and Wakhlu, 2001; Vijayan *et al.*, 2011). Organogenesis via callus formation (Figure 3) has also been established to develop new plantlets from important genotypes and also to isolate beneficial plants (Narayan *et al.*, 1989; Jain and Datta, 1992; Susheelamma *et al.*, 1996). A somaclonal variant with higher branching and leaf yield potential was isolated from plants regenerated from a popular cultivar, S1 and testing of it in the field showed drought resistance as well (Narayan *et al.*, 1993; Chakraborti *et al.*, 1999). Another application of tissue culture in mulberry genetic improvement is to screen germplasm resources for stress tolerance. Using axillary bud growth, Hossain *et al.* (1991) and Vijayan *et al.* (2009 a) isolated salt tolerant genotypes from germplasm accessions while Tewary *et al.* (2000) did it for drought tolerance. Tissue culture techniques have also been used for induction of tetraploids (Chakraborti *et al.*, 1998), artificial seed synthesis (Chand *et al.*, 1994) and development of triploids from endosperm tissues (Thomas *et al.*, 2000).

Marker assisted selection breeding

Since phenotypic markers rely to a great extent on the environmental and developmental factors for their

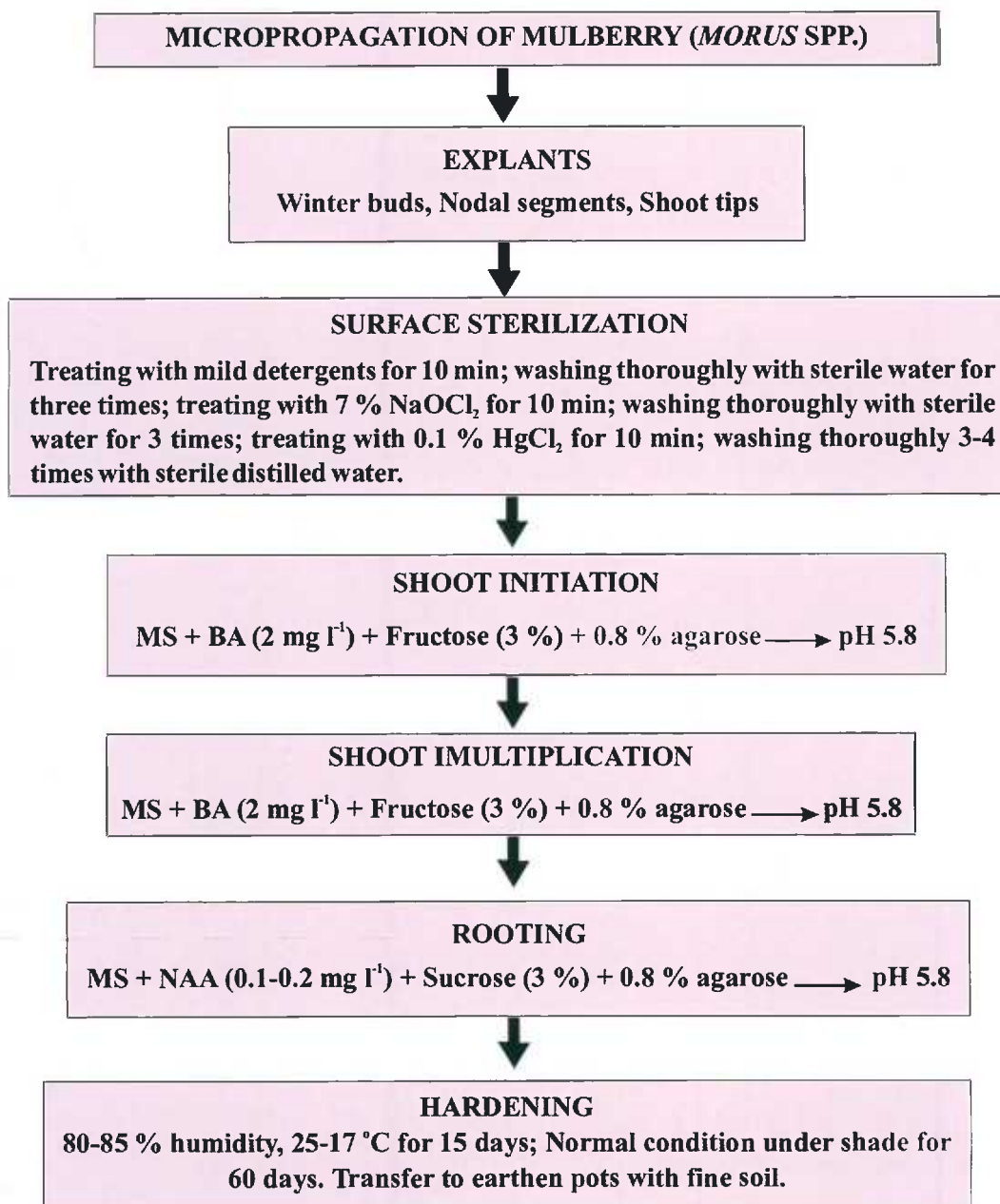


Figure 2: Schematic representation of the procedures of micropropagation in mulberry

expression, it is not appropriate to depend on them fully for assessment of the genetic diversity among the germplasm accessions and selection of appropriate parents. Thus, in order to evaluate the genetic resources, environmentally insensitive, developmentally stable, reproducible, easy to define, unbiased, numerous, and ubiquitous markers are needed especially for a tree crop like mulberry (Vijayan *et al.*, 2006 b). Thus, DNA

markers have been developed and are being used for the purpose. The most commonly used molecular markers in mulberry are RAPD (Srivastava *et al.*, 2004), AFLP (Wang and Yu, 2001) and ISSR (Vijayan *et al.*, 2005, 2006 b ; Zhao *et al.*, 2006). A few examples of the molecular marker utilization in germplasm assessment are, genetic divergence among 34 indigenous mulberry accessions was worked out and the genetically distant parents with

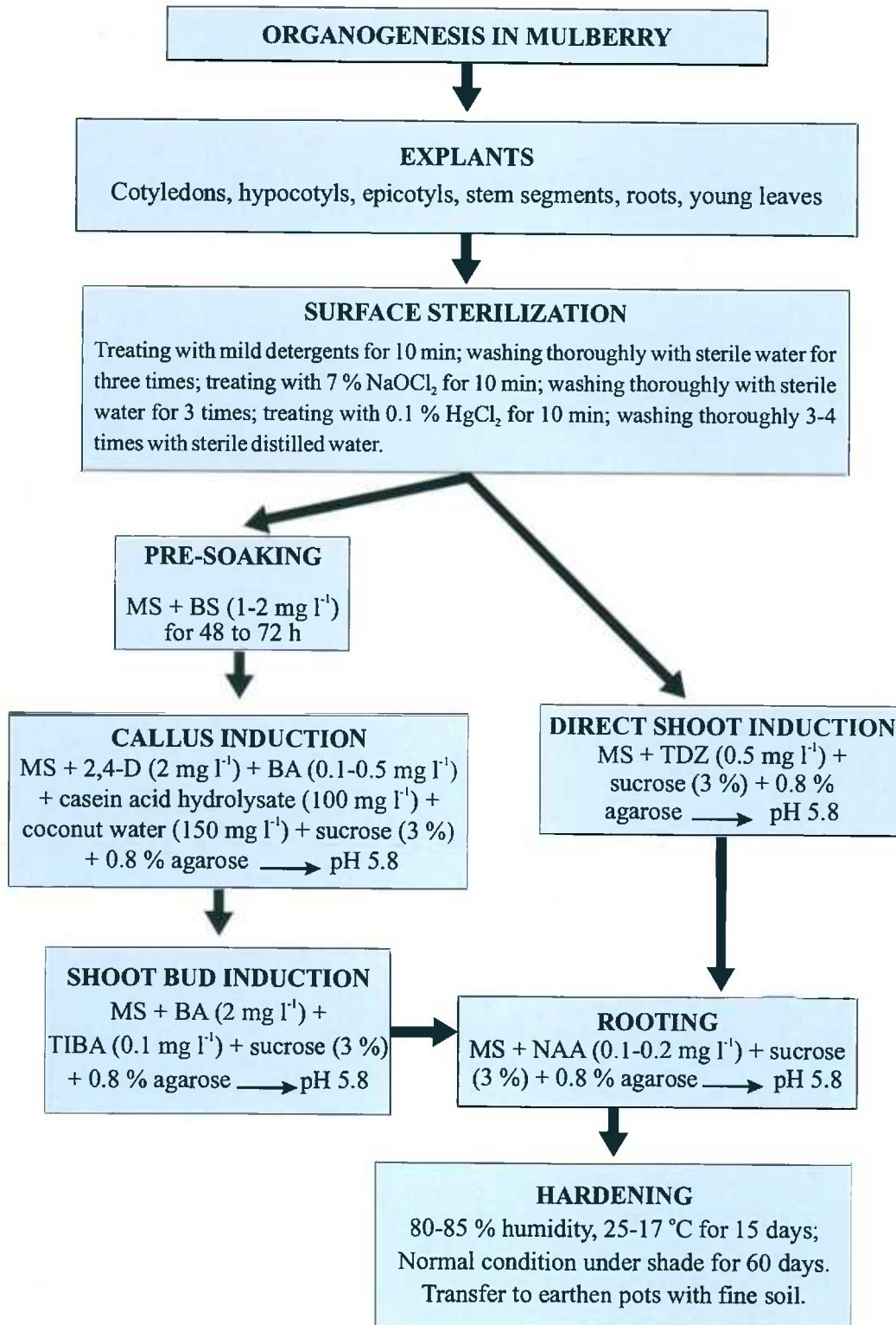


Figure 3: Schematic representation of the procedures of organogenesis in mulberry

better economic traits were identified for breeding purposes (Vijayan *et al.*, 2005), genetic divergence among 16 populations of the Himalayan mulberry species (*M. serrata*) was worked out for better utilization in breeding as well as formulating conservation strategies (Vijayan *et al.*, 2004). Since, RAPD and ISSR marker systems are reported to have problems of reproducibility, more stable and robust SSR marker systems were developed (Agarwal and Udaykumar, 2004). Using SSR markers, hybrid nature of a few genotypes and genetic diversity among mulberry germplasm as well as other related species were worked out (Mishra *et al.*, 2010; Mathithumilan *et al.*, 2013; Arora *et al.*, 2014). Thus, at present, the mulberry breeders can use these marker systems for their breeding programs to identify appropriate parents and hybrids.

Marker assisted selection (MAS) breeding is the most sought after technology in breeding as it aids the breeder to select precisely and much faster than the conventional breeding techniques. However, the pre-requisite for marker assisted selection breeding is the availability of molecular markers that are tightly associated with traits of interest. In mulberry, even though much efforts have been made, only a little information has been generated so far, on QTL-marker association that could be used in breeding programs. However, using multiple regression analysis of molecular markers from germplasm accessions, several putative molecular markers associated with several important agronomic and biochemical characters have been identified (Vijayan and Chatterjee, 2003; Vijayan *et al.*, 2006 a, 2009 a; Kar *et al.*, 2007). These markers have to be validated for their true association and inheritance, before being used for MAS.

Genetic engineering

Genetic engineering has recently made inroads into mulberry genetic improvement. Protocols have been developed for plant regeneration from explants and insertion of desired genes into the plant genome via *Agrobacterium tumefaciens* (Chitra *et al.*, 2014) and particle bombardment mediated methods (Bhatnagar *et*

al., 2002, 2003). Transgenic mulberry plants with several desired genes (Table 6) have been developed (Lal *et al.*, 2008) and are being tested to assess their suitability for silkworm rearing.

Conclusions and prospects

Thus, over the years, conventional breeding has made considerable achievement in mulberry by developing varieties with high leaf yield, wider adaptability, better leaf quality, and suitable to specific cultural practices. However, the changing climatic conditions, shrinkage of arable lands, labor shortage *etc.*, necessitates development of new high yielding mulberry varieties with greater resilience. The high heterozygosity and out-breeding reproductive system and lack of information on genetics of mulberry remain the major constraints to the mulberry breeders. Recent advancements in biological tools and techniques have armed the geneticists and breeders with new tools to tackle some of these perennial problems. Characterization of germplasm with molecular markers enables selection of parents with wider genetic differences and desirable traits. DNA markers tightly associated with desirable traits are handy for earlier identification of hybrids with desirable gene combinations. Genetic engineering is another potential tool that can be used for mulberry genetic improvement. Thus, concerted efforts are to be made to integrate conventional breeding with advanced technological developments to hasten varietal development in mulberry for better sustainability and profitability of silk industry in India.

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Revue

AMELIORATION GENETIQUE DU MURIER EN INDE: DEFIS ET PERSPECTIVES

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ABSTRACT

Le mûrier (*Morus* spp.), appartenant à l'ordre des Rosales et à la famille des Moraceae, a été l'objet de beaucoup d'attentions en raison de sa valeur économique et médicinale ainsi que de son rôle dans la préservation écologique. C'est un arbre pérenne présentant une forte hétérozygotie due à sa reproduction ouverte. En Inde, il est principalement cultivé pour sa feuille qui permet d'élever des chenilles productrices de soie. Des efforts considérables ont été consentis afin d'améliorer le rendement et la qualité de la feuille avec des croisements conventionnels et des méthodes biotechnologiques modernes. Un nombre de variétés ont été développées en Inde au cours des 40 dernières années grâce aux croisements conventionnels. L'autorisation de variétés par le All India Coordinated Experiment est un concept est relativement nouveau en Inde et jusqu'à aujourd'hui 18 variétés ont été autorisées pour usage commercial par ce système basé sur l'adéquation aux différentes conditions agro-climatiques. Les variétés nouvellement autorisées sous des conditions culturelles et climatiques idéales ont un potentiel de production de 55-60 t/ha/an. De plus, plusieurs variétés ont été développées pour différentes régions agro-climatiques avec des nécessités spécifiques. La méthode conventionnelle de croisements a contribué grandement au développement de la sériciculture malgré sa difficulté, sa demande de main-d'œuvre et sa durée puisqu'il faut 20-25 ans pour obtenir une variété. Le besoin se fait sentir de réduire le temps nécessaire à l'obtention d'une variété avec des caractères spécifiques en utilisant des méthodes biotechnologiques modernes. Le marquage moléculaire doit être adopté pour réduire le temps nécessaire à la caractérisation complète des ressources génétiques, une sélection précise des parents et des descendants. La transgénèse doit être également utilisée pour l'amélioration génétique du mûrier. En utilisant l'ingénierie génétique des mûriers transgéniques tolérant la sécheresse ont été développés. La culture de tissus a également contribué au triage rapide et efficace des banques génétiques pour la tolérance au stress. Notre article passe en revue les problèmes, les défis et les contraintes ainsi que les réalisations obtenues dans le domaine du croisement du mûrier ainsi que les avancées récentes réalisées avec les biotechnologies et la biologie moléculaire pour permettre aux obtenteurs de résoudre les problèmes spécifiques plus systématiquement et efficacement.

Mots-clés: Croisement, mûrier, sériciculture.



Research Paper

INCIDENCE, DISTRIBUTION AND MANAGEMENT OF ROOT ROT DISEASE OF MULBERRY IN SERICULTURE PRACTICING AREAS OF KASHMIR, INDIA

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ABSTRACT

Root rot is one of the major economically important diseases of mulberry which affects its leaf quality and quantity. The present study was taken up during 2016-17 to assess the incidence and distribution of the disease and to develop appropriate management measures against root rot pathogens in sericulture practicing areas of Kashmir, India. The disease incidence recorded in various systems, locations and varieties differed significantly from each other. Bush plantation exhibited the maximum (27.13 %) and tall plantation, the minimum (3.62 %) disease incidence. Maximum (19.99 %) disease incidence was recorded in the variety Chinese white at mulberry farm, Kupwara and minimum (6.23 %) in Gosheorami at mulberry farm, Central Sericultural Research and Training Institute (CSRTI), Pampore. The root rot causing fungi were isolated from infected plant parts and identified based on morphological and cultural characters as *Fusarium oxysporum* and *Rhizoctonia solani*. The efficacy of different biocontrol agents and fungicides against the root rot infected mulberry saplings varied significantly. The highest degree of survival of saplings was recorded with Navinya and Carbendazim which were significantly superior to other treatments. It is concluded from the present study that Navinya and Carbendazim can effectively be utilized as components of Integrated Disease Management (IDM) package against root rot disease of mulberry in Kashmir, India.

Key words: *Fusarium oxysporum*, mulberry, Navinya, *Rhizoctonia solani*, root rot.

INTRODUCTION

Mulberry (*Morus* spp.; Family : Moraceae) is the sole food plant for silkworm, *Bombyx mori* L. (Lepidoptera: Bombycidae) which feeds exclusively on its leaves. The mulberry diseases have been reported to cause 5 to 10 % loss in leaf yield by defoliation and an additional loss of 20 to 25 % by deterioration in leaf quality (Sukumar and Padma, 1999). Compared to foliar diseases, the soil borne diseases are more serious due to perennial nature of the crop and soil borne habitat of the pathogens. Among the soil borne diseases, the root rot is considered worse because of its potentiality to cause sudden leaf withering, defoliation and subsequent death of the mulberry plants

(Govindaiah *et al.*, 2005). The root starts decaying due to the fungal infection. The fungal mycelia and spores are seen just below the root epidermis. The severely affected plants loose adherence to the soil and entire root system gets decayed leading to death of plants. The saplings raised for grafting of the commercially important cultivars and also saplings planted in the field fail because of the root rot disease. Even sudden death of the older plantations, irrespective of age and system has been reported due to root rot disease (Munshi *et al.*, 2009).

The root rot disease has been a major problem encountered in mulberry cultivation in many sericultural countries *viz.*, India, Japan, China, Russia and Thailand

(Philip *et al.*, 1995, 1997; Sukumar and Padma, 1999). Manmohan and Govindaiah (2014) reported the root rot disease incidence of 6.60 – 47.60 % in major mulberry growing areas of Karnataka, India. Jammu & Kashmir state is traditionally known for producing high quality bivoltine silk due to its favorable climatic conditions. In Jammu & Kashmir, mulberry is cultivated on about 3,178 acres of land under farms / blocks / departmental nurseries with 30,455 silkworm rearers of 2836 villages (J & K Economic Status, 2014-15) and many marginal class families depend exclusively on earnings from sericulture for their livelihood. However, the occurrence of diseases is one of the major constraints in speedy popularization of sericulture and superior quality mulberry leaf production (Munshi *et al.*, 2009). The incidence of root rot disease was 16.85 % during 2001-02 in Kashmir valley (Anonymous, 2002). However, considering the importance of the crop and severity of the disease, no in-depth studies have been conducted on root rot pathogens of mulberry in this part of the country. In accordance with this, the present study was planned to determine the incidence and distribution of the root rot disease followed by development of suitable management practices in sericulture practicing areas of Kashmir, India.

MATERIALS AND METHODS

Incidence and distribution of root rot disease of mulberry

Periodical surveys of the major sericulture practicing/mulberry growing areas of Kashmir were conducted during the years 2016-17 to ascertain the status of root rot disease of mulberry in the region. Fifteen major mulberry farms / nurseries were randomly selected with 5 from each region (North, Central and South Kashmir). Five plots in each type of plantation system *viz.*, tree, dwarf, bush and sapling were selected randomly at each location and the disease incidence was recorded using the following formula (Mayee and Datar, 1986).

$$\text{Disease incidence (\%)} = \frac{\text{Number of infected plants}}{\text{Total number of plants examined}} \times 100$$

After proper evaluation, the plants showing disease symptoms such as wilting and rotting were collected, bagged separately in perforated polythene bags and brought to the laboratory for isolation and identification of the associated pathogen.

Isolation and identification of causal organisms associated with the root rot disease of mulberry

Fungal pathogens were isolated from the infected plant parts of mulberry collected during the course of surveys. Bits of approximately 2-3 mm in size were cut at the junction of the diseased and healthy portion of the infected tissue with the help of sterile blade. The bits were surface sterilized in 0.1 per cent mercuric chloride (HgCl₂) solution for 30 seconds followed by three consecutive washings in sterile distilled water and then dried on a sterilized blotter paper. The bits were aseptically transferred to Petri plates containing Potato Dextrose Agar (PDA) medium amended with Streptomycin and incubated at 25 ± 2 °C for the growth of fungus. The fungal growth obtained from the diseased tissues was purified by single hyphal tip method (Hansen, 1926). Stock cultures were made on PDA slants in the tubes and were sub cultured at 15 days interval. Identification of isolated fungi was done through Koch's postulates and by studying their cultural and morphological characters as per the methods described by Sutthisa *et al.* (2010) and Dar *et al.* (2011).

Management of root rot disease of mulberry

The experiment was conducted by planting fresh cuttings of mulberry variety cv. Chinese white in polyethylene bags (20 × 10 cm) filled with infected soil at the mulberry research farm of CSRTI, Pampore. The infected soil was prepared by mixing sterilized soil mixture (Sand: Soil : FYM in the ratio of 6:3:1) with one month old culture of test fungus *i.e.*, *Fusarium oxysporum* @ 4 × 10⁴ conidia/ml of water. Six biocontrol agents (0.2%) and two chemicals (0.1 %) were evaluated for the management of root rot disease of mulberry. The microbial antagonists were obtained from Sher-e-Kashmir University of Agricultural Sciences and Technology,

Kashmir. The fungal antagonists were mass multiplied on overnight soaked maize grains which were pre-boiled, sterilized and supplemented with 33 per cent sand. The Erlenmeyer flasks containing 300 g maize grains were autoclaved at 15 psi for 1 h and inoculated with six 5 mm actively growing discs from 7 day old culture of the selected antagonist. The flasks were incubated at $25 \pm 2^\circ\text{C}$ for 25 days to obtain complete fungal colonization of grains. The flasks were shaken regularly to ensure thorough colonization. After the grains were well colonized, the inoculum was air dried in shade, broken apart into individual grains, placed in plastic bags and stored at 4°C until further use. Navinya (0.2 %) a target specific plant based formulation (Herbal; 80 % & Chemicals 20 %) developed by CSRTI, Mysuru was also used as one of the treatments. The treatments were repeated thrice at one month interval, starting from the date of planting the cuttings. The experiment consisted of 10 treatments each replicated 3 times and for each replication, nine polyethylene bags were kept, each with single cutting. The control set was treated with sterilized distilled water. The survival percentage of cuttings on 60, 90 and 150 days after planting (DAP) was recorded. The percentage survival was calculated by the formula,

$$\text{Per cent survival of cuttings} = \frac{\text{Number of cuttings survived}}{\text{Total number of cuttings planted}} \times 100$$

STATISTICAL ANALYSES

The comparison of data on disease incidence between systems of plantation, varieties and locations and their interaction effect was done through three-way factor analysis. The correlation and regression analysis was done between disease incidence and weather parameters. The data on efficacy of bio-control agents and fungicides on the survival of cuttings were subjected to one way ANOVA.

RESULTS

The study revealed that the root rot disease of mulberry was prevalent in all the mulberry farms and in all types of

plantations in Kashmir valley (Figure 1, A, B). Significant differences were observed in the degree of disease incidence among the systems of plantations, varieties and locations. Bush plantation exhibited the maximum (27.13%) and tall plantation, the minimum (3.62 %) disease incidence. Maximum (19.99 %) disease incidence was recorded in the variety Chinese white at mulberry farm, Kupwara and minimum (6.23 %) in Gosheorami at mulberry farm, CSRTI, Pampore. The mean disease incidence recorded in dwarf plantation and two year saplings was 9.80 % and 5.48 %, respectively. The interaction effects between system of plantation $\times$ variety, system of plantation $\times$ location, variety $\times$ location and among system of plantation $\times$ variety $\times$ location were all significant. Based on morphological and cultural characters, the fungi associated with root rot disease of mulberry in Kashmir valley were identified as *Fusarium oxysporum* Schlecht (Division: Ascomycota; Family: Nectriaceae) and *Rhizoctonia solani* Kuhn (Division: Basidiomycota; Family: Ceratobasidiaceae) (Figure 1 C, D, E and F). The pathogenicity of both the pathogens was confirmed through Koch's postulates and symptoms typical to root rot disease were observed. The *F. oxysporum* was found the most dominant root rot pathogen in Kashmir valley as it was isolated from nearly 65 % of the samples. It was found that the maximum disease development occurred during the months of June to August and minimum, during the months of March and November. The study revealed that the disease incidence (%) had a significant and positive correlation with maximum and minimum temperature and soil moisture. Correlation of disease incidence (%) with relative humidity and rainfall were non-significant (Table 1). The regression analysis revealed that the coefficient of determination between disease incidence (%) and maximum and minimum temperature, soil moisture, relative humidity and rainfall was 82.90 %.

The data presented in Table 2 indicated that all the biocontrol agents and fungicides have increased the survival of cuttings in infected soil as compared to control. The highest survival of 86.42 % and 83.50 % was recorded against Navinya and Carbendazim, respectively at 150

Table 1: Correlation matrix and regression line showing relationship between root rot disease incidence of mulberry and various abiotic factors during April to October, 2016 at CSRTI, Pampore

	Temperature (Max.) °C	Temperature (Min.) °C	Mean R. H. (%)	Rainfall (mm)	Soil moisture
Disease incidence (%)	0.652*	0.549*	0.125	0.442	0.532*

* Correlation is significant at 0.05 level

Regression Line:

$$Y = 17.84 + 0.326 X_1 + 0.310 X_2 + 0.217 X_3 + 0.146 X_4 + 0.321 X_5$$

Where, Y: Disease incidence (%), X1: T (max.), X2: T (min.), X3: R.H., X4: Rainfall, X5: Soil moisture; $R^2 = 0.829$ **Table 2: Effect of various biocontrol agents and fungicides on the survival of mulberry saplings of variety Chinese White in *F. oxysporum* infected soil**

Treatment	Survival (%)		
	60 DAP	90 DAP	150 DAP
<i>T. roseum</i>	59.30 ± 2.75	54.72 ± 2.54	52.33 ± 2.51
<i>T. viridae</i>	68.30 ± 3.27	61.39 ± 2.77	59.39 ± 2.89
<i>T. harzianum</i>	67.30 ± 2.98	62.31 ± 2.79	56.72 ± 2.86
<i>F. fluorescens</i>	56.00 ± 2.72	47.75 ± 2.42	43.47 ± 2.27
<i>B. thuringiensis</i>	67.04 ± 2.80	59.00 ± 2.76	55.02 ± 2.68
<i>P. varioti</i>	65.00 ± 2.73	59.32 ± 2.74	59.06 ± 2.87
Navinya	89.25 ± 3.91	88.45 ± 3.32	86.42 ± 3.02
Carbendazim	87.53 ± 3.82	87.13 ± 3.36	83.50 ± 2.97
Dithane M-45	70.31 ± 2.88	69.33 ± 2.88	67.03 ± 2.91
Control	29.13 ± 1.12	18.62 ± 1.05	17.89 ± 1.02
F/d/p	9.065/10/0.013	11.273/10/0.006	11.876/10/0.003

days after planting. Navinya and Carbendazim were followed by Dithane M-45 (67.03 %), *Trichoderma viridae* (59.39 %), *Paecilomyces varioti* (59.06 %), *Trichoderma harzianum* (56.72 %), *Bacillus thuringiensis* (55.02 %), *Trichoderma roseum* (52.33 %) and *Pseudomonas fluorescens* (43.47 %).

DISCUSSION

Root rot is considered as a serious disease of mulberry throughout the Kashmir valley. The root-rotted plants are usually smaller, less vigorous and are found to produce fewer and small leaves than healthy plants of same age. The leaves appear yellow and roots turn into dark brown / black / violet in colour and the infected plants are easy to uproot. Considering the importance of the crop and

severity of the disease, the above study was proposed to record the incidence of root rot disease in mulberry and to develop suitable management measures against root rot disease in major sericulture practicing areas of Kashmir. The results revealed that the system of plantation, location and variety have profound influence on the disease incidence. The maximum disease incidence of 27.13 % was recorded in bush followed by dwarf and tall plantation. The disease incidence of 5.48 % was observed in saplings. The predisposing factors for the development of root rot disease are high moisture and low organic matter. The maximum disease incidence in bush system was attributed to high level of moisture due to closer spacing (0.9 × 0.9 m) and low cut plantation (length of main stem less than 50 cm). Among the surveyed farms,

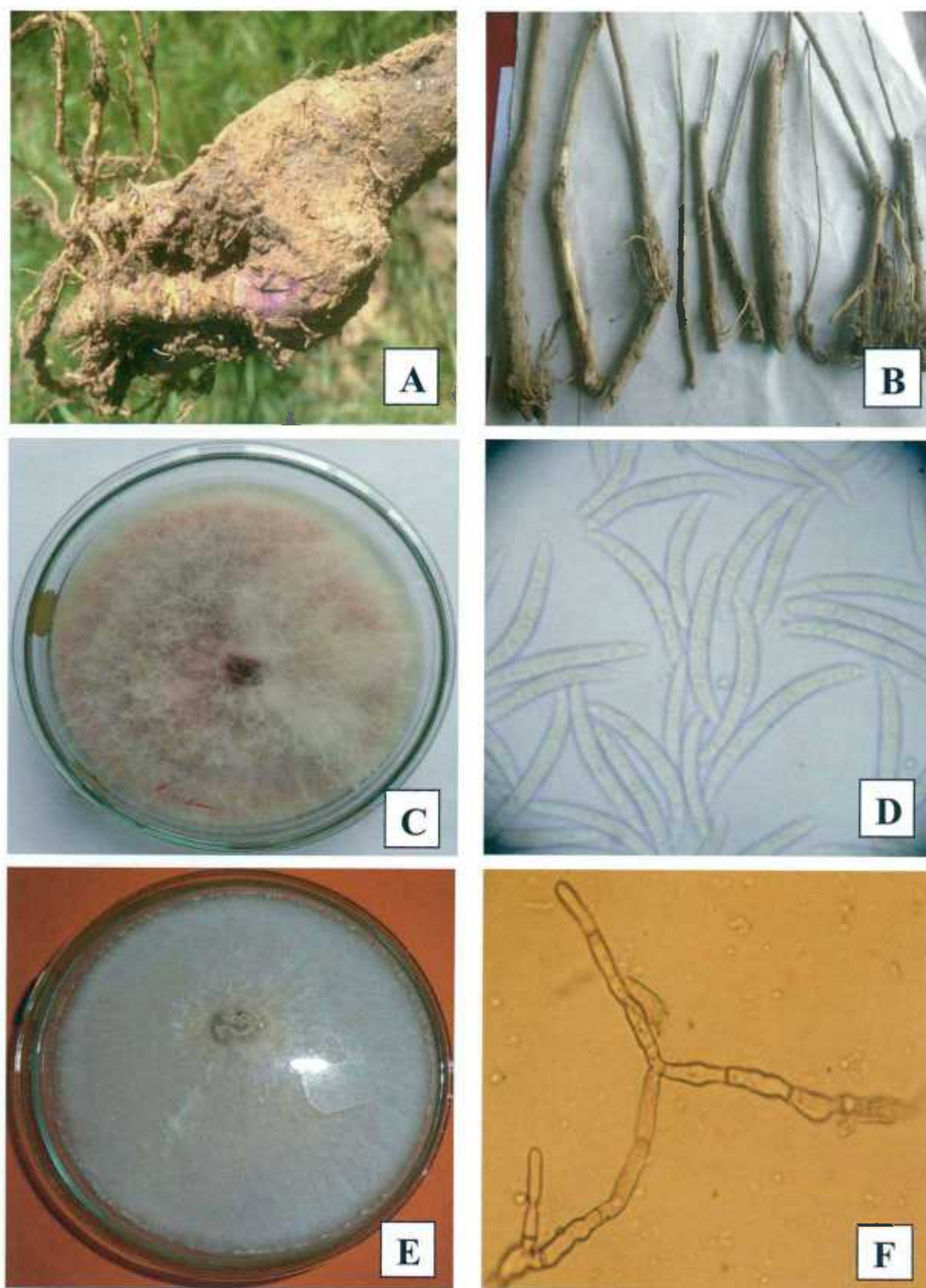


Figure 1: Symptoms and causative pathogens of root rot disease of mulberry

A, B: Below ground symptoms of root rot disease of mulberry; C, D: *F. oxysporum* colony and microscopic view;
E, F: *R. solani* colony and microscopic view.

the disease incidence was maximum in variety Chinese white at mulberry farm, Kupwara and minimum, in Gosheorami at mulberry farm, CSRTI, Pampore. The high disease incidence in the farms was attributed to the dense plantation and the low organic matter and the varietal specificity might be attributed to the genetic makeup. The causal organisms of the root rot disease were identified by their morphological and cultural characters and comparisons were made with standard authentic description from the literature. The pathogens were identified as *F. oxysporum* and *R. solani*. Among these, *F. oxysporum* is more alarming due to the ability to thrive well in soil and fast spread of disease besides absence of disease resistant varieties and inadequate control measures against this disease (Vineet *et al.*, 1998). There was a significant and positive correlation between disease incidence and maximum and minimum temperature. The correlations between disease incidence and other meteorological parameters viz., rainfall and relative humidity were positive but non-significant. Further, a significant positive correlation was observed between disease incidence and soil moisture.

The efficacy of different biocontrol agents and fungicides against the root rot infected mulberry saplings varied significantly. Overall comparison of treatments revealed that Navinya and Carbendazim were significantly superior to all other treatments. The descending order of the effect of other treatments on the survival of mulberry saplings was Dithane M-45 > *T. viridae* > *P. varioti* > *T. harzianum* > *B. thuringiensis* > *T. roseum* > *P. fluorescens*. The control saplings recorded an average survival of 17.89 % at 150 days after planting. It was found that the disease can be controlled effectively by the application of Navinya - a target specific plant based formulation developed by CSRTI, Mysuru. The fungicides inhibit fungal growth by damaging cell membranes, inactivating critical enzymes or proteins and interfering with key metabolic processes e.g., respiration (Qin *et al.*, 2016). The reduction in root rot disease by biocontrol agents is due to antagonistic potential and production of lytic enzymes (Iqbal *et al.*, 1994; Michrina *et al.*, 1995; Singh *et al.*, 2004; Beevi and Qadri, 2010). It

is concluded from the present study that Navinya and Carbendazim can effectively be utilized for the development of Integrated Disease Management (IDM) package for the management of root rot disease of mulberry in Kashmir.

ACKNOWLEDGEMENT

The authors are grateful to the Director, CSRTI, Pampore for suggestions and guidance during the course of investigation and to the Director (Tech), Central Silk Board, Bengaluru for support. Our sincere thanks are also due to the Central Silk Board, Ministry of Textiles, Government of India for funding, encouragement and co-operation.

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Article scientifique

INCIDENCE, DISTRIBUTION ET GESTION DE LA ROUILLE DE LA RACINE DU MURIER DANS LES ZONES PRATIQUANT LA SERICICULTURE DU CASHMIRE EN INDE

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ABSTRACT

La rouille de la racine est l'une des maladies les plus importantes économiquement parmi les maladies du mûrier qui affecte la qualité et la quantité de ses feuilles. Notre étude a été réalisée en 2016-17 pour déterminer l'incidence et la distribution de la maladie afin de développer une gestion appropriée contre les pathogènes de la rouille de la racine dans les zones pratiquant la sériciculture au Cachemire en Inde. L'incidence enregistrée dans des systèmes, des localités et des variétés diffèrent significativement de l'un à l'autre. La plantation en buissons donne l'incidence maximale (27,13 %) et la plantation arbustive la minimale (3,62 %). L'incidence maximale de la maladie est observée avec la variété Chinese white (19,99 %) à la ferme de Kupwara et la minimale (6,23 %) à la ferme de Gosheorami du CSRTI de Pampore. Les champignons responsables de la rouille ont été isolés des plantes infectées et identifiés par leur morphologie et leurs caractères cultureux comme étant *Fusarium oxysporum* et *Rhizoctonia solani*. L'efficacité des agents de bio-contrôle et des fongicides contre la rouille des boutures de mûrier varie significativement. Le plus fort degré de survie des boutures est obtenu avec Navinya et la Carbendazime. Nous concluons que ces deux produits peuvent être utilisés efficacement comme composants d'une gestion intégrée de la maladie contre la rouille de la racine chez le mûrier au Cachemire en Inde.

Mots-clés: *Fusarium oxysporum*, mûrier, Navinya, *Rhizoctonia solani*, rouille de la racine.



STANDARDIZATION OF PROCESS PARAMETERS FOR IMPROVING THE BULKINESS OF SILK FABRICS BY CHEMICAL TREATMENT USING BOX AND BEHNKEN EXPERIMENTAL METHODOLOGY

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ABSTRACT

This study was taken up with an aim to introduce bulkiness in the raw silk fabrics through chemical treatment. A suitable chemical that can impart swelling to silk fabric was used to obtain bulkiness in the bivoltine raw silk fabrics. In the Box-Behnken method of experimental design used here, 15 different combinations were formed to standardize the process variables viz., temperature, duration and concentration of chemical treatment. The bulky raw silk fabric thus produced was characterized for various physical, mechanical and comfort properties using standard testing procedures. The results indicate that the crease recovery and bending length were significantly influenced by the temperature and duration of the treatment and concentration of chemical. The study indicates that the bivoltine raw silk fabric can be imparted bulkiness through chemical treatment.

Key words: Bending length, bivoltine raw silk fabric, chemical treatment, crease recovery angle, crimp, silk swelling.

INTRODUCTION

Silk is the most beautiful of all natural fibers. The characteristics of raw silk viz., softness, luster, durability, elegance, smooth texture and mechanical strength have made it the queen of fabrics for many centuries. The comfort properties make the fabric a pride possession. There has been continuous demand for bulky silk fabric so that raw silk can have better comfort properties. Preliminary studies carried out in Japan by Natsuki Ikegami *et al.* (1998 a, b) for assembled degummed silk using braiding machine did not show significant difference but the bulkiness increased after treatment. Central Silk Technological Research Institute (CSTRI), Bengaluru has developed a methodology to impart bulkiness in twisted raw silk and standardized the process variables using box and behnken experimental methodology as reported by Hariraj *et al.* (2015). In continuation with this work, the chemical treatment was tried on the fabric samples to impart bulkiness and to study the fabric characteristics.

MATERIALS AND METHODS

Raw material: Bivoltine raw silk fabric produced with standard process parameters were used for the study. The twisted silk possessing single ply was used as warp and 4 ply was used as weft. The experimental fabric weighed 55 grams per square meter.

Chemical treatment for imparting bulkiness: The filament yarns can be crimped by means of chemical treatment. This has the effect of modifying the geometry and structural properties of filament or in other words, geometric shape of the filaments is deformed by either bending them or inserting crimps, coils, and curls into them by a number of means to provide a higher specific volume to the yarns. In this work, an attempt was made to introduce bulk structure in bivoltine raw silk fabric by treating it with calcium nitrate.

Design of experiment: The bivoltine raw silk fabric was subjected to chemical treatment with varying temperature,

durations and different chemical concentrations using calcium nitrate solution (Table 1). Based on the design of experiments, the actual factors used for the experiment and the coded factors are presented in Table 2.

Standard test methods to study the physical, mechanical and comfort properties of fabrics: The chemically treated fabrics of different combinations were tested following the standard testing procedures for various characteristics viz., threads in cloths IS 1963:1981, count of warp / weft IS 3442:1980, crimp percentage of warp / weft IS 1963:1981, tensile strength IS 1969:1985, crease recovery IS 4681:1981, flexural rigidity ASTM D 1388-96, option A, drape coefficient percentage IS 8357:1977, air permeability IS 11056:1984 and fabric thickness IS 7702:1975 (Book of standards, 1952-1968).

Table 1: Raw materials, chemical and parameters used for the study

Raw material	Bivoltine raw silk fabric
Chemical	Calcium nitrate
Temperature	70, 75, 80 °C
Duration of treatment	3, 6, 9 minutes
Concentration	1, 5.5, 10 %
Data collected	EPI, PPI, count, crimp, air permeability, tensile strength, elongation, crease recovery, bending length, drape, fabric thickness and shrinkage characteristics.

Table 2: Actual factor level for the process variables

Run order	Temperature (°C)	Time (Min.)	Concentration (%)
1	70	3	5.5
2	75	6	5.5
3	75	3	10
4	80	3	5.5
5	70	6	10
6	80	6	10
7	80	9	5.5
8	70	9	5.5
9	75	9	1
10	80	6	1
11	75	9	10
12	75	6	5.5
13	75	3	1
14	75	6	5.5
15	70	6	1

The data thus obtained were analyzed statistically using SPSS package.

RESULTS AND DISCUSSION

Box-Behnken method was adopted to formulate the experimental design in which 15 different combinations are formed. This method also offers the advantage of being rotatable which means the fitted model estimates the precision at all points in the factor space that are estimated from the centre.

A quadratic polynomial was used to analyze the relationship of each response with the four independent variables as given below.

$$Y = b_0 + \sum_{i=1} b_{ixi} + \sum_{i=1} b_{ixi}^2 + \sum_{i=1} b_{ijxixj} + \sum_{i<j} b_{ijxixj}$$

Where, Y is the response of the dependent variable, xi and xj are the process variables and b₀, b_i and b_{ij} are the coefficients of the regression equations. Influence of factors of chemical treatment on fabric characteristics when Box – Behnken design of experiment was followed is provided in Table 3 and the response surface equations derived from the analysis of fabric properties of chemically treated silk fabrics are presented in Table 4.

Influence of chemical treatment on fabric characteristics

Table 3 presents the various yarn characteristics of silk treated with calcium nitrate solution at different treatment temperature, duration and concentration of chemical. The regression equations in respect of various parameters viz., fabric thickness (Y1), warp crimp (Y2), crease recovery in warp (Y3), crease recovery in weft (Y4) and bending length in warp (Y5) reveal significant influence of process variables viz., temperature of treatment (X1), duration of treatment (X2) and concentration of chemical (X3). The estimated regression equation was evaluated in terms of Fisher's test (F-value) and multiple correlations co-efficient (R²).

Fabric thickness: From Table 3, it could be observed that fabric thickness varied from 0.189 to 0.206 mm for various process variables. The estimated regression co-efficient

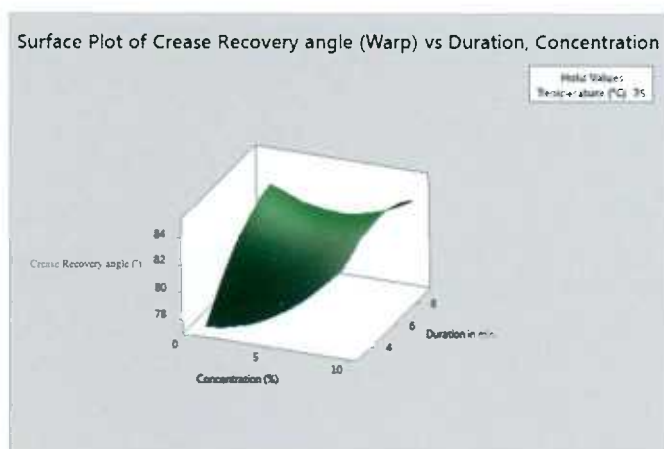


Figure 1: The surface plot of crease recovery angle in warp direction of fabric with reference to temperature, duration of chemical treatment and concentration of chemical

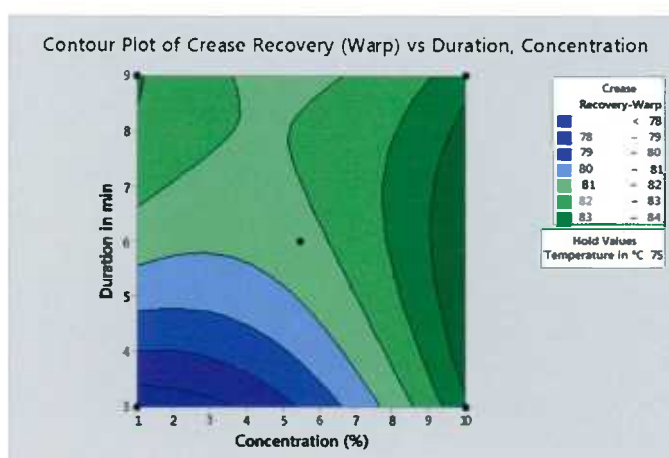


Figure 2: The contour plot of crease recovery angle in warp direction of fabric with reference to temperature, duration of chemical treatment and concentration of chemical

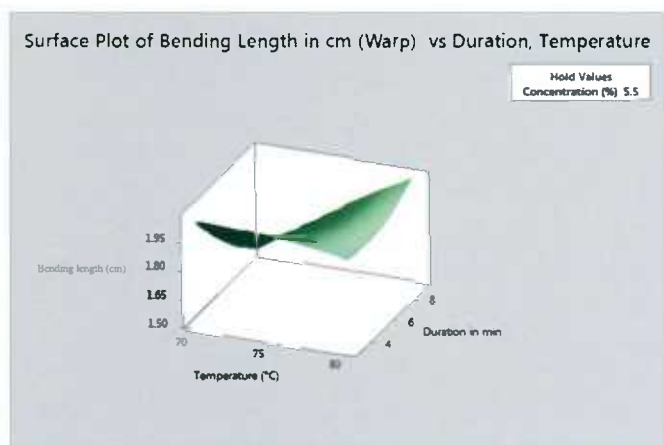


Figure 3: The surface plot of bending length (cm) in warp direction of fabric with reference to temperature, duration of chemical treatment and concentration of chemical

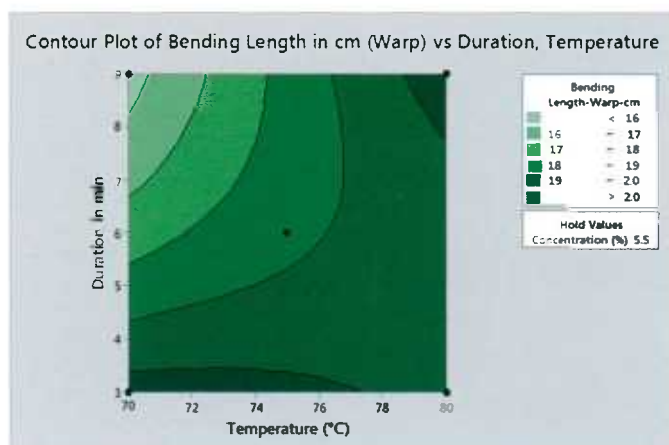


Figure 4: The contour plot of bending length (cm) in warp direction of fabric with reference to temperature, duration of chemical treatment and concentration of chemical

on the fabric thickness does not show any significant influence of process variables. However, the fabric thickness is found to increase from 2 to 11 % on original thickness, after treatment, indicating the impact of chemical treatment process.

Warp crimp: The data show (Table 3) that warp crimp varied from 8.7 to 13.3 % for various process variables. The estimated regression co-efficient on the warp crimp does not show any significant influence inserted by process variables, except concentration of chemical.

Crease recovery angle: Crease recovery angle of the chemically treated fabric samples was found to have significantly influenced by concentration of chemical

used for treatment. It showed values varying from 78° to 87° in warp direction and 91° to 100° in west direction of the fabric samples (Table 3). The estimated regression co-efficient on crease recovery in warp direction of fabric samples showed significant influence of duration of treatment and concentration of the chemical as indicated by the p value of 0.050 and 0.022 for warp as shown in Table 4. The analysis of variance of the regression co-efficient has shown dependence on second order polynomial equation at 5 % level (Table 4). The surface plot and the contour plots for the variable, crease recovery of chemically treated silk fabrics in warp direction are shown in Figures 1 and 2. The duration of treatment and concentration of chemical were found to influence the crease recovery of fabric in warp direction.

Table 3: Influence of factors of chemical treatment on fabric characteristics

Variable	Mean	SE Mean	Std Deviation	Minimum	Maximum
Ends per inch	122.33	0.252	0.976	121.00	125.00
Picks per inch	107.20	0.341	1.32	104.00	109.00
Warp count-Single ply	22.061	0.244	0.946	20.460	24.150
West count-4 p.y	86.154	0.353	1.368	83.070	88.560
Warp crimp (%)	11.821	0.289	1.118	8.720	13.280
West crimp (%)	0.735	0.042	0.161	0.480	1.140
Air permeability (m ³ _m ² _m)	720.61	6.91	26.78	672.66	765.87
Breaking load-Warp - (kgf)	16.287	0.230	0.890	14.500	17.700
Elongation-Warp (%)	26.053	0.513	1.986	22.900	29.300
Breaking load-West- (kgf)	68.01	1.06	4.11	58.70	73.90
Elongation-West (%)	17.200	0.389	1.505	14.600	19.200
Fabric thickness (mm)	0.19610	0.00134	0.00520	0.18900	0.20650
Crease recovery angle -Warp	81.733	0.693	2.685	78.000	87.000
Crease recovery angle -West	96.000	0.787	3.047	91.000	100.000
Total crease recovery angle	177.73	1.02	3.95	169.00	185.00
Bending length-Warp (cm)	1.8833	0.0389	0.1505	1.5750	2.0750
Bending length-West (cm)	4.8033	0.0954	0.3696	4.3000	5.4500
Flexural rigidity-Warp (m)	0.10160	0.00219	0.00849	0.08678	0.11724
Flexural rigidity-West (m)	0.25905	0.00503	0.01948	0.22663	0.29245
Drape coefficient (%)	86.86	1.16	4.51	78.30	92.45
Shrinkage-Warp	5.443	0.233	0.901	4.330	7.600
Shrinkage-West	1.5278	0.0678	0.2626	1.0000	2.1000
Change in weight after treatment	0.888	0.122	0.473	0.224	1.621
Fabric weight (g-m ²)	53.947	0.261	1.011	52.400	56.500

Table 4: Response surface equations of fabric properties of chemically treated silk fabrics

Property	Regression equation	R ²	ANOVA p value
Warp crimp (%)	Y1 = 17 - 0.46 X1 + 3.20 X2 + 1.80 X3 + 0.0049 X1*X1 - 0.0435 X2*X2 - 0.0305 X3*X3 - 0.0390 X1*X2 - 0.0187 X1*X3 + 0.0248 X2*X3	78.8	0.023*
Fabric thickness (mm)	Y2 = 0.247 - 0.0018 X1 + 0.0027 X2 + 0.00370 X3 + 0.000010 X1*X1 - 0.000333 X2*X2 - 0.000086 X3*X3 + 0.000033 X1*X2 + 0.000000 X1*X3 - 0.000296 X2*X3	73.2	0.040*
Crease recovery-Warp	Y3 = -24 + 1.89 X1 + 8.93 X2 + 5.22 X3 - 0.0083 X1*X1 - 0.1343 X2*X2 + 0.0761 X3*X3 - 0.0833 X1*X2 - 0.0667 X1*X3 - 0.1111 X2*X3	88.7	0.050* 0.022*
Crease recovery-West	Y4 = -134 + 7.78 X1 - 17.66 X2 - 4.74 X3 - 0.0617 X1*X1 + 0.162 X2*X2 + 0.1584 X3*X3 + 0.2167 X1*X2 + 0.0444 X1*X3 - 0.0741 X2*X3	85.5	0.025*
Bending length-Warp (cm)	Y5 = 0.8 + 0.085 X1 - 0.827 X2 - 0.118 X3 - 0.00088 X1*X1 + 0.00590 X2*X2 - 0.00077 X3*X3 + 0.00958 X1*X2 + 0.00167 X1*X3 + 0.00093 X2*X3	83.9	0.034* 0.042*

* - Significant at 5 % level

Bending length: Bending length of the chemically treated fabric samples showed values varying from 1.575 to 2.075 cm for various process variables as could be seen in Table 3. The estimated regression co-efficient on

bending length in warp direction of fabric samples showed significant influence of temperature and duration of chemical treatment as indicated by the p values of 0.034 and 0.042, respectively (Table 4). The analysis of variance

of the regression co-efficient has shown dependence on second order polynomial equation at 5 % level (Table 4). The surface plot and the contour plot for the variable, bending length in warp direction of fabric samples are shown in Figures 3 and 4. The temperature and duration of treatment were found to influence the bending length of fabric. The regression equation indicates that the square effect is significant at 5 % level as revealed in the analysis of variance results (Table 4).

Other characteristics taken for the study did not show significant differences in relation with the process variables. The untreated and chemically texturized silk is shown in Figure 5, for a comparative view.

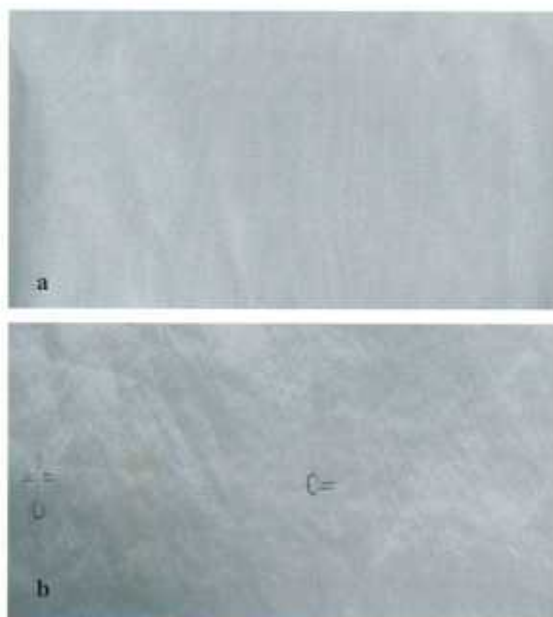


Figure 5: Untreated (a) and chemically treated (b) silk fabric

Conclusion

Based on the studies conducted for standardization of bulky silk fabric production parameters using Box and Behnken design of experiments, it was observed that bivoltine raw silk fabric could be imparted bulkiness by treating with calcium nitrate solution having 5.5 % concentration at 75 °C for 6 minutes. After this particular treatment, the crease recovery and bending length characteristics of the fabric were noticed as improved.

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Article scientifique

STANDARDISATION DES PARAMETRES DU PROCEDE POUR AMELIORER LE VOLUME DES TISSUS PAR TRAITEMENT CHIMIQUE EN UTILISANT LA METHODOLOGIE EXPERIMENTALE DE BOX ET BEHNKEN

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ABSTRACT

Cette étude a été entreprise avec l'objectif d'introduire du volume dans les tissus de soie grâce à un traitement chimique. Un produit chimique convenable pour donner de la souplesse au tissu de soie a été utilisé pour obtenir du volume de tissus de soie bivoltine. Dans la méthode Box-behnken, 15 combinaisons différentes sont formées pour standardiser les variables du procédé comme la température, la durée et la concentration du traitement chimique. Le tissu de soie ainsi produit est caractérisé par diverses propriétés physique, mécanique et de confort en utilisant les tests standard. Les résultats indiquent que le froissement et la longueur de pli récupérés sont significativement influencés par la température et la durée du traitement ainsi que par la concentration du produit chimique. L'étude montre que le tissu de soie bivoltine peut être gonflé par traitement chimique.

Mots-clés: Longueur de pli, tissu de soie grège bivoltine, traitement chimique, froissement, crêpe, souplesse de la soie.



EVALUATION OF PROXIMATE NUTRIENT AND MINERAL COMPOSITIONS OF CASTOR LEAVES AND THEIR RELATIONSHIP WITH ERI SILKWORM (*SAMIA CYNTHIA RICINI* B.) TRAITS

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ABSTRACT

Host plant nutrition is the one major factor which affect development and productivity of silkworms. The present study was undertaken to evaluate thirty-two castor plant accessions for their proximate nutrient composition and relationship with silkworm traits at Eladale Research Station of Jimma University College of Agriculture and Veterinary Medicine, South West Ethiopia. The silkworm feeding experiment was laid out in CRD with two replications. Among castor accessions tested, Acc219662/1 stood high for nitrogen (3.898 %) and protein (24.421 %) content while, high phosphorus (1.997 %) and fat (1.262 %) were detected in Acc200361. The highest carbohydrate (52.149 %) content was associated with Acc200355 whereas, Acc219665 was rich in moisture (83.135 %). Besides, in terms of silkworm rearing performance, Acc 200361 delivered shorter larval duration (17.5 days), higher larval weight (7.6 g) and higher fecundity (351) while higher hatchability (96.75 %) was recorded in respect of Acc201067. In addition, eri worms fed on leaves of Acc200361 were found to be superior in terms of cocoon weight (3.55 g), shell weight (0.509 g), shell percentage (14.33) and ERR (98.6 %). Moreover, high ash (22.9 %) and fiber (24 %) content were recorded from Acc219647. Furthermore, significant and positive correlation was observed between eri-silkworm traits and nitrogen, protein, moisture, phosphorus, fat and carbohydrate content of the leaves. On the other hand, negative association was observed with ash and fiber content of the leaves except for larval duration and survival rate.

Key words: Bio-chemical composition, correlation, eri silkworms, rearing performance.

INTRODUCTION

Leaf quality is an important parameter used for evaluation of genotypes when aimed at selection of superior variety for rearing performance (Bongale *et al.*, 1997). It is a confirmed fact that leaf quality differs among varieties and specific components of the leaves are responsible for the difference in rearing performances of the silkworm (Machii and Katagiri, 1991; Aruga, 1994).

The quality and quantity of castor leaves therefore, play an important role in growth and development of eri

silkworm, particularly during larval stages, which in turn influence the cocoon productivity and the economic traits of the cocoon. Good quality and sufficient quantity of castor leaves fed to the developing worms leads to an increase in body size and dry weight of cellular mass which are dependent on the rate of metabolism, absorption of nutrients, and stage of development (Rajanna, 1991). Also, Joshi (1992) opined that quality of castor leaves contributes 38.20 per cent for superior quality cocoon production.

Nutritionally superior feed has a profound effect on the

supremacy of silk produced by *Samia cynthia ricini*. (Ravikumar, 1988; Murugan *et al.*, 1998; Raina *et al.*, 2004; Seidavi *et al.*, 2005). On top of this, Sarkar *et al.* (2015) reported that, food quality can reduce the actual performance of an insect below its physiological potential. In this direction, we took up an attempt to evaluate thirty-two castor plant accessions for their proximate nutrient composition and its impact on eri silkworm rearing performance.

Description of the study area

The research was undertaken during the rainy seasons of 2015/2016 at Eladale Research Station of Jimma University College of Agriculture and Veterinary Medicine, southwest Ethiopia (N 7°40' E 36°50', 1753 m.a.s.l.), characterized with long-term average annual

al., 2011). The dominant soils of the area are Nitisol and Cambisol which drains well, a favorable physical property for agricultural practices and so, well recognized as the most productive soils in Ethiopia (Mesfin, 1998).

Experimental materials

The thirty-two experimental accessions were selected out of hundred accessions of castor collected from various parts of the country based upon their yield performance and later maintained at Melkasa Agricultural Research Center (MARC).

Experimental procedures

Biochemical characterization of castor foliage

Mineral and nutrient compositions of leaves were determined by taking leaf samples from all treatments which were grown in the middle row in the plot. The leaves were collected from three different heights of the plant *viz.*, top, middle and bottom, in paper bags. They were oven dried at 70 °C until constant weight was obtained, ground to fine powder and subjected to laboratory analysis for the determination of mineral and nutrient composition. N and P were determined using techniques and procedures as described by Sahlemedhin and Taye (2000). Nutrient composition such as ash and total carbohydrate were determined according to methods developed by Ranjhan and Krishna (1981) while crude fiber and crude fat were determined by techniques and procedures outlined by Association of Official Analytical Chemists (A.O.A.C., 1970). Crude protein was estimated based on the total nitrogen content (Sahlemedhin and Taye, 2000).

Silkworm rearing

The silkworm rearing room and equipment were cleaned, washed and disinfected with 2 % formalin solution at the rate of 800 ml/10 m² before the commencement of the experiment (Dayashankar, 1982). Eri-silkworm (*S. c. ricini*) was reared using completely randomized design (CRD) with two replications for each

Table 1: Castor accessions used as treatment for experiment

Notation	Accession	Notation	Accession
T1	Acc 200361	T17	Acc 212534
T2	Acc 200377	T18	Acc 212631
T3	Acc200390	T19	Acc219627
T4	White castor	T20	Acc21963
T5	Acc200355	T21	Acc219645
T6	Acc203644	T22	Acc 219647
T7	Local (Jimma)	T23	Acc219648
T8	AccM-16	T24	Acc219650
T9	Acc219662/1	T25	Acc219653
T10	Acc Hiruy (Gk-sel-1)	T26	Acc219654
T11	Acc GE-sel-1/63-271	T27	Acc219662
T12	Acc208950/2	T28	Acc219665
T13	Acc106501	T29	Acc219668
T14	Acc106564	T30	Acc219671
T15	Acc201067	T31	Acc219673
T16	Acc203241	T32	Acc219682

rainfall of 1500 mm, average monthly relative humidity of 91 %, average daily maximum and minimum temperature of 26.8 and 11.8 °C, respectively (Abera *et*

treatment in the laboratory. In each tray, which has a size of 9.2 sq. ft, young age (chawki) silkworms were reared uniformly. Tender and semi tender leaves were offered three times per day. Twenty selected late age worms were grown in each tray and allowed to complete their larval period on the selected castor accession. The same aged and equal weight of castor leaf was offered to the worms as per the recommendation for tropical countries (Dandin *et al.*, 2003). Mature leaves were provided three to four times daily to the late age worms. Cocoon harvesting was carried out five to six days after spinning.

Data collection and analysis

Data were recorded on the status of biochemical components *viz.*, nitrogen, protein, ash, fiber, moisture, fat, carbohydrate and phosphorus. The rearing performance of each accession was assessed in terms of parameters *viz.*, hatchability, weight of 5th instar full grown worm, larval duration till maturity, cocoon and shell weight, shell percentage and ERR. All the collected data were subjected to analysis of variance using SAS statistical software package 9.2 (SAS, 2008). The differences between treatment means were compared using the least significance difference (LSD) test at 5 % level of significance. Pearson's correlation analysis was done to observe the relationship between leaf biochemical compositions and eri-silkworm traits.

RESULTS AND DISCUSSION

Proximate nutrient composition of castor accessions

Moisture

Analysis of variance revealed that there was significant ($P < 0.01$) variation in leaf moisture content among castor accessions. The higher moisture content was recorded in the leaf of Acc200361 (83.135 %) followed by Acc201067 (82.71 %), Acc203644 (82.07%), Acc200390 (81.945 %) and Acc219665 (81.22 %). On the other hand, the least moisture content was noticed in Acc200377 which scored 70.09 % and the local (73.87 %)

castor accession was the second least in moisture content next to Acc200377 (Table 2). These results are in conformity with the observations of Sannappa and Jayaramaiah (2002) and Chandrappa *et al.* (2005) who observed variations in moisture content of leaves among the castor genotypes. The increased leaf moisture content in a few genotypes might be due to enhancement of hydrogen ion concentration in plant sap due to accumulation of chlorides and less moisture loss by evapotranspiration in the leaves (Eaton, 1942).

Ash

Ash content of leaves showed significant variation ($P < 0.001$) among castor accessions. Acc219647 had the maximum ash content (22.9 %) while Acc219662/1 possessed the minimum ash (15.385 %). However, the local check was equivalent with Acc219671 in ash content (21.95 %) but lower than Acc219645 (22.21 %) (Table 2). The variation in ash content might be due to the variation in genetic constitution of different castor accessions. Similarly, Kedir (2016) observed significant variation in ash content among eight different castor genotypes. Even in the same plant species, among varieties, ash content may vary due to variation in metal composition (Selema and Farago, 1996).

Crude protein

The analysis of variance showed that there was significant variation in leaf crude protein content among castor accessions. The highest crude protein (24.412 %) estimated was from leaves of Acc219662/1 followed by Acc200361 (23.984 %) but, the lowest (7.967 %) was from Acc219647. In addition, even the local check (19.972 %) was good in crude protein content as compared to many castor accessions (Table 2). The variation in crude protein content might be attributed to difference in genetic variation among castor accessions. Earlier studies had established this fact (Sannappa and Jayaramaiah, 2002; Chandrappa *et al.*, 2005; Sarmah *et al.*, 2011; Manjunath and Sannappa, 2012; Chandrashekhara *et al.*, 2013).

Crude fiber

There was significant variation in crude fiber content also. The crude fiber content ranged from a maximum of 24.005 % (Acc219647) to a minimum of 13.070 % (Acc219662). The local check had its fiber content (14.761%) less than that of twenty seven experimental castor accessions except Acc219662 (13.070 %), Acc219662/1 (13.46 %), Acc219627 (13.725 %), Acc200361 (14.385 %) and Acc212534 (14.405 %) (Table 2). Kedir (2016) recorded minimum crude fiber in Abaro (17.54 %) and maximum in GK sel (21.58 %) during his evaluation of eight castor genotypes. Also, Sarmah *et al.* (2011) observed significantly higher fiber content in Acc36 and the minimum in Acc03. The variation in fiber content among different accessions could be attributed to their inherent characters.

Crude fat

Crude fat content of the leaves also displayed significant variations among treatments/ accessions. According to analysis of variance, the highest fat content (1.262 %) was recorded from Acc200361 followed by Acc219662/1 (0.9355 %) and the lowest (0.3205 %) was recorded from Acc201067. Sarmah *et al.* (2011) and Kedir *et al.* (2014) also had results in the similar line. The difference in crude fat content in the present study may be due to the inherited variation existing among castor accessions.

Total carbohydrate

Significant variations were noticed for total leaf carbohydrate content among castor accessions. Acc200355 topped the list (52.149 %) whereas, the the local check and Acc219648 remained at the bottom (42.983 % and 42.698 %, respectively). The present observations are in agreement with that of Sannappa and Jayaramaiah (2002) and Govindan *et al.* (2002) and Chancrappa *et al.* (2005) who also observed variations in the total carbohydrate content among the castor genotypes due to the genetic differences.

Proximate mineral composition of castor accessions

Nitrogen

The compositions of leaf mineral (nitrogen) have also shown highly significant ($P \leq 0.001$) variations among castor accessions. As it can be observed from the trend exhibited by crude protein, the nitrogen content of the leaf of castor accessions too was significantly different. Nitrogen content was high in Acc219662/1 (3.898 %) closely followed by Acc200361 (3.8375 %) but, considerably low in Acc219647 (1.275 %). The variation in nitrogen content of the leaves may be due to the differences in genetic constitution of different castor accessions. Kedir (2011), Sarmah *et al.* (2011) and Chandrashekhar *et al.* (2013) could draw a similar conclusion in respect of nitrogen content.

Phosphorus

As in the case of other components, phosphorus content of leaves also presented significant variations ($P < 0.001$) among castor accessions. It displayed a range from 1.997 % in Acc200361 to 0.64 % in Acc219665. The local check castor also belonged to the category of low phosphorus content (0.655 %) but higher than Acc219665. Contrary to this, Chandrashekhar *et al.* (2013) in Bangalore district, India observed significantly higher (0.396 %) phosphorus content in Local castor genotype and lower amount (0.125 %) in DCH-177 among eight castor genotypes. The genetic variation which exist among castor accessions must have been the basis of these differences (Kedir, 2011).

Larval parameters

Significant variations were evident in respect of larval duration and mature larval weight of each treatment. Shorter larval duration (17.5 days) was noticed in the silkworms fed with Acc200361 and Acc212534 and longer larval duration (21.0 days) against Acc200355, Acc208950/2, Acc201067, Acc219645 and Acc219673. On the other hand, larvae attained 7.6 and 7.4 g of mature

Table 2: Proximate nutrient and mineral composition of castor accessions, Jimma, 20015/2016

Castor Accession	Nitrogen (%)	Protein (%)	Ash (%)	Fiber (%)	Moisture (%)	Fat (%)	Carbohydrate (%)	Phosphorus (%)
Acc 200361	3.8375 ^{ab}	23.984 ^{ab}	16.935 ^{klm}	14.385 ^{kl}	81.22 ^{abcde}	1.262 ^a	43.434 ^{gh}	1.997 ^a
Acc 200377	1.4595 ^{no}	9.122 ^{mn}	21.89 ^{abc}	23.28 ^{ab}	70.9 ^j	0.387 ^{hijk}	45.322 ^{defgh}	0.8955 ^{uklmo}
Acc200390	1.54 ^{no}	9.625 ^{mn}	20.705 ^{bcd}	20.961 ^{bcd}	81.945 ^{abcd}	0.335 ^k	48.375 ^{abcd}	1.0605 ^{ghijk}
white castor	1.632 ^{lmno}	10.2 ^{klmn}	19.06 ^{ghij}	20.086 ^{cdef}	80.95 ^{abcde}	0.37 ^{ijk}	50.285 ^{ab}	1.365 ^{bcd}
Acc200355	2.2915 ^j	14.322 ^{hi}	16.45 ^{klm}	16.385 ^{ghij}	77.670 ^{cdefgh}	0.695 ^{def}	52.14 ^a	1.52 ^{bc}
Acc203644	2.361 ^{hij}	14.6 ^{ghi}	18.895 ^{hij}	18.185 ^{fgh}	82.07 ^{abc}	0.739 ^{cde}	47.425 ^{bcd}	1.0035 ^{hijkl}
Local	3.1955 ^{cde}	19.972 ^{cde}	21.95 ^{ab}	14.761 ^{kl}	73.87 ^j	0.335 ^k	42.983 ^{gh}	0.6550 ^{no}
AccM-16	2.407 ^{hij}	15.044 ^{ghi}	19.05 ^{ghij}	18.125 ^{fghi}	79.335 ^{abcde}	0.526 ^{fghij}	47.256 ^{bcd}	0.922 ^{ijklmn}
Acc219662/1	3.898 ^a	24.421 ^a	15.385 ^m	13.46 ^{kl}	78.4 ^{bcd}	0.9355 ^b	45.799 ^{cdef}	1.836 ^a
Acc Hiruy(Gk-sel-1)	1.584 ^{mno}	9.91 ^{mn}	20.69 ^{bcd}	21.131 ^{bcd}	78.72 ^{abcde}	0.7425 ^{cde}	47.538 ^{bcd}	1.255 ^{cdefgh}
Acc GE-sel-1/63-271	1.9175 ^{klm}	11.984 ^{ijklm}	21.105 ^{bcd}	21.643 ^{abc}	78.195 ^{bcd}	0.5705 ^{efgh}	44.698 ^{defgh}	0.965 ^{ijklm}
Acc208950/2	2.2125 ^{jk}	13.828 ^{hij}	21.2 ^{bcd}	19.538 ^{cdef}	82.12 ^{abcde}	0.6465 ^{cdef}	44.789 ^{defgh}	0.819 ^{klmno}
Acc106501	2.1 ^{ijklm}	13.125 ^{hijk}	20.11 ^{defg}	20.764 ^{bcd}	77.705 ^{cdefgh}	0.685 ^{def}	43.816 ^{gh}	1.255 ^{cdefgh}
Acc106564	1.731 ^{klmn}	10.819 ^{klmn}	21.685 ^{abcd}	20.982 ^{bcd}	76.935 ^{efgh}	0.355 ^{ijk}	46.194 ^{bcd}	0.799 ^{klmno}
Acc201067	2.5015 ^{fghi}	15.634 ^{fgh}	19.575 ^{efgh}	18.3 ^{efgh}	82.71 ^{ab}	0.3205 ^k	46.171 ^{bcd}	0.6995 ^{mno}
Acc203241	3.2905 ^{bcd}	20.566 ^{bcd}	16.48 ^{klm}	16.585 ^{ghij}	77.97 ^{cdefgh}	0.905 ^{bc}	45.465 ^{defgh}	1.15 ^{efgh}
Acc 212534	3.0450 ^{def}	19.988 ^{cde}	16.28 ^{lm}	14.405 ^{kl}	77.67 ^{cdefgh}	0.6465 ^{def}	48.681 ^{abcd}	1.541 ^b
Acc 212631	2.908 ^{efgh}	18.175 ^{efg}	17.71 ^{gh}	16.775 ^{ghij}	77.98 ^{cdefgh}	0.656 ^{def}	46.678 ^{bcd}	1.105 ^{ghij}
Acc219627	3.548 ^{abcd}	22.175 ^{abcd}	16.785 ^{klm}	13.752 ^{kl}	80.68 ^{abcde}	0.904 ^{bc}	46.412 ^{bcd}	1.3265 ^{bcd}
Acc21963	2.608 ^{fghi}	16.3 ^{fgh}	17.94 ^{ijk}	15.35 ^{kl}	79.79 ^{abcde}	0.539 ^{fghi}	49.681 ^{abc}	0.8575 ^{klmno}
Acc219645	1.545 ^{no}	9.656 ^{mn}	23.21 ^a	20.781 ^{bcd}	74.57 ^{hi}	0.35 ^k	46.314 ^{bcd}	1.065 ^{hijk}
Acc 219647	1.275 ^o	7.969 ⁿ	22.9 ^a	24.005 ^a	75.175 ^{ghij}	0.372 ^{ijk}	44.445 ^{cdef}	0.795 ^{mno}
Acc219648	3.5380 ^{abcd}	22.113 ^{abcd}	19.145 ^{ghij}	15.585 ^{ijkl}	76.645 ^{efgh}	0.46 ^{ghijk}	42.698 ^b	1.45 ^{bcd}
Acc219650	3.273 ^{cde}	20.453 ^{cde}	19.46 ^{fghi}	15.075 ^{kl}	77.37 ^{cdefgh}	0.60 ^{efg}	44.412 ^{efgh}	1.25 ^{defgh}
Acc219653	3.0355 ^{defg}	18.972 ^{de}	15.745 ^m	15.975 ^{hijk}	78.44 ^{bcd}	0.677 ^{def}	48.632 ^{abcd}	0.824 ^{klmno}
Acc219654	2.581 ^{fghi}	16.131 ^{fgh}	19.25 ^{ghij}	18.3 ^{efgh}	77.04 ^{cdefgh}	0.75 ^{cde}	45.504 ^{defgh}	1.001 ^{ijkl}
Acc219662	3.6405 ^{abc}	22.175 ^{abc}	16.795 ^{klm}	13.07 ^j	79.595 ^{abcde}	0.375 ^{ijk}	47.227 ^{bcd}	1.38 ^{bcd}
Acc219665	2.495 ^{ghi}	15.594 ^{fghi}	18.07 ^{ijk}	18.72 ^{cdefg}	83.135 ^a	0.39 ^{hijk}	47.227 ^{bcd}	0.64 ^o
Acc219668	2.18 ^{ijkl}	13.625 ^{hijk}	20.965 ^{bcd}	20.2 ^{cdef}	76.05 ^{fghi}	0.7425 ^{cde}	44.463 ^{cdef}	1.3155 ^{bcd}
Acc219671	2.2535 ^{ijk}	14.178 ^{hij}	21.95 ^{ab}	19.521 ^{cdef}	79.265 ^{abcde}	0.425 ^{ghijk}	43.927 ^{fgh}	1.435 ^{bcd}
Acc219673	2.222 ^{ijk}	13.887 ^{hij}	20.235 ^{cdefg}	20.281 ^{cdef}	79.775 ^{abcde}	0.601 ^{efg}	44.996 ^{defgh}	1.1365 ^{cdefgh}
Acc219682	1.5685 ^{mno}	9.816 ^{mn}	21.755 ^{abcd}	23.135 ^{ab}	77.445 ^{cdefgh}	0.8155 ^{bcd}	44.476 ^{efgh}	0.917 ^{ijklm}
LSD (5 %)	0.5483	3.4456	1.6565	2.5594	4.6512	0.1835	4.1477	0.2677
CV (%)	10.79656	10.83237	4.19626	6.881763	2.907062	15.06039	4.404775	11.58995

LSD = least significant difference; CV = coefficient of variation; Means sharing the same letter(s) in each column do not differ significantly at 5 % P level according to the LSD test.

larval weight when fed with Acc200361 and Acc219654, respectively whereas, lower weight of 5.6 g was noticed with Acc219665 and Acc200390. Similar observations were reported by Jayaramaiah and Sannappa (2000 a), Govindar *et al.* (2002), Hazarika *et al.* (2003), Ramakrishna *et al.* (2003), Sannappa *et al.* (2007), Dasari *et al.* (2013) and Rajasri and Lakshmi (2015) who reported differences in larval parameters among silkworms because of differences in castor genotypes. The variations observed in silkworms that fed on different accessions of castor might be due to the fact that these castor accessions vary in their composition of foliar constituents, as discussed above which in turn contribute for differences in larval characters.

Grainage parameters

Silkworms fed on Acc200361 possessed significantly higher fecundity (351) followed by Acc212534 (345). The lowest fecundity (113) was recorded against Acc106501 followed by Acc208950/2 (116). The differences in feed quality were well reflected in the hatching percentage, showing significant variations among castor accessions studied. Acc201067 was noticed to result insignificantly higher hatching percentage (96.75 %) followed by AccHiruy (Gk-sel-1) and Acc200361 (96.5 %). The local check castor accession which was medium performer as compared to the other accessions was the lowest in terms of hatching percentage (88.25 %). These observations are in line with those of Sannappa *et al.* (2007) and Kedir *et al.* (2014) who reported variations in fecundity and hatchability of eri silkworm due to differences in castor genotypes. The ovipositional behavior of eri silkworm varied with respect to feeding of different accessions of castor which in turn had an impact on fecundity (Sarkar *et al.*, 2015).

Cocoon parameters

ERR showed significant variation when eri silkworms were fed on different castor accessions. ERR varied from

82.5 to 98.6 %. Larva fed on Acc200361 showed maximum ERR (98.6 %) followed by Acc212534 (98.5 %). Lower ERR was recorded from larvae fed on Acc200377, Acc219662 and Acc219665 (82.5 %). The variation in ERR of silkworm fed with different castor accessions may be due to the differences in foliar composition and nutrients availability in different accession which contribute to the growth and development of silkworms. Similar findings were reported by Chandrashekhar and Govindan (2010), Kedir *et al.* (2014) and Dasari *et al.* (2013).

Cocoons formed by the worms fed on leaves of selected castor accessions exhibited significant variations in cocoon traits in the first rearing. Significantly, higher cocoon weight (3.55 g) and shell weight (0.509 g) were recorded from larvae fed on Acc200361. However, the higher shell percentage (14.585) was recorded from AccHiruy (Gk-sel-1) closely followed by Acc219645 (14.455 %), Acc201067 (14.375 %), Acc219647 (14.37%) and Acc 200361 (14.33 %). On the contrary, lower cocoon weight (2.500 g), shell weight (0.307 g) and shell percentage (12.315) were recorded from larvae fed on leaves of Acc219662. The worms fed on local check scored medium cocoon weight (3.2 g), shell weight (0.4015 g) and lower shell percentage (12.54 %) as compared to other accessions. These results are in agreement with the findings of Patil *et al.* (2000), Pandey (2003), Ahmed *et al.* (2015) and Sarkar *et al.* (2015) who recorded variations in cocoon traits when different castor genotypes were offered as food.

The variations noticed in cocoon characters may be a reflection of the nutritional status of the castor accessions as evidenced by the positive and significant correlation coefficients worked out between the foliar constituents and eri silkworm cocoon traits. Many previous workers have reported such significant correlation between castor leaf nutritional status and eri silkworm cocoon traits (Chaudhary, 1979; Jayaramaiah and Sannappa, 2000 b; Chandrappa *et al.*, 2005; Sannappa *et al.*, 2007; Sarmah *et al.*, 2011).

Table 3: Performance of eri-silkworm fed on different castor accessions at Jimma, 2015/2016

Castor Accession	Larval duration (days)	Mature larval weight (g)	Survival rate (%)	Fecundity (No.)	Hatchability (%)	ERR (%)	Single cocoon weight (g)	Shell weight (g)	Shell percentage
Acc 200361	17.5 ^a	7.6 ^a	98 ^{abc}	351.45 ^a	96.5 ^a	98.6 ^a	3.55 ^a	0.509 ^a	14.33 ^a
Acc 200377	19 ^{de}	6.1 ^{kl}	98 ^{abc}	217.55 ⁱ	96.5 ^a	82.5 ^d	3.2 ^{bcd}	0.4275 ^{efgh}	13.32 ^{def}
Acc200390	19 ^{de}	5.6 ^m	98 ^{abc}	133.75 ^a	96.0 ^{abc}	98 ^a	3.4 ^{ab}	0.4625 ^{bode}	13.57 ^{ode}
white castor	20 ^{bc}	7.0 ^{cdef}	97.5 ^{bcd}	269.4 ^d	95.25 ^{abcde}	95 ^{abc}	3.3 ^{abc}	0.453 ^{bodefg}	13.75 ^{bode}
Acc200355	21 ^a	7.0 ^{cdef}	98 ^{abc}	262.05 ^c	96.15 ^{ab}	95.5 ^{ab}	3.15 ^{bode}	0.3915 ⁱ	12.425 ^b
Acc203644	19 ^{de}	6.4 ^{jk}	97.5 ^{bcd}	234.8 ^e	95.15 ^{abcdef}	97 ^a	3.5 ^a	0.4635 ^{bode}	13.235 ^{efg}
Local	20 ^{bc}	6.9 ^{cdefg}	96.5 ^{def}	191.5 ^m	88.25 ^k	92.5 ^{abc}	3.2 ^{bcd}	0.4015 ^{hi}	12.54 ^b
AccM-16	18 ^{fg}	6.7 ^{gh}	97 ^{cde}	211.5 ^j	94.9 ^{abcdef}	97.5 ^a	3.5 ^a	0.4475 ^{bodefg}	12.78 ^{gh}
Acc219662/1	19 ^{de}	6.5 ^{hij}	95.5 ^f	195.15 ^m	96.3 ^{ab}	96.5 ^a	3.5 ^a	0.4765 ^{ab}	13.615 ^{cde}
Acc Hiruy(Gk-sel-1)	20 ^{bc}	6.7 ^{gh}	99 ^a	208.75 ^j	96.5 ^a	97 ^a	3.1 ^{cde}	0.4525 ^{bodefg}	14.585 ^a
Acc GE-sel-1/63-271	20 ^{bc}	6.55 ^{gh}	97 ^{cde}	150.3 ^t	95.55 ^{abcd}	92.5 ^{abc}	3.3 ^{abc}	0.4545 ^{bodef}	13.76 ^{bode}
Acc208950/2	21 ^a	6.2 ^{jk}	98 ^{abc}	116 ^l	93.5 ^{defgh}	97 ^a	3.1 ^{cde}	0.4235 ^{efgh}	13.33 ^{def}
Acc106501	19 ^{de}	7.2 ^{bcd}	97.5 ^{bcd}	113.0 ⁱ	93.1 ^{efgh}	92.5 ^{abc}	2.8 ^f	0.349 ^j	12.46 ^b
Acc106564	20.5 ^{ab}	7.3 ^{abc}	98 ^{abc}	193.5 ^m	95.5 ^{abcd}	95 ^{abc}	3.1 ^{cde}	0.4285 ^{defgh}	13.775 ^{bcd}
Acc201067	21 ^a	7.0 ^{cdef}	96 ^{cdef}	343.75 ^b	96.75 ^a	96 ^{ab}	3.3 ^{abc}	0.4745 ^{abc}	14.375 ^a
Acc203241	19 ^{de}	7.2 ^{bcd}	97.5 ^{bcd}	249.65 ^f	92.9 ^{ghi}	92.5 ^{abc}	3.5 ^a	0.476 ^{ab}	13.39 ^{de}
Acc 212534	17.5 ^a	6.9 ^{cdefg}	97.5 ^{bcd}	345.95 ^b	94.5 ^{abcdefg}	98.5 ^a	3.1 ^{cde}	0.413 ^{ghi}	13.325 ^{cdef}
Acc 212631	19 ^{de}	7.0 ^{cdef}	97 ^{cde}	180.7 ^a	93.8 ^{cdefgh}	92.5 ^{abc}	3.1 ^{cde}	0.437 ^{bodefg}	14.09 ^{abc}
Acc219627	18.5 ^{ef}	6.8 ^{efgh}	97 ^{cde}	246.8 ⁱ	96.5 ^a	97 ^a	3.3 ^{abc}	0.441 ^{bodefg}	13.365 ^{der}
Acc21963	20 ^{bc}	6.5 ^{hij}	97.5 ^{bcd}	263.95 ^c	95.1 ^{abcdef}	95 ^{abc}	3.2 ^{bcd}	0.425 ^{efgh}	13.275 ^{defg}
Acc219645	21 ^a	6.9 ^{cdefg}	98.5 ^{ab}	235.425 ^a	96.25 ^{ab}	97.5 ^a	3.3 ^{abc}	0.477 ^{ab}	14.455 ^a
Acc 219647	18 ^{fg}	7.4 ^{ab}	96.5 ^{def}	203.5 ^t	90.1 ^{jk}	88 ^{cd}	3.1 ^{cde}	0.4455 ^{bodefg}	14.37 ^a
Acc219648	19 ^{de}	6.8 ^{efgh}	98 ^{abc}	177.5 ^a	93.2 ^{efgh}	96 ^{ab}	3.3 ^{abc}	0.45 ^{bodefg}	13.665 ^{cde}
Acc219650	20.5 ^{ab}	5.8 ^{lm}	97 ^{cde}	302.9 ^c	95 ^{abcdef}	89 ^{bcd}	3.5 ^a	0.4685 ^{bod}	13.385 ^{ce}
Acc219653	19 ^{de}	6.1 ^{kl}	98 ^{abc}	220.3 ^{hi}	92.25 ^{gh}	92.5 ^{abc}	3.1 ^{cde}	0.4265 ^{efghi}	13.75 ^{bode}
Acc219654	19 ^{de}	7.4 ^{ab}	97.5 ^{bcd}	223.325 ^h	95.5 ^{abcd}	92.5 ^{abc}	3.2 ^{bcd}	0.4345 ^{bodefg}	13.57 ^{ode}
Acc219662	19.5 ^{cd}	6.7 ^{gh}	98 ^{abc}	199.25 ⁱ	95.65 ^{abcd}	82.5 ^d	2.5 ^e	0.307 ^k	12.315 ^b
Acc219665	19 ^{de}	5.6 ^m	98.5 ^{ab}	172.05 ^o	95.9 ^{abc}	82.5 ^d	3 ^{def}	0.4275 ^{efgh}	14.25 ^{ab}
Acc219668	18.5 ^{ef}	6.5 ^{hij}	97 ^{cde}	149.125 ^q	94.15 ^{bodefg}	96 ^{ab}	3.2 ^{bcd}	0.416 ^{fghi}	12.84 ^h
Acc219671	20 ^{bc}	7.1 ^{bode}	97 ^{cde}	152.125 ^q	91.25 ^u	92.5 ^{abc}	3 ^{def}	0.405 ^{hi}	13.48 ^{de}
Acc219673	21 ^a	6.9 ^{cdefg}	97.5 ^{bcd}	158.65 ^p	92 ^{hij}	96 ^a	3.3 ^{abc}	0.451 ^{bodefg}	13.67 ^{de}
Acc219682	18 ^{fg}	6.4 ^{ijk}	98 ^{abc}	141.75 ^v	93.5 ^{defghi}	97.5 ^a	2.9 ^{def}	0.348 ⁱ	12.425 ^b
LSD (5 %)	0.6714	0.3813	1.2548	3.7677	2.2627	7.4496	0.2798	0.06	1.4603
CV (%)	1.72115	2.785924	0.631123	0.867365	1.174217	3.894718	4.015186	5.801148	4.813193

Relationship between proximate nutrient and mineral compositions of castor leaves and eri silkworm traits

The foliar proximate composition of castor accession resulted in significantly different relationship with performance of eri-silkworms. The result of the relationship between leaf nutrient as well as mineral composition and eri-silkworm traits were worked out using Pearson's correlation coefficient analysis.

Moisture content of leaves showed significant positive correlation with mature larval weight ($r=0.41960$) and hatchability ($r=0.2451$). In addition, non-significant positive correlation was observed with fecundity ($r=0.10086$), larval duration ($r=0.045827$), cocoon weight ($r=0.096207$), shell weight ($r=0.029131$) and ERR ($r=0.214136$).

Ash content showed strong negative correlation with shell weight ($r=-0.46787$), shell percentage ($r=-0.48676$) and fecundity ($r=-0.44694$) and positive relation with larval duration ($r=0.08773$) and survival rate ($r=0.18176$). However, statistically non-significant but negative correlations were observed for the rest of the silkworm traits.

Crude fiber analysis in relation to the eri silkworm traits revealed significant negative correlation with fecundity ($r=-0.428$), cocoon weight ($r=-0.25006$), shell weight ($r=-0.402977$) and shell percentage ($r=-0.43388$) but hatchability and ERR showed non-significant negative correlation. It also revealed non-significant positive correlation with larval duration ($r=0.25586$), mature larval weight ($r=0.027851$) and survival rate ($r=0.030804$).

Crude fat content of the leaf showed significant positive relation with cocoon traits, such as cocoon weight ($r=0.26122$), shell weight ($r=0.40596$), shell percentage ($r=0.32921$) and ERR ($r=0.35281$). However, negative relation was observed with larval duration ($r=-0.38229$) and survival rate ($r=-0.01054$) and non-significant positive relation with the rest of the traits.

Total carbohydrate displayed significant positive relation with fecundity ($r=0.2584$) and hatchability ($r=0.31711$). Non-significant positive correlation was also observed with shell weight ($r=0.00015$), shell percentage ($r=0.02778$), ERR ($r=0.09616$), larval duration ($r=0.12864$) and survival rate ($r=0.17510$).

Nitrogen had strong, significant positive correlation

Table 4: Correlation coefficients between eri-silkworm traits and biochemical constituents of castor leaf

Silkworm trait	Leaf biochemical content							
	Nitrogen	Protein	Ash	Fiber	Moisture	Phosphorus	Fat	Total carbohydrate
LD	-0.21356	-0.22619	0.08773	0.25586*	0.0458	-0.24088	-0.38229	0.12864
MLW	0.08233	0.07798	-0.03939	0.02785	0.41960**	0.26974*	0.19008	-0.15106
FUC	0.34806**	0.35831**	-0.44694	-0.42800	0.10086	0.26314*	0.19005	0.25849*
HAT	0.00612	0.01006	-0.07709	-0.27975	0.24510*	0.25138*	0.18147	0.31711**
SRV	-0.22782	-0.22370	0.18176	0.03080	-0.03338	-0.02866	-0.01254	0.1751
CW	0.20214	0.19625	-0.13017	-0.25006	0.17039	0.15165	0.26122*	-0.0418
SW	0.49548***	0.49259***	-0.46787	-0.40297	0.02913	0.34942**	0.40596***	0.00015
SR	0.49689***	0.50042***	-0.48676	-0.43388	-0.09888	0.32126**	0.32921**	0.02778
ERR	0.00387	0.01092	-0.05108	-0.10789	0.21414	0.31042**	0.35281**	0.09616

LD = Larval duration, MLW = Mature larval weight, FUC = Fecundity, HAT = Hatchability, SRV = Survival rate, CW = Cocoon weight, SW = Shell weight, SR = Shell percentage, ERR = Effective rate of rearing.

*, **, *** denote significance at ($P \leq 0.05$), ($P \leq 0.01$), and ($P \leq 0.001$), respectively.

with shell weight ($r=0.49548$) and shell percentage ($r=0.49689$) and non-significant but positive correlation with fecundity ($r=0.34806$), larval weight ($r=0.25164$), hatchability ($r=0.00612$), cocoon weight ($r=0.20214$) and ERR ($r=0.00387$). However, it showed negative non-significant correlation with larval duration ($r=-0.21356$) and survival rate ($r=-0.22782$).

Similar to that of nitrogen, protein also showed strong significant positive correlation with shell weight ($r=0.49259$) and shell percentage ($r=0.50042$) and non-significant but positive correlation with fecundity ($r=0.35831$), larval weight ($r=0.07798$), hatchability ($r=0.01006$), cocoon weight ($r=0.19625$) and ERR ($r=0.01092$). But, it revealed non-significant negative correlation with larval duration ($r=-0.22619$) and survival rate ($r=-0.22370$).

Analysis of phosphorus content of castor accessions in relation to silkworm traits revealed significant positive relation with cocoon weight ($r=0.15165$), shell weight ($r=0.034942$), shell percentage ($r=0.032126$), ERR ($r=0.31042$), fecundity ($r=0.26314$), mature larval weight ($r=0.26974$) and hatchability ($r=0.25138$). However, larval duration and survival rate exhibited non-significant negative relation with leaf phosphorus content.

Conclusion

Leaf quality is the major factor that influences the growth and development of silkworms as well as the production of superior quality cocoon. The relationship of biochemical constituents of castor accessions with cocoon characteristics revealed a significant positive correlation with nitrogen, crude protein, crude fat, phosphorus and moisture contents. In addition, their interaction with larval traits were found to have positive relationship with nitrogen, crude protein, crude fat, phosphorus, and moisture contents except for larval duration and survival rate. On the other hand, all other silkworm traits except survival rate and larval duration showed negative correlation with ash and crude fiber content of the leaves.

In general, the present study revealed the differential influence of castor accessions on eri silkworm rearing performance. Hence, a prudent selection of castor variety may lead to better larval development, cocoon and silk yield.

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Article scientifique

EVALUATION DES COMPOSITIONS MINERALE ET NUTRITIVE DES FEUILLES DE RICIN ET LEUR RELATION AVEC LES CARACTERES DU VER A SOIE ERI (*SAMIA CYNTHIA RICINI* B.)

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ABSTRACT

La nutrition des plantes hôtes est l'un des facteurs majeurs qui affectent le développement et la productivité des vers à soie. Notre étude a été entreprise pour évaluer trente deux accessions de ricin pour leur composition nutritionnelle et sa relation avec les caractères du ver à soie à l' Eladale Research Station du Jimma University College of Agriculture and Veterinary Medicine, South West Ethiopia. Les expériences de nourrissage du ver à soie ont été réalisées en deux répétitions. Parmi les accessions testées, Acc219662/1 a un fort contenu en azote (3.898 %) et en protéines (24.421 %) alors qu'un contenu élevé en phosphore (1.997 %) et en lipides (1.262 %) est détecté chez Acc200361. Le plus fort taux d'hydrates de carbone (52.149 %) est enregistré chez Acc200355 alors que Acc219665 est riche en humidité (83.135 %). Pour ce qui est des performances d'élevage, Acc200361 donne la plus faible durée larvaire (17.5 jours), le poids larvaire le plus élevé (7.6 g) et la plus forte fécondité (351) alors que la plus forte éclosion (96.75 %) est

observée avec Acc201067. De plus, les vers à soie eri nourris avec les feuilles de Acc200361 donnent le poids de cocon le plus élevé (3.55 g), ainsi que le poids de la coque (0.509 g), la richesse soyeuse (14.33) et le taux effectif d'élevage (98.6 %). Un taux élevé de cendres (22.9 %) et de fibres (24 %) a été enregistré avec Acc219647. Une corrélation positive significative est observée entre les caractères du ver à soie eri et les contenus en azote, protéines, humidité, phosphore, lipides et hydrates de carbone des feuilles. Par ailleurs une association négative est observée avec le contenu en cendres et en fibres des feuilles, sauf pour la durée larvaire et le taux de survie.

Mots-clés: Composition biochimique, corrélation, ver à soie eri, performance d'élevage.



RAPID ASSESSMENT OF FERTILIZER SUFFICIENCY AND LEAF QUALITY IN MULBERRY USING CHLOROPHYLL METER AND LEAF COLOR CHART

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ABSTRACT

This study explored the possibility of predicting fertilizer sufficiency and leaf nutrient status of V-1 mulberry variety using chlorophyll meter (Soil Plant Analysis Development – SPAD-502) at Central Sericultural Research and Training Institute (CSRTI), Mysuru. The experiment was laid out in randomized block design (RBD) with four replications and five fertilizer treatments and data were recorded 30 to 70 days after pruning (DAP) with 10 days interval. Significant variations were observed in SPAD values, leaf yield, total chlorophyll, leaf nitrogen and carbohydrate contents at different levels of fertilizer treatments. Critical SPAD values under different fertility levels were identified as 30.1 (30 DAP) and 34.9 (40 DAP) for V-1 mulberry variety. Significant and high correlations were obtained between SPAD values and total chlorophyll content, leaf nitrogen and total carbohydrate content at all five growth stages. Based on the critical SPAD values under different levels of fertilizers, efforts were made to develop a leaf color chart (LCC). Further, regression equations were developed for predicting leaf yield under particular fertilizer dosage in field conditions. The present study unravels the utility of SPAD values to assess the status of soil fertility and leaf quality in mulberry instantly without sophisticated laboratory analysis.

Key words: Leaf quality, mulberry, SPAD.

INTRODUCTION

Mulberry productivity and leaf quality are largely determined by mulberry variety used, fertilizer and water management practices and other cultural activities. It has been reported that inadequate irrigation and fertilizer application disturb the balance between synthesis and decomposition of organic matter and results in lower productivity and poor quality leaves (Krishnaswami *et al.*, 1970; Bhargavi, 1991; Bongale *et al.*, 1995). It requires elaborative laboratory facilities, chemicals and instrumentation to find out suitability of mulberry leaf in advance, for rearing silkworm. Further, such studies has a limited impact in the context of field rearing, as it is very difficult to analyze large samples of leaves from many farmers within a very short period of time. However, recent advances in spectrometry and instrumentation

technology raise possibility of estimating the contents of bio-chemicals in foliage using sensors. The potential of such technology for ecological research is enormous.

Nitrogen is the major nutrient affecting mulberry growth, yield and quality. A chlorophyll meter can conveniently estimate foliar chlorophyll and nitrogen status. Chlorophyll meter (SPAD-502) was found to be effective in determination of fertilizer deficiency / sufficiency and quality in various crops (Richardson *et al.*, 2002). To mention some of the advantages of using chlorophyll meter are, convenience of handling, rapidity of testing, eco-friendly nature and possibility to rectify fertilizer deficit situations on the spot.

Keeping the emphasis on management of V-1 mulberry variety for its full potential under irrigated

field conditions, a study was carried out to explore the possibility of predicting fertilizer sufficiency and nutrient status using chlorophyll meter (SPAD-502). The experiment was worked out at CSRTI, Mysuru using V-1 mulberry plantation with an objective to identify standard / critical SPAD values at different growth stages under different fertility levels and prepare LCC and to standardize the relationship between SPAD values, leaf yield and quality parameters for V-1 mulberry variety.

MATERIALS AND METHODS

The experiment was conducted utilizing an already established, six years old plantation of V-1 mulberry with 90 x 90 cm spacing under completely irrigated condition. Soil of the experimental plot was red sandy loamy and the soil reaction was alkaline with pH 8.3. The organic carbon, available nitrogen, phosphorus and potash in experimental plot prior to treatments were 0.62 %, 380 kg / ha, 23.5 kg / ha and 430 kg / ha, respectively. The experiment was laid out in RBD with four replications and five fertilizer treatments. The fertilizer treatments consisted of i) T1 - No fertilizers, ii) T2 - 25 % of recommended dose *i.e.*, NPK @ 87.5 : 35 : 35 kg/ha/year, iii) T3 - 50 % of recommended dose *i.e.*, NPK @ 175 : 70 : 70 kg/ha/year, iv) T4 - 75 % of recommended fertilizer dose *i.e.*, NPK @ 262.5 : 105 : 105 kg/ha/year and v) T5 - full dose of recommended fertilizer *i.e.*, NPK @ 350 : 140 : 140 kg/ha/year, in five equal splits. The gross and net plot size of an individual treatment of the experiment plot was 91.4 sq. m and 52.5 sq. m, respectively with 112 plants / plot. Nitrogen, phosphorus and potash fertilizers were applied in the form of ammonium sulphate (20 % N), single super phosphate (16 % P₂O₅) and muriate of potash (60 % K₂O), respectively. Fertilizer mixture was applied 21 days after pruning (DAP) in each crop. Except for differences in inorganic fertilizer levels, other cultural practices for irrigated mulberry were adopted uniformly (Sarkar *et al.*, 1999).

Data were collected from five plants in each plot, periodically from 30 to 70 days after pruning with 10 days interval for a period of two years. A total of 5 harvests /

annum and 5 observations on chlorophyll meter, leaf yield, leaf nitrogen, carbohydrate and chlorophyll contents for each growth stage were recorded. Chlorophyll meter readings (SPAD values) of sixth leaf from the top of the longest shoot were taken covering the entire leaf. Care was taken to avoid any damaged / diseased spots. Total chlorophyll contents were extracted using 6th leaf (which is used for SPAD readings) from the top of the longest branches on 30th, 40th, 50th, 60th and 70th days after pruning from all the five treatments by employing the method of Hiscox and Israelstam (1979). All the leaves of each of five plants per replication under each treatment were harvested at different growth stages and weighed using Sartorius top loading balance for leaf yield estimation. The leaf samples were dried under shade and used for estimation of nitrogen content using Kjeltex apparatus (Tandon, 1993) and total carbohydrates content was estimated following Anthrone method (Hegde and Hofreifer, 1962). The differences among the fertilizer treatments at different growth stages were tested for significance using Analysis of variance (Panse and Sukhatme, 1967). Phenotypic correlation of SPAD values with different characters were worked out from variance-covariance analysis, separately for different harvesting days.

RESULTS AND DISCUSSION

The relationship between leaf yield, leaf quality and doses of fertilizer application and their relationship with cocoon production has been studied by various scientists (Machii and Katagiri, 1990, 1991; Bhargavi, 1991; Lou Cheng Fu, 1994; Bongale *et al.*, 1995; Dinesh *et al.*, 2017). Nevertheless, such studies have a limited impact in farmer's field, as it is very difficult to analyze quite a large number of samples of leaves from many farmers within a short period. The use of the portable chlorophyll meters / LCC is a non-destructive method for measurement of greenness of the leaf. Several researchers have established relationship between the greenness index and the extractable chlorophyll content (Marquard and Tipton, 1987) on apple (Kaakeh *et al.*, 1992), cotton (Edmisten *et al.*, 1992), peppers (Hartz *et al.*, 1993), rice (Turner and Jand, 1991; Peng *et al.*, 1993) and wheat (Reeves *et al.*,

Table 1: SPAD values, leaf yield, nitrogen and carbohydrate contents under different levels of fertilizers at different growth stages of V-1 mulberry variety

Growth stage	Parameter	Fertilizer level					CD at 5 %	CV (%)
		T1	T2	T3	T4	T5		
30 DAP	SPAD	22.2	25.2	27.3	29.4	30.1	0.94	2.27
	Total chlorophyll	1.247	1.356	1.679	2.190	2.878	0.064	2.25
	Leaf yield (g/plant)	57.3	72.1	104.6	131.3	171.3	13.84	8.37
	Nitrogen (%) DW	3.08	3.51	3.81	4.11	4.21	0.046	0.79
	Carbohydrate (%) DW	18.07	20.47	22.10	23.65	24.48	0.77	2.29
40 DAP	SPAD	26.2	28.5	31.6	32.6	34.9	0.66	1.41
	Total chlorophyll	1.408	1.754	2.092	2.676	2.978	0.070	2.09
	Leaf yield (g/plant)	120.6	192.5	222.6	333.3	421.3	22.83	5.74
	Nitrogen (%) DW	3.07	3.36	3.74	3.92	4.14	0.029	0.52
	Carbohydrate (%) DW	18.40	21.14	23.08	24.33	25.45	0.47	1.38
50 DAP	SPAD	27.3	29.6	32.1	33.2	35.0	0.85	1.75
	Total chlorophyll	1.471	1.843	2.169	2.929	3.116	0.122	3.46
	Leaf yield (g/plant)	236.1	322.0	436.8	533.6	667.4	40.09	0.37
	Nitrogen (%) DW	3.02	3.31	3.67	3.91	4.09	0.020	1.68
	Carbohydrate (%) DW	20.23	22.30	24.44	25.27	26.49	0.61	
60 DAP	SPAD	27.2	29.5	31.7	32.9	34.5	0.73	0.62
	Total chlorophyll	1.466	1.818	2.167	2.713	3.095	0.059	1.71
	Leaf yield (g/plant)	280.2	458.8	597.2	678.0	868.4	46.31	5.21
	Nitrogen (%) DW	2.95	3.21	3.56	3.70	3.88	0.022	0.42
	Carbohydrate (%) DW	21.51	23.43	25.20	26.42	27.69	0.53	1.37
70 DAP	SPAD	27.1	29.5	30.8	32.2	33.6	0.62	1.31
	Total chlorophyll	1.465	1.802	2.136	2.670	3.038	0.113	3.31
	Leaf yield (g/plant)	337.5	591.6	717.1	800.6	1120.3	77.77	7.08
	Nitrogen (%) DW	2.91	3.19	3.51	3.67	3.83	0.017	0.32
	Carbohydrate (%) DW	22.01	25.04	25.85	27.40	28.48	0.71	1.79

DAP – Days after pruning; DW – Dry weight.

1993).

SPAD values, leaf yield, total chlorophyll, leaf nitrogen and carbohydrate contents varied significantly at different levels of fertilizers (Table 1). SPAD values increased from 30 DAP to 40 and 50 DAP in all the fertilizer treatments and slightly decreased from 50 DAP onwards to 70 DAP (Table 1). Under full fertilizer dose, the SPAD values of 30.1, 34.9, 35.0, 34.5 and 33.6 were recorded at 30, 40, 50, 60 and 70 DAP, respectively. At '0' fertilizer treatment (T1), there was no significant difference in SPAD values on different growth stages. The variability in SPAD values at different fertilizer levels opens up the possibility of using this portable meter in mulberry. Based on the results, SPAD values of 30.1 (30 DAP) and 34.9 (40 DAP) could be considered as critical SPAD values for V-1 mulberry variety. If SPAD values are

lesser than these critical values on that particular growth stage, corrective measures should be undertaken by applying additional dose of fertilizers to maintain the leaf quality.

Leaf yield was responsive to the levels of fertilizers and was found to be decreased with decrease in fertilizer level. A perusal of Table 1, indicated that the average leaf yield progressively increased from 30 to 70 DAP under all fertilizer treatments. However, there were significant differences in leaf yield among different fertilizer levels in all the five growth stages. The highest leaf yield of 1120 g/plant was recorded on 70 DAP under full dose (T5) of fertilizer treatment. The significant differences noticed on 30 DAP after 10 days of fertilizer application, exhibit the strong effect of fertilizer level on initial growth and its final yield. The leaves under optimum fertilizer dose were

Table 2: Relationship between leaf yield / leaf quality parameters and SPAD values at different growth stages in V-1 mulberry variety

Dependent variable	Growth stage	Regression equation	r	R ²
Leaf yield (g/plant)	30 DAP	$Y=13.368x - 251.1$	0.938**	0.881
	40 DAP	$Y=33.0x - 757.62$	0.947**	0.898
	50 DAP	$Y=54.829x - 1284.9$	0.980**	0.961
	60 DAP	$Y=76.139x - 1796$	0.988**	0.976
	70 DAP	$Y=112.56x - 2734.7$	0.978**	0.956
	Pooled	$Y=61.589x - 1439.9$	0.719**	0.517
Total chlorophyll content (mg/g FW)	30 DAP	$Y=0.1811x - 2.986$	0.879**	0.774
	40 DAP	$Y=0.1818x - 3.415$	0.967**	0.935
	50 DAP	$Y=0.216x - 4.485$	0.939**	0.882
	60 DAP	$Y=0.2193x - 4.582$	0.967**	0.935
	70 DAP	$Y=0.2464x - 5.325$	0.970**	0.942
	Pooled	$Y=0.1725x - 3.0426$	0.903**	0.813
Leaf nitrogen content (% DW)	30 DAP	$Y=0.138x - 0.0377$	0.968**	0.971
	40 DAP	$Y=0.1241x - 0.1704$	0.991**	0.984
	50 DAP	$Y=0.1389x - 0.767$	0.977**	0.956
	60 DAP	$Y=0.1273x - 0.501$	0.983**	0.967
	70 DAP	$Y=0.1453x - 1.025$	0.978**	0.958
	Pooled	$Y=0.0839x + 1.044$	0.69**	0.476
Leaf carbohydrate content (% DW)	30 DAP	$Y=0.7956x + 0.417$	0.998**	0.997
	40 DAP	$Y=0.8017x - 2.196$	0.987**	0.975
	50 DAP	$Y=0.8184x - 1.988$	0.952**	0.997
	60 DAP	$Y=0.8407x - 1.345$	0.993**	0.987
	70 DAP	$Y=0.9719x - 4.019$	0.974**	0.949
	Pooled	$Y=0.7554x + 0.9172$	0.887**	0.787

FW – Fresh weight; DW – Dry weight;** - Significant at $P<0.01$.

dark green in color and the intensity of greenness gradually decreased with decrease in fertilizer dose, which was reflected in total chlorophyll content and also in SPAD values (Table 1). The reliability of using the SPAD meter values in predicting the yield, nitrogen status *etc.*, has been ascertained by various authors (Piekielek *et al.*, 1995; Bijay Singh *et al.*, 2002; Janaki and Thiagarajan, 2003; Islam *et al.*, 2014).

The leaf nitrogen content not only indicates sufficiency of nitrogen fertilizer, but also is an important

parameter depicting leaf quality in sericulture. Analysis of data showed significant differences in leaf nitrogen content under different levels of fertilizers. Higher nitrogen contents were recorded at 30 DAP in all fertilizer treatments which gradually decreased with increase in growth stage. The nitrogen content ranged from 4.21 to 3.83 % under full dose of fertilizers (Table 1). The carbohydrate content, another important parameter determining leaf quality, progressively increased from 30 to 70 DAP under all the fertilizer treatments. The differences in carbohydrate contents in relation to fertilizer

levels were significant at all growth stages studied.

As the results obtained in the study exhibited sufficient variability with respect to SPAD values, leaf yield and quality parameters, the correlation co-efficient and regression equations for prediction of fertilizer sufficiency were estimated (Table 2). The correlation co-efficient between SPAD values and leaf yield at different growth stages was found significant and ranged from 0.938 at 30 DAP to 0.988 at 60 DAP. The R^2 value at different growth stages, separately, indicated that the accuracy of the measurement is to the extent of 88 to 97.6%. The R^2 based on pooled data was found to be 51.7%. Significant and high positive correlations were obtained between SPAD values and total chlorophyll content, leaf nitrogen and total carbohydrate contents at all five growth stages studied. Suzuki (1993), Sarkar *et al.* (1999), Fallah (2012) and Xiong *et al.* (2015) also observed high correlation between SPAD values and leaf yield, yield contributing characters and biochemical parameters in three Japanese mulberry varieties.

Based on the critical SPAD values obtained on 40 DAP under different levels of fertilizers and assessment of leaf greenness, efforts were made to develop leaf color chart (LCC) possessing different shades of green color corresponding to SPAD values. The green color shades corresponding to full fertilizer dose, 75 % of recommended dose, 50 % of recommended dose, 25 % of recommended dose and no fertilizer application for V-1 mulberry variety are represented as LCC in Figure 1. Further work on LCC is being carried out to develop it as a tool for use at any farmer's garden for assessing existing status of fertility. If the leaf color tallies with the color shades of LCC representing 50 % fertilizer level, on spot recommendation could be made to apply remaining 50 % of recommended dose of fertilizer to obtain expected leaf yield and quality.

In contrast to grain crops where SPAD values are used mostly for checking soil fertility status, SPAD values provide the status of soil fertility as well as leaf quality in mulberry. Hence, the SPAD value-guided fertilizer

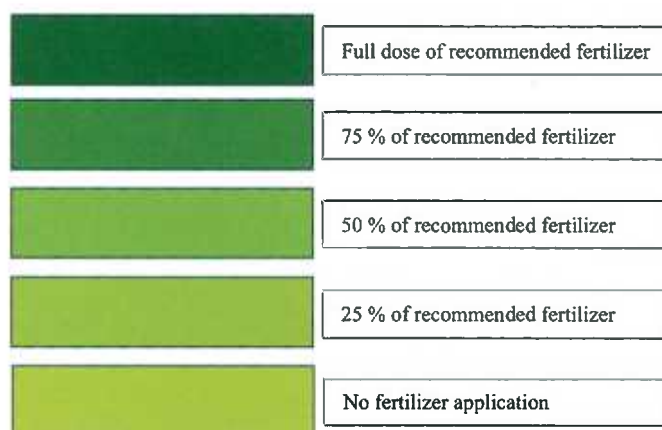


Figure 1: Leaf color chart (LCC) indicating shades of green color under different fertilizer doses

management may be helpful in predicting the leaf yield and leaf quality instantly. The identified critical SPAD values of 30.1 ± 0.94 and 34.9 ± 0.66 at 30 and 40 DAP, respectively are variety specific and useful for assessment of fertility status / side dress requirement / quality of V-1 mulberry plantation. The work has an immense potential to provide on-spot guidance to farmers with regard to additional requirement of fertilizers and prediction of leaf yield and quality without any special laboratory analysis.

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Article scientifique

EVALUATION RAPIDE DE LA SUFFISANCE EN ENGRAIS ET DE LA QUALITE DE LA FEUILLE CHEZ LE MURIER EN UTILISANT LA MESURE EN CHLOROPHYLLE ET UNE CHARTE DE COULEUR

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ABSTRACT

Cette étude explore la possibilité de prédire la suffisance en engrais et le statut des nutriments foliaires de la variété V-1 de mûrier en utilisant un doseur de chlorophylle (Soil Plant Analysis Development-SPAD-502) au Central Sericultural and Training Institute (CSRTI) de Mysuru. L'expérience est menée selon un plan de blocks aléatoires (RDB) avec quatre réplifications et cinq traitements d'engrais et les données sont enregistrées 30 à 70 jours après le débouillage à 10 jours d'intervalle. Des variations significatives sont observées dans les valeurs SPAD, le rendement en feuilles, la chlorophylle totale, l'azote foliaire et les hydrates de carbone à différents niveaux de traitements. Des valeurs critiques de SPAD à différents niveaux d'engrais sont identifiées comme 30,1 (30 DAP) et 34,9 (40 DAP) pour la variété de mûrier V-1. Des corrélations élevées significatives sont obtenues entre les valeurs SPAD et le contenu total en chlorophylle, l'azote foliaire et les hydrates de carbone totaux à tous les stades de croissance. Basés sur les valeurs critiques SPAD à différents niveaux d'engrais, des efforts ont été développés pour obtenir une charte de couleur. Des équations de régression permettent de prédire le rendement en feuilles selon la dose d'engrais et les conditions de terrain. Notre étude permet de montrer l'utilité des valeurs SPAD pour déterminer la fertilité du sol et la qualité de la feuille chez le mûrier de manière instantanée sans analyses sophistiquées de laboratoire.

Mots-clés: Qualité de la feuille, mûrier, SPAD.



Brief Note

IMPACT OF MIXED INFECTION OF *BACILLUS SUBTILIS* AND OTHER MICROORGANISMS ON LARVAL PARAMETERS OF SILKWORM, *BOMBYX MORI* L. (PM × CSR₂)

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ABSTRACT

Infection due to combinations of pathogenic organisms cause a type of bacterial flacherie disease in silkworm characterized by flaccid condition, vomiting and dysentery. The disease is common during summer and rainy seasons in all the sericultural areas of India and it is caused by different species of bacteria, viruses or their mixed population. Per oral inoculation of different pathogenic bacteria viz., *Lysinibacillus sphaericus*, *Alcaligenes faecalis* and *Bacillus subtilis* and virus, NPV revealed significant reduction in larval weight and per cent larval weight reduction since end of the third instar through subsequent instars. Altered larval duration (days) and moulting hours (hours) were noticed in third instar inoculated batch which indirectly affect the silk productivity. The larvae of PM × CSR₂ inoculated during third instar, recorded higher reduction in larval weight in respect of treatment, *B. subtilis* + *L. sphaericus* + NPV (35 %). Further, maximum extension in larval and moulting durations (23.98 days and 78.77 h) were noticed when administered with *B. subtilis* + *L. sphaericus* + *A. faecalis*, followed by dual inoculation with *B. subtilis* and *A. faecalis* (22.93 days and 72.67 h) and the least was recorded in *B. subtilis* inoculated batch (21.66 days and 57.96 h) whereas, the control batch recorded 14.42 days and 52.30 h, respectively.

Key words: Bacterial isolates, larval parameters, mixed infection, silkworm.

INTRODUCTION

The silkworm, *Bombyx mori* is one of the beneficial insects which has been exploited for production of raw silk. Sericulture has a potential in generating employment and provides sustainable income at regular interval with comparatively low investment and short gestation period. But, during silkworm rearing, changes in environmental factors and micro environment in the bed make it sensitive to microbial infections in nature and susceptible to various kinds of diseases due to the presence of different types of pathogens (protozoan, viral, bacterial and fungal) in the rearing houses. In addition, diseases are also caused by combinations of both viruses and bacteria (flacherie) which lead to considerable cocoon crop loss by adversely affecting the larval growth and development. The attributing factors for the flacherie infection are presence

of many bacterial isolates more specifically, *Streptococcus* sp., *Micrococcus* sp., *Bacillus* sp. and *Serratia marcescens*, whereas, flacherie caused by viruses involves that due to infectious flacherie virus, denonucleosis and cytoplasmic polyhedrosis viruses and *Coccus* spp. of bacteria or mixed infection by both bacteria and viruses (Selvakumar and Datta, 2013).

Of late, Anusha *et al.* (2016) isolated bacteria such as *Lysinibacillus sphaericus*, *Alcaligenes faecalis* and *Bacillus subtilis* from the flacherized cadavers of silkworm in support of their synergistic association in causing the disease. The average flacherie disease incidence in Chikkaballapur area during summer season was found to be 5 ~ 15 per cent, and 5 ~ 10 per cent during rainy and winter months, respectively. The highest incidence was observed during summer season followed

by rainy and winter seasons (Swathi, 2015). Therefore, the present study was carried out to explore the impact of mixed infection of *B. subtilis* and other microorganisms on larval growth and development of silkworm, *Bombyx mori* L.

MATERIALS AND METHODS

The present study was carried out during 2014-16 at the Department of Sericulture, University of Agricultural Sciences, GKVK, Bengaluru. Known volume of inoculum was administered to the silkworm at the rate of 0.25 ml per 25 larvae with 10^{-7} dilution to each replication at the beginning of the third instar. The inoculums (*B. subtilis* + other organisms) were administered first individually, later bacterial isolates were inoculated in combinations of two viz., bacterium + virus, virus + bacterium and three organisms viz., bacterium + two bacteria, virus + two bacteria, bacterium + (virus + bacterium). While inoculating two micro-organisms, first micro-organism was inoculated at the beginning of the third instar and the second organism (isolate) was inoculated during middle of the third instar. In the case of administration of three micro-organisms, first micro-organism was administered at the beginning and the other two micro-organisms were inoculated at the middle of the third instar of larvae of PM $\times$ CSR₂. The bacterial pathogens were identified through molecular characterization and reported as *A. faecalis*, *L. sphaericus* and *B. subtilis*. Silkworm parameters were recorded and one way ANOVA was resorted for statistical analysis of data.

Stock concentration of bacterial pathogens and NPV used were as following.

Bacterial isolates / NPV	10^7 dilution
<i>L. sphaericus</i>	2.84×10^9 CFU/ml
<i>A. faecalis</i>	2.75×10^9 CFU/ml
<i>B. subtilis</i>	2.80×10^9 CFU/ml
NPV	3.4×10^{-11} Polyhedral bodies/ ml

The various treatments (*B. subtilis* and other micro-organisms) imposed for the experiment were as listed below.

- T1 - *B. subtilis*
- T2 - *B. subtilis* + *L. sphaericus*
- T3 - *B. subtilis* + *A. faecalis*
- T4 - *B. subtilis* + NPV
- T5 - *B. subtilis* + *L. sphaericus* + *A. faecalis*
- T6 - *B. subtilis* + *L. sphaericus* + NPV
- T7 - Normal leaf
- T8 - Sterile water

The larval parameters viz., larval weight, larval duration and moulting duration affected due to mixed infection were considered for evaluation.

RESULTS AND DISCUSSION

The combined inoculation of *B. subtilis* and other organisms during third instar caused weight reduction in the experimental batch. However, in all the three instars, the decreasing trend of larval weight from 0.77-0.84, 3.02-3.96 and 16.00-20.18 g/10 larvae was registered in respect of T4 (*B. subtilis* + NPV), T2 (*B. subtilis* + *L. sphaericus*), T6 (*B. subtilis* + *L. sphaericus* + NPV) and T5 (*B. subtilis* + *L. sphaericus* + *A. faecalis*). The combined effect of *B. subtilis* + *L. sphaericus* + NPV (T6) registered minimum larval weight. It was clearly observed that, T2 (*B. subtilis* + *L. sphaericus*) registered increased larval weight at the end of third and fifth instar larvae whereas, T5 (*B. subtilis* + *L. sphaericus* + *A. faecalis*) at the end of fourth instar of third instar inoculated batch (Table 1 and Figure 1).

Further, the per cent weight reduction over sterile water (SW) control in all the three instars also registered significant differences. However, maximum of 22.18, 23.04-33.23, 31.93-28.36 per cent reduction was noticed at the end of third instar and both at the beginning and end of fourth and fifth instars for T4 whereas, in T6, it registered larval weight reduction of 34.32 and 35.60 per cent which were found to be the highest of larval weight reduction at the end of fourth and fifth instar in larvae of third instar inoculated batch over the sterile water control.

Table 1: Combined effect of *Bacillus subtilis* and other organisms on larval weight and per cent larval weight reduction over sterile water control of PM × CSR₂ (third instar inoculated batch)

Treatment	Larval weight (g/10 larvae)						Larval weight reduction (%)					
	Instar						Instar					
	III		IV		V		III		IV		V	
	Beginning	End	Beginning	End	Beginning	End	End	Beginning	End	Beginning	End	
T1	0.24	0.79	0.85	3.84	3.94	20.10	20.20(26.70)	18.17(25.11)	16.49(23.94)	15.89(23.48)	19.10(25.85)	
T2	0.24	0.84	0.89	3.30	3.72	20.18	15.14(22.89)	14.37(22.19)	28.24(34.15)	24.06(29.33)	18.78(25.61)	
T3	0.24	0.80	0.87	3.40	3.70	19.98	19.12(25.90)	16.22(23.53)	26.07(30.47)	22.91(28.59)	19.59(26.27)	
T4	0.24	0.77	0.80	3.07	3.46	17.80	22.18(28.09)	23.04(28.64)	33.23(35.20)	31.93(34.40)	28.36(32.17)	
T5	0.24	0.81	0.87	3.96	3.98	17.89	18.09(25.13)	16.28(23.74)	13.89(21.86)	15.00 (23.58)	28.00(31.95)	
T6	0.24	0.78	0.83	3.02	3.21	16.00	21.14(27.35)	20.29(26.66)	34.32(35.86)	31.08(33.88)	35.60(36.63)	
T7 Control	0.24	0.96	0.99	4.50	4.60	24.65	2.90(7.48)	4.40(11.84)	2.15(6.99)	2.56(7.41)	0.80(5.13)	
T8 SW	0.24	0.99	1.04	4.60	4.68	24.85	0.00(0.58)	0.00(0.58)	0.00(0.58)	0.00(0.58)	0.00(0.58)	
F test	NS	*	*	*	*	*	*	*	*	*	*	
SEm ±	0.02	0.02	0.03	0.12	0.05	0.39	1.74	3.12	2.83	3.99	1.57	
CD at 5 %	0.05	0.05	0.06	0.26	0.12	0.82	3.69	6.62	6.01	8.46	3.34	

* - Significant at 5 %; NS - Non significant; () - Arcsine transformation.

T1 - *Bacillus subtilis*; T2 - *Bacillus subtilis* + *Lysinibacillus sphaericus*; T3 - *Bacillus subtilis* + *Alcaligenes faecalis*; T4 - *Bacillus subtilis* + NPV; T5 - *Bacillus subtilis* + *Lysinibacillus sphaericus* + *Alcaligenes faecalis*; T6 - *Bacillus subtilis* + *Lysinibacillus sphaericus* + NPV; T7 - Normal leaf (Control); T8 - Sterile water (SW).

As per the data, the combined effect of *B. subtilis* and NPV recorded maximum per cent larval weight reduction compared to administration of other dual bacterial inoculums (Table 1).

The data on larval duration revealed significant variations due to inoculation of *B. subtilis* and other bacterial isolates and NPV during third instar. The third instar inoculated larvae have taken more number of days for completion of larval growth of third, fourth and fifth instars. The maximum extension was noticed for T5 i.e., 23.98 days followed by T6 (23.40 days), T3 (*B. subtilis* + *A. faecalis*) (22.92 days), T4 (22.34 days) and T2 (22.01 days) whereas, comparatively less duration was recorded for T1 (*B. subtilis*) (21.66 days) (Table 2).

Significant differences were also noticed in respect of IV instar duration (days), among the treatments, T1 (6.08), T3 (6.58), T4 (6.30), T5 (6.98) and T6 (6.70). However, the trend was not same in the fifth instar,

Table 2: Influence of combined inoculation of *Bacillus subtilis* and other pathogenic micro-organisms on larval (days) and moulting duration (h) of PM × CSR₂

Treatment	Larval duration (Days)				Moulting duration (h)		
	III instar inoculated batch				III instar inoculated batch		
	III	IV	V	Total	III	IV	Total
T1	4.90	6.08	10.68	21.66	28.00	29.96	57.96
T2	5.00	6.22	10.79	22.01	30.10	31.26	61.36
T3	5.36	6.58	10.98	22.92	35.89	36.78	72.67
T4	5.20	6.30	10.84	22.34	34.26	35.96	70.22
T5	5.62	6.98	11.38	23.98	38.78	39.99	78.77
T6	5.50	6.70	11.20	23.40	37.46	38.18	75.64
T7 Control	3.16	4.28	6.98	14.42	26.10	26.20	52.30
T8 SW	3.16	4.28	6.98	14.42	26.10	26.20	52.30
F-test	*	*	*		*	*	
SEm ±	0.05	0.04	0.06		0.3	0.28	
CD at 5 %	0.10	0.09	0.13		0.63	0.61	

* - Significant at 5 %.

T1 - *Bacillus subtilis*; T2 - *Bacillus subtilis* + *Lysinibacillus sphaericus*; T3 - *Bacillus subtilis* + *Alcaligenes faecalis*; T4 - *Bacillus subtilis* + NPV; T5 - *Bacillus subtilis* + *Lysinibacillus sphaericus* + *Alcaligenes faecalis*; T6 - *Bacillus subtilis* + *Lysinibacillus sphaericus* + NPV; T7 - Normal leaf (Control); T8 - Sterile water (SW).

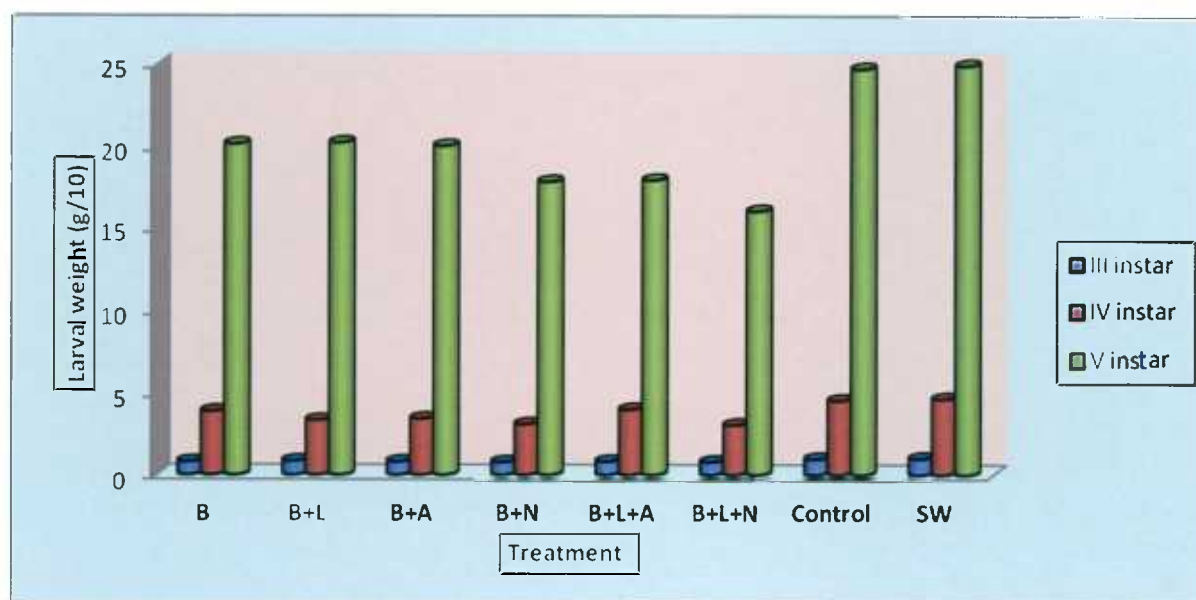


Figure 1: Combined effect of *Bacillus subtilis* with other organisms on larval weight of PM × CSR₂ (third instar inoculated batch)

B: T1 - *Bacillus subtilis*; B+L: T2 - *Bacillus subtilis* + *Lysinibacillus sphaericus*; B+A: T3 - *Bacillus subtilis* + *Alcaligenes faecalis*; B+N: T4 - *Bacillus subtilis* + NPV; B+L+A: T5 - *Bacillus subtilis* + *Lysinibacillus sphaericus* + *Alcaligenes faecalis*; B+L+N: T6 - *Bacillus subtilis* + *Lysinibacillus sphaericus* + NPV; Control: T7 - Normal leaf; SW: T8 - Sterile water.

significant differences were noticed between treatments, T2 (10.79) and T3 (10.98), T4 (10.84) and T5 (11.38), T5 (11.38) and T6 (11.20) except between T1 (10.68 days) and T2 (10.79 days) (Table 2).

In addition, significant differences were recorded in moulting duration of third instar inoculated batches both among the treatments and also over the control. Total moulting duration of 78.77 hours was recorded, for the larvae administered with T5 which appeared to be the maximum to complete moulting, over the control, whereas, shorter duration of 57.96 hours was noticed in the treatment T1 of third instar inoculated batch (Table 2).

These experimental results are confirmative of the findings of Doreswamy *et al.* (2004) who reported that, the incidence of flacherie disease was more during summer season followed by winter and rainy seasons and recorded the least larval weight of 26.43 g/10 larvae during May. The highest larval weight was recorded during December (34.88 g/10 larvae) followed by January (34.50 g/10 larvae). Further, larval weight was

significantly less (23.04 g/10 larvae) in the treatment of inoculation with *BmDNV* + *Bacillus* sp. which was found on par with *BmIFV* + *BmDNV*, *BmIFV* + *BmDNV* + *Bacillus* sp., *BmIFV* + *BmDNV* + *S. faecalis*, *BmIFV* + *BmDNV* + *S. aureus*, *BmDNV* + *Streptococcus faecalis* and *BmDNV* + *Staphylococcus aureus* in the mean dilutions of stock, 10^{-2} , 10^{-4} , 10^{-8} , 10^{-16} and 10^{-32} . The highest larval weight was recorded against untreated (39.00 g/10 larvae) and distilled water control (36.00 g/10 larvae). In addition, when *Bacillus* sp., *S. faecalis* and *S. aureus* were administered to fourth instar larvae of PM × NB₄D₂ hybrid, significantly longer IV instar durations of 114.88, 119.66 and 123.05 h, respectively were noticed compared to control (102.00 h) (Doreswamy, 2002).

In this context, Rai *et al.* (2013) reported that, when bacterial suspensions of 1.0×10^6 CFU and 4.0×10^6 CFU were inoculated to the silkworm larvae of PM × CSR₂ individually, moulting was delayed by nearly 24 h in the inoculated groups compared to control as reflected in the present data.

The altered moulting period as a result of bacterial infection may be attributed to weak primary structural defence mechanism in the infected batch and because of the delay in formation of new cuticle (Wago and Ichikawa, 1979). Similar results were reported in *Helicoverpa armigera* larvae exposed to the *Bs/Bt* mixture wherein the larval period was the longest in treatments as against shortest duration in the control larvae, the differences being significant ($F = 2.61$, $df = 39$,

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Note brève

IMPACT DE L'INFECTION MIXTE DE *BACILLUS SUBTILIS* AVEC D'AUTRES MICROORGANISMES SUR LES PARAMETRES LARVAIRES DU VER A SOIE, *BOMBYX MORI* L. (PM × CSR₂)

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ABSTRACT

L'infection due à des combinaisons d'organismes pathogènes cause un type de flacherie chez le ver à soie caractérisée par la molesse, les vomissements et la dysenterie. La maladie est commune pendant l'été et la saison des pluies dans toutes les zones séricicoles en Inde, causée par différentes espèces de bactéries, de virus et de populations mixtes. L'inoculation per os de différentes bactéries pathogènes comme *Lysinibacillus sphaericus* (L), *Alcaligenes faecalis* (A) et *Bacillus subtilis* (B) et NPV (N) entraîne une réduction significative du poids larvaire depuis la fin du troisième stade à travers tous les âges. La durée larvaire (jours) et de la mue (heures) est affectée au troisième âge des larves inoculées ce qui affecte indirectement la productivité en soie. Les larves de PMxCSR₂ inoculées au troisième âge montrent la plus forte réduction du poids larvaire lorsque l'inoculation concerne *Bacillus subtilis*+*Lysinibacillus sphaericus*+NPV (35 %). L'augmentation des durées larvaire et de mue (23,98 jours et 78,77 h) est obtenue avec *Bacillus subtilis*+*Lysinibacillus sphaericus* + *Alcaligenes faecalis*, suivie par l'inoculation de *Bacillus subtilis* + *Alcaligenes faecalis* (22,93 jours et 72,67 h) la plus faible étant obtenue avec les lots inoculés par *Bacillus subtilis* (21,66 jours et 57,96 h) alors que les témoins donnent 14,42 jours et 52,30 h..

Mots-clés: Isolats bactériens, paramètres larvaires, infection mixte, ver à soie.



SERICULTURE ACHIEVING SUSTAINABLE DEVELOPMENT GOALS (SDG) 2030 - SOME EXPERIENCES OF INDIA

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SYNOPSIS

Sericulture, covering a chain of activities, namely plantation of silkworm food plants, rearing of silkworm, reeling of yarn and weaving silk fabrics, is an important agro based rural industry activity known for its potential of optimisation of use of labor and poverty alleviation in general and empowerment of women in particular. India is the second largest global silk producer, after China. Indian sericulture has been concentrated in the five traditional states around Karnataka. With land and labour becoming costly in this traditional area, special initiatives were taken for introducing sericulture on a commercial scale in the North-Eastern Region (NER), which has favourable conditions viz., fertile land, good rainfall and abundant labour. Early reports on production of quality silk, decent return and bringing cheers to the women have been positive. This has in turn, proved effective in reduction of poverty and hunger, empowerment of women and environment conservation, some of the important components of the Sustainable Development Goals (SDG) 2030. This experience can be replicated at other places / countries with favourable agro-climatic conditions for promotion of sericulture as a tool for socio-economic inclusion and to achieve the Sustainable Development Goals.

Key words: Indian sericulture, sustainable development goals.

BACKGROUND

Because of its unique characteristics, silk has a distinct place and importance in the textile basket notwithstanding its relatively small share. The unique features, such as lustre, strength and dye-absorbing capacity, make silk popularly known as the “*Queen of Textiles*”. Sericulture is a land based industrial activity. Its economic features, like low capital requirement, highly labour intensive nature, short gestation, high return, good market *etc.* make it an ideal tool for the disadvantaged small and marginal farmers in using surplus labour effectively and getting a decent earning. Further, as silkworm (mulberry) rearing is less strenuous and done indoor, it is particularly useful for the women who can take it up along with other household works, like taking care of children and aged, cleaning and cooking. By providing productive employment in the rural areas, it checks urbanisation and related adverse issues like creation of slums and environmental degradation.

Table 1: Production of different types of silk in India during 2014-15 and 2015-16

	2015-16	2014-15	Change (%)
Area under mulberry (ha)	208947	219819	-4.9
Mulberry raw silk Bivoltine (MT)	4613	3870	19.2
Mulberry raw silk Multivoltine (MT)	15865	17520	-9.4
Total mulberry yarn (MT)	20478	21390	-4.3
Tasar (MT)	2819	2434	15.8
Eri Spun (MT)	5060	4726	7.1
Muga (MT)	166	158	5.1
Total non- mulberry yarn (MT)	8045	7318	9.9
Total silk yarn	28523	28708	-0.6

Source: Annual Report 2015-16, Central Silk Board.

India has the distinction of producing four types of silk; mulberry as well as non-mulberry including Tasar (Oak Tasar and Tropical tasar), Eri and Muga. An account of

different types of silk produced in India during 2014-15 and 2015-16 is given in Table 1. Mulberry sericulture, which contributes bulk of the silk production, is concentrated in five states, viz., Karnataka, Andhra Pradesh (undivided), Tamil Nadu, West Bengal and Jammu & Kashmir, which are commonly known as the traditional states. Favourable climate, infrastructure and state patronage led to development of Karnataka and adjoining areas as the hub of Indian sericulture industry.

Decades after launching of the new economic policy in 1991, we saw rapid urbanisation and industrialisation all over India. During this period, Information Technology based start-ups changed the economic scenario of Karnataka and adjoining areas to a considerable extent. There were sharp increases in the per capita income and wage structure for unskilled jobs in the urban and rural areas. Simultaneously, sizeable chunk of agricultural land used for mulberry plantation was diverted for development of physical infrastructure viz., airport, road, and railway line as well as real estates. These developments have affected status and promotion of mulberry sericulture in the traditional states. Being a labour intensive, land based activity, sericulture or production of silk is a function of cheap land and labour. As availability of land went down and price of land and labour went up, sericulture became economically non-viable. As a result, sericulture has to shift from the so called traditional states to the new and non-traditional states as well as non-traditional areas of the traditional states, where suitable land and cheap labour are available. This has been noticed world over in the developed countries as well as within India in the economically developed states practicing sericulture as well. Further, Indian sericulture faces another major challenge on account of production of quality bivoltine silk. Even though India is the second biggest producer of raw silk in the world, quality of Indian silk has been an issue because bulk of the silk produced is of multivoltine origin, which is of relatively inferior quality. As a result of concerted efforts of the Central Silk Board, production of quality

bivoltine silk has been going up steadily.

Sericulture with its high production potential represents a possible driver of economic growth in North East states. However, a myriad of obstacles stand in the way of realizing this potential. These include limited to no use of improved sericultural production technologies and practices that keep productivity low, poor transportation infrastructure that make markets inaccessible to many farmers, low rates of literacy and numeracy that limit farmers' abilities to effectively practice farming as a remunerative enterprise.

The changing profile of Indian sericulture is evident from the state-wise account of area under mulberry sericulture and production of mulberry silk during the years 2014-15 and 2015-16 which is given in Table 2.

New interventions

The strategy for promotion of sericulture was modified by the Ministry of Textiles with technical input from the Central Silk Board. Promotion of mulberry sericulture in the non-traditional areas in general and in the North Eastern Region (NER) in particular was given specific attention for exploiting the relatively cheap labour, land and rainfall in general and for empowerment of the women in particular. Future expansion of mulberry sericulture was taken up based on production of quality bivoltine silk by replacing the multivoltine breed by improved bivoltine. Further, specific support was extended for consolidating muga sericulture typical to the North Eastern Region.

The NER of the country have inherent strengths, such as good soil, high rainfall and hardworking people, as well as constraints on account of geographical isolation, poor physical infrastructure, non-availability of raw material for industrialisation and small market. Prevailing conditions offer huge potential for expansion of mulberry sericulture in the NER. "North Eastern Region Textile Promotion Scheme" (NERTPS) of the Ministry of Textiles provided for undertaking innovative schemes in the NER out of the ten per cent of the total budgetary provisions of

Table 2: State-wise area and production of mulberry silk and total silk production during 2014-15 and 2015-16

State	Mulberry area (ha)		Change (%)	Mulberry BV Silk (MT)		Change (%)	Total Mulberry Silk (MT)		Change (%)	Total silk (MT)		Change (%)
	2014-15	2015-16		2014-15	2015-16		2014-15	2015-16		2014-15	2015-16	
Arunachal Pradesh	342	341	-0.3	1	3	200	1	3	200	12	37	208
Assam	7356	7765	5.6	29	32	10	31	39	26	3222	3324	3
Manipur	6858	7338	7.0	138	133	-4	150	144	-4	516	518	0.4
Meghalaya	2659	3009	13.2	17	15	-12	17	15	-12	655	857	31
Mizoram	3700	3843	3.9	32	46	44	40	55	38	50.12	64.125	28
Nagaland	633	743	17.4	6	4	-33	6	7	17	619.1	631.07	2
Sikkim	198	198	0.0	5	4	-20	5	4	-20	8.17	7.15	-12
Tripura	2426	3161	30.3	33	22	-33	48	53	10	48	53	10
Total NE	24172	26398	9.2	261	259	-1	298	320	7	5130.39	5491.345	7
Andhra Pradesh	45726	29829	-34.8	495	708	43	6485	5086	-22	6485	5086	-22
Telangana	1862	2509	34.7	51	89	75	100	115	15	100.3	116	16
Jammu & Kashmir	8132	8237	1.3	138	127	-8	138	127	-8	138	127	-8
Karnataka	88469	87598	-1.0	1203	1344	12	9645	9823	2	9645	9823	2
Tamil Nadu	16576	16160	-2.5	1207	1532	27	1602	1898	18	1602	1898	18
West Bengal	15153	15500	2.3	27	31	15	2450	2351	-4	2499.27	2391.21	-4
Total Traditional states	175918	159833	-9.1	3121	3831	23	20420	19400	-5	20469.57	19441.21	-5
Total for India*	219819	208947	-4.9	3870	4613	19	21390	20478	-4	28708	28523	-1

*Includes non-traditional areas other than the NE states as well.

the Ministry is meant for expenditure in the NE region. Prior to 2014-15, this amount was being spent on traditional handloom and handicraft in a routine manner.

Area specific *Integrated Sericulture Development Project* (ISDP) and *Intensive Bivoltine Sericulture Development Project* (IBSDP) were taken up in identified blocks based on “Soil to Silk” approach. All activities viz., plantation of mulberry, rearing of silkworm, reeling, twisting and silk weaving were taken up in an integrated manner on a project mode by mobilising rural women into cooperatives and providing them necessary financial assistance, technological knowledge and managerial skill; based on the experience of Tripura for promotion of sericulture, which had yielded good result. These projects were funded by the Ministry of Textiles on hundred per cent basis and state government support was to make available staff, existing infrastructure and administrative

support for implementation of the project. As many as 24 projects with an outlay of Rs.819.19 crore were sanctioned out of which, the major part of Rs.690.01 crore was funded as central share under ISDP and IBSDP. These projects were approved for implementation during 2014-15 to 2018-19 envisaging employment for 1,67,700 persons, involving 33,550 families and production of 1,100 MT silk per annum. Details are provided in Tables 3.1 and 3.2.

Sixteen number of Integrated Sericulture Development Projects (ISDP), were approved at a total cost of Rs.582.42 crore including Rs.479.60 crore as central share for implementation in 8 NE states viz., Assam, BTC, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland and Tripura, for raising 10,360 acres of new plantation and maintaining 17,650 acres of existing plantation (Mulberry, Eri & Muga). Besides, special projects, namely setting up of a Silk Printing & Processing

unit for Tripura, Soil to Silk Project in Udalguri for BTC and Post Cocoon Development for Nagaland were sanctioned for meeting state specific requirements. Out of this, 15 projects were sanctioned to consolidate the states' efforts to strengthen the existing facilities including support for infrastructure creation at farmers / seed cocoon producers / reelers / weavers' level in identified areas, one project is meant for creation of Seed Infrastructure for CSB to produce and supply quality seed to NE States. Rs.249.78 crore has been sanctioned for these projects, out of which about Rs.177.08 crore (71%) has been reportedly spent (March 2017).

Under the Intensive Bivoltine Sericulture Development Project (IBSDP), eight projects were sanctioned with an outlay of Rs.236.78 crore including Rs.210.41 crore as central share for implementation from 2015-16 to 2017-18. These projects aim at production of better quality bivoltine silk for import substitution in the

coming years. The project envisages covering 200 ha. under mulberry plantation in a geographical cluster in two blocks with about 1,100 women beneficiaries rearers / weavers in a state. Overall, it aims to cover 4,000 acres of mulberry plantation benefitting around 8,750 women stakeholders covering 8 clusters in NE States. Social Mobilization and Women Beneficiaries Group Formation along with supporting interventions for plantation development and infrastructure creation are integral part of the project.

Impact of new interventions

These projects are under implementation by the respective State agencies. Rs.110.07 crore has been reportedly released for these projects (up to March 2017), out of which Rs.85.47 crore (78 %) has been spent. An account of physical progress and raw silk production in NE States are furnished in Tables 4 and 5.

Table 3.1: ISDP project sanctioned (project period from 2014-15 to 2018-19)

#	State	Project cost (Rs. in crores)	GoI share (Rs. in crores)
1	Assam	66.67	47.42
2	BTC	34.92	24.68
2a	BTC (IEDPB)	11.41	10.61
2b	BTC (Soil to Silk)	51.61	49.37
3	Arunachal Pradesh	18.42	18.42
4a	Manipur (Valley)	149.76	126.60
4b	Manipur (Hill)	30.39	24.67
5	Meghalaya	30.16	21.91
6	Mizoram	32.49	24.49
6a	Mizoram (IMSDP)	13.52	12.83
7	Nagaland	31.47	22.66
7a	Nagaland (IESDP)	13.66	12.83
7b	Nagaland (PCT)	8.57	8.48
8	Tripura	47.95	33.20
	Sub Total	541.00	438.17
8a	Tripura (Printing)	3.71	3.71
9	Mulberry & Vanya Seed Infrastructure under CSB	37.71	37.71
	Total (A)	582.42	479.59

Table 3.2 : IBSDP project sanctioned (Project period from 2015-16 to 2017-18)

#	State	Project cost (Rs. in crores)	GoI share (Rs. in crores)
1	Assam	29.55	26.28
2	BTC	30.06	26.75
3	Arunachal Pradesh	29.47	26.20
4	Meghalaya	29.01	25.77
5	Mizoram	30.15	26.88
6	Nagaland	29.43	26.16
7	Sikkim	29.68	26.43
8	Tripura	29.43	25.95
	Total (B)	236.777	210.42
	Grand Total (A+B)	819.19	690.01

Table 4: Plantation (hectares) raised and production of raw silk (Metric Tonnes)

#	Particulars	2014-15		2015-16		2016-17	
		Country	NER	Country	NER	Country	NER
A	Mulberry						
	Plantation	219,819	24,208	208,947	26,398	221,518	27,571
	Bi-voltine (BV)	3,870	261	4,613	259	5,205	369
	Cross Breed (CB)	17,520	37	15,865	60	15,998	79
	Sub-Total	21,390	298	20,478	319	21,203	448
B	Vanya						
	Tasar *	2,434	4.00	2,819	4	3,259	4.84
	Eri	4,726	4,671	5,060	5,002	5,629	5,709
	Muga	158	157	166	166	171	171
	Total for NE States	7,318	4,832	8,045	5,172	9,059	5,885
	Total for the Country	28,708	5,130	28,523	5,491	30,262	6,333
	NE share (%)		18		19		21

*Provisional; Figures presented under NER (North-eastern region) are sub-set of the data pertaining to the country.
Source: Central Silk Board and State Sericulture Departments of the NER

Analysis

The special initiative for expansion of mulberry sericulture in commercial scale in the North-Eastern Region was launched during 2014-15. As per the reports available for the years 2015-16 and 2016-17, the area under mulberry cultivation increased from 24,208 ha in 2014-15 by 13.8 %, to 27,571 ha in 2016-17; whereas, area under mulberry at the national level remained almost stagnant. The strength of the new intervention in the NER lies in the fact that production of improved variety of bivoltine breed of silkworm was introduced in the NER which ensured better quality and better return to the primary producers; as compared to the national scenario, where bulk of the production is of relatively inferior quality of multi-voltine / cross breed. Production of

bivoltine silk in the project area in NER increased substantially from 261 tonnes in 2014-15 by 41.3 %, to 369 tonnes in 2016-17. These initial results appear to be promising for expansion of mulberry sericulture in the NER. It appears that while there is somewhat a saturation at the national position, which is mainly due to the stagnation in the traditional states on account of competing land use opportunity, NER holds considerable promise due to prevalent factors notwithstanding the fact that sericulture is relatively new. However, stabilising sericulture in the NER would require considerable efforts both from technical and administrative angles, on a continuous basis giving particular attention to the following.

(i) **Plantation of high yielding variety of mulberry**

Table 5: Production of raw silk under the project [up to March 2017 (provisional)]
(Area in hectares and quantity in Metric Tonnes)

#	State	Mulberry				Non Mulberry		Total raw silk	
		Plantation		Mulberry silk		Non Mulberry silk		Target	Achievement
		Target	Achievement	Target	Achievement	Target	Achievement		
1	Assam	7900	7553	55	39.6	3160	2814	3215	2854
1a	BTC	400	441	15	14.5	873	998	888	1012
2	Ar.Pradesh	450	381	5	2.0	43	43.02	48	45
3	Manipur	7500	7548	186	160.6	345	368.7	531	529
4	Meghalaya	2900	3137	25	48.7	875	940.1	900	989
5	Mizoram	4150	4009	60	86.88	10	10.99	70	98
6	Nagaland	1200	1043	13	14.8	677	710	690	725
7	Sikkim	260	198	6	6	4	0	9.5	6
8	Tripura	3500	3261	65	75	0	0	65	75
Total for NE		28260	27571	430	448.08	5987	5885	6416.5	6333
Achievement (%)		98		104		98		99	

Source: State Sericulture Departments of the NER

saplings along with raising *kisan* nursery through women self help groups in the identified blocks, for ensuring better survival, higher leaf yield and reduced cost of transportation of sapling.

- (ii) Introduce **tree type mulberry** in the forestland, on which right to use has been given under the RoFR Act.
- (iii) Introduce the culture of **chawki (young) worm rearing** through enterprising trained women rearers and supply chawki worm, rather than silkworm egg [Disease Free Layings (DFL)] for rearing by individual rearers.
- (iv) Extending financial support and helping for **construction of rearing house** and purchase of rearing equipment to each rearer along with regular monitoring for ensuring quality construction and acquisition of quality equipment.
- (v) Undertaking **stifling, storing and reeling** of cocoon and twisting.
- (vi) Taking up **weaving** both on handloom and power loom.
- (vii) **Branding and marketing silk fabrics** under India Handloom / Indian Silk brand(s) for assuring the customer quality of the product.

Role of Central Silk Board in promotion of sericulture

In this regard, it may be mentioned that as the apex body dealing with research and development of sericulture in India, the Central Silk Board (CSB) has launched several initiatives for sericulture development on cluster mode with participatory approach and active participation of people in planning and implementation, through its flagship Catalytic Development Programme (CDP). Skill enhancement programmes are being conducted in language-neutral training material, ICT based training programmes and an extensive use of audio-visual presentation which has helped in effective technology absorption. Through its premier research and development organization in the mulberry and vanya sector, CSB has evolved R&D technologies which are user and women-friendly. In the pre-cocoon sector, focus has been given on people's involvement; especially small and marginal farmers in chawki rearing, cocoon harvesting and post cocoon technologies viz., Ushnakoti, hot-air dryer, cocoon deflossers, multi-end reeling machines etc. in the mulberry sector. CSB has been engaging in dissemination of technologies with active involvement of local youth and women in various income generating activities, eg, Sericulture Resource Centres (SRCs), Grainages and mobile disinfectant units. In the Vanya

sector, special initiatives have been taken on introducing solar operated spinning machines and motorised-cum-peddle operated spinning machines. All these technologies have been user friendly, environment-conscious and cost effective, thereby contributing to a large number of small and marginal rearers-cum-reelers taking assistance from the schemes. The technologies evolved by the R&D Institutes have been simple, yet innovative and deliberately kept at a low cost, so as to include the small and the marginal. With a view to meet the requirement of quality silk of the silk weaving sector, specific emphasis has been laid on production of bivoltine silk and a comprehensive programme has been rolled out across the states in 174 clusters. Farmers in these clusters are being federated into community based organizations with significant women participation. Chawki rearing Centres, Seri-Polyclinics and Kisan Nurseries are being encouraged through people's participation. These activities have been identified as People Based Activities run through federation of farmers' groups specially women Self-Help Groups (SHGs). The focussed approach of the CDP has been not merely one of "adding on" women to various processes in the silk value chain, but also of reshaping these processes to create space for women's involvement not only in implementing the development agenda but also in agenda setting. Ongoing programmes of the CSB are being targeted for inclusive development in the North Eastern Region using sericulture as the tool.

Sericulture and SDG

Achievements of the project speak for itself. It appears that while there has been a beginning in introduction of sericulture on a commercial scale in the NER, the physical achievement has been below the projected level. Nevertheless, in view of the constraints and general experience of implementation of various projects in the NER, the achievement of the above project appears to be reasonable and satisfactory.

Eradication of poverty, empowerment of women and conservation of environment are some of the major SDG 2030. Achieving these goals particularly in respect of the rural population, women and other disadvantaged groups with low financial resource base, continue to be a daunting task. Experience of expansion of mulberry sericulture in Tripura indicates that with necessary technical and financial support, handholding and guidance on a long term basis, the entire operation can be taken up in an economic manner giving an assured return to the primary producers and quality material to the consumer, thereby reducing dependence on government fund and making the operations sustainable.

Conclusion

Rapid economic development for mainstreaming NER has been an important component of the national agenda for development. Being home to peace loving, hardworking people and a matriarchal society, the NER has several inherent strengths. However, geographical isolation, lack of physical infrastructure and dormant private sector are issues, which hinder economic development and are required to be addressed for developing the NER with peace and prosperity on a sustainable basis. The golden muga silk, unique of its kind in the silk world, is home to NER. It is also known for the eri silk, known as the vegetarian silk, as the silkworm is not required to be killed for extraction of fibre out of the cocoon for production of the silk. Efforts made by the Ministry of Textiles by launching special products for introduction of mulberry sericulture on a project mode and fast track basis along with consolidation of the muga and eri culture would spur economic activities on a sustainable basis in the region and provide adequate income to the rearers particularly women. It is expected that these will contribute positively to development of the region and achievement of the Sustainable Development Goals.

Rapport technique

LA SERICICULTURE PERMET D'ATTEINDRE LES BUTS DU DEVELOPPEMENT DURABLE 2030- QUELQUES EXPERIENCES EN INDE

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La sériciculture comprenant une chaîne d'activités comme la plantation des plantes nourricières des vers à soie, l'élevage des vers à soie, la filature et le tissage de tissus de soie est une agro-industrie rurale importante connue pour son potentiel de l'utilisation de la main d'œuvre et la lutte contre la pauvreté en général et des femmes en particulier. L'Inde est le deuxième producteur mondial de soie après la Chine. La sériciculture indienne est concentrée dans les cinq états traditionnels autour du Karnataka. Avec l'augmentation du coût des terres et du travail dans ces zones, des initiatives ont été prises pour introduire la sériciculture à une échelle commerciale dans les régions du Nord Est ayant des conditions favorables comme des terres fertiles, une bonne pluviométrie et beaucoup de travail disponible. Les premiers rapports sur la production de soie de qualité, un retour décent pour les femmes sont positifs. Ceci apparaît efficace dans la réduction de la pauvreté et de la faim, l'emploi des femmes et la préservation de l'environnement, quelques uns des composants importants des buts du développement durable 2030. Cette expérience peut être reproduite à d'autres endroits, d'autres pays ayant des conditions agro-climatiques favorables pour la promotion de la sériciculture comme outil pour l'inclusion socio-économique et pour atteindre les buts du développement durable.

Mots-clés: Inde, sériciculture, buts du développement durable.

Revue

**REPRODUCTION DU VER A SOIE TASAR, *ANTHRAEA MYLITTA*
DRURY: REVUE**

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ABSTRACT

Le ver à soie tasar tropical, *Antheraea mylitta* Drury est exploité commercialement en Inde pour la production de soie sauvage qui permet la subsistance de milliers de familles rurales engagées dans l'élevage tasar. Beaucoup de races géographiques de ver à soie tasar ont été trouvées dans les forêts tropicales où les populations se perpétuent en se nourrissant de beaucoup de types de plantes nourricières et se reproduisent de manière ouverte par nature. Cependant, des efforts vde R et D pendant des années ont généré un système de production extensive d'œufs ainsi que des pratiques d'élevage systématiquement développées sur des plantations de *Terminalia arjuna* et *T. tomentosa*. depuis les années 1960 des tentatives pour développer des lignées et des croisements de ver à soie tasar et exploiter la vigueur hybride ont été effectuées. Toutefois, jusqu'à maintenant, l'utilisation à grande échelle des vers à soie tasar hybride demeure un rêve. Ce secteur de travail nécessite des efforts concertés et systématiques vers l'isolement et le développement de lignées de vers à soie tasar suivis par l'exploitation de la vigueur hybride pour une transformation totale du scénario de la production de la soie vanya dans le pays. Cette revue étant le point complet sur les efforts de lignage du ver à soie dans plusieurs poches de l'élevage tasar en Inde peut servir d'information de base pour de futures tentatives sérieuses dans cette direction.

Mots - clés: *Antheraea mylitta*, reproduction, hétérosis, hybridation, ver à soie tasar.

PERFORMANCES DE POPULATIONS F₁ DU VER A SOIE TASAR TROPICAL, *ANTHERAEA MYLITTA* D. (LEPIDOPTERE: SATURNIDE) SUR DIFFERENTES PLANTES NOURRICIERES PRIMAIRES

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ABSTRACT

L'expression de l'hétérosis chez les caractères économiques du ver à soie tasar semi-domestiqué est souhaitable d'un point de vue commercial ainsi que pour l'amélioration génétique. Le ver à soie tasar polyphage s'alimente de diverses plantes et exprime des caractères phénotypiques dans différentes niches écologiques. Les populations F₁ des croisements réciproques de deux races sauvages Sal c'est à dire, Raily et Laria et la semi-domestiqué Daba croisée avec Laria ont été réalisées. Les performances des hybrides ont été étudiées sur trois plantes nourricières primaires à savoir Arjun, Asan et sal et comparées à celles des parents. Des différences significatives ($p < 0.001$) pour les performances des combinaisons F₁ et des parents ont été enregistrées avec le croisement Laria x Daba qui présente une hétérosis élevée pour la fécondité (+ 15.16 %) et le taux d'éclosion (83 ± 2.56 %). Des variations significatives ont été enregistrées pour le rendement en cocons et les caractères du cocon pendant la première et la deuxième récolte ainsi que parmi les différentes plantes. Le poids de la chrysalide et la fécondité sont plus élevés chez les vers à soie nourris sur *Terminalia*. Les plantes Arjun et Asan sont meilleures que Sal pour ce qui concerne le rendement en cocons. Les résultats révèlent le fort potentiel d'utilisation des hybrides simples (F₁) du ver à soie tasar pour pousser la productivité et l'exploitation de la vaste flore Sal.

Mots clés: *Antheraea mylitta*, Daba, population F₁, hétérosis, Laria, Raily, croisement réciproque, *Shorea robusta*.

L'EMISSION D'ANTIMOUSTIQUE A BASE D'ALLETHRINE ET DE PRALLETRINE INDUIT UNE TOXICITE ET ALTERE LES PROTEINES DE L'HEMOLYMPHE ET LES CARACTERES DU COCON CHEZ *BOMBYX MORI* L.

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ABSTRACT

Le brûlage de produits repoussant les moustiques n'est pas rare dans notre vie quotidienne afin de prévenir les maladies transportées par les moustiques. L'effet de l'exposition continue et à long terme à un tel environnement vaporisé d'insecticide est à déterminer pour la santé humaine. De manière surprenante le personnel impliqué dans l'élevage du ver à soie (*Bombyx mori* L.) pour la production de cocons de soie n'est pas informé sur la sécurité de son usage à l'intérieur de la magnanerie. Cette étude est la première de cette sorte pour examiner l'impact des anti-moustiques de deux marques commerciales populaires à savoir Mortein et Allout, sur la croissance du ver à soie, les protéines de l'hémolymph larvaire, la formation du cocon et les caractères économiques en exposant des larves de CSR₂ et de PM x CSR₂ à une fumée d'antimoustique 12h par jour à partir du jour 1 du premier stade larvaire jusqu'au filage. En conséquence, il y a un déclin de la croissance des larves chez les lots traités par rapport aux témoins. De manière plus importante une protéine de masse moléculaire de 82 kDa identifiée comme une protéine de stockage clé est dérégulée ce qui résulte dans le développement de papillons déformés chez CSR₂. De plus, les caractères du cocon et le rendement sont plus affectés chez CSR₂ que chez PM x CSR₂ exposés à l'émission d'alléthrine et la pralléthrine. Nos investigations révèlent donc bien que les deux insecticides soient toxiques l'alléthrine induit plus de toxicité que la pralléthrine et que CSR₂ est plus sensible que PM x CSR₂. Les fermiers activement impliqués dans l'élevage des vers à soie doivent être prudents quant à l'utilisation des anti-moustiques dans la magnanerie pour se protéger des moustiques car cela peut conduire à des pertes de récoltes.

Mots clés: Alléthrine, *Bombyx mori*, cocon, anti-moustique, prallethrine, protéine.

REPONSE METABOLIQUE DU VER A SOIE TASAR, *ANTHERAEA MYLITTA* DRURY A L'AUGMENTATION DE LA TENEUR EN TANINS

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ABSTRACT

Cette étude a pour but de déterminer la photosynthèse nette de la feuille de la plante hôte, la transpiration et la conductance stomatique à côté du stress oxydatif, les défenses antioxydant et les caractères commerciaux du ver à soie tasar nourri avec des feuilles de *Terminalia tomentosa* enrichies de tanins. Pour évaluer l'impact des tanins sur les métabolites secondaires, les niveaux de phénol total et de tanins ont été augmentés dans les feuilles traitées. L'ajout de concentrations élevées de tanins influence négativement le taux de transpiration et l'humidité relative de la feuille de la plante hôte alors qu'il n'a pas d'effet sur le dioxyde de carbone, la conductance stomatique et la photosynthèse. Chez l'intestin du ver à soie, l'activité alpha-amylase est réduite chez les groupes traités. La modulation du stress oxydatif (peroxydation des lipides et hydroperoxydes totaux) et des antioxydants (catalase, glutathion-s-transférase et acide ascorbique) est détectée chez les larves nourries avec tanins. On observe une détérioration des caractères commerciaux chez les mâles et les femelles nourris avec tanins. Les résultats suggèrent que les tanins régulent le métabolisme des vers à soie tasar de manière importante ce qui peut affecter la santé de la larve et les caractères commerciaux de la soie tasar. Ceci peut être utile pour l'utilisation du très largement disponible *Shorea robusta* qui est connu pour avoir un contenu en tanins important.

Mots clés: *Antheraea mylitta*, antioxydants, caractères du cocon, phénols, photosynthèse, tanins.

CHANGEMENTS HISTOPATHOLOGIQUES AU COURS DE L'INFECTION PAR BmIFV CHEZ LES LIGNEES SENSIBLES ET TOLERANTES DE *BOMBYX MORI* L.

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ABSTRACT

La flacherie infectieuse du ver à soie est causée par le virus BmIFV (virus de la flacherie infectieuse chez *Bombyx mori*). En Inde cette maladie a été trouvée par Sato (1992) et ensuite d'autres chercheurs ont initié des travaux sur divers aspects de la maladie chez le ver à soie. Il existe peu de rapports disponibles sur la sensibilité des différentes souches ou hybrides de vers à soie à BmIFV et seules quelques lignées sensibles ou tolérantes à ce pathogène ont été identifiées. Nos premières études indiquèrent que CSR2 est très sensible et 5N la lignée la plus tolérante contre l'infection par BmIFV. Ce pathogène infecte seulement le tube digestif mais pas d'autres tissus comme l'hémolymph, le corps adipeux, la glande séricigène, les gonades et les tubes de Malpighi aussi bien chez CSR2 que 5N. Nous avons tenté ici de comprendre les changements histologiques qui s'opèrent dans le tube digestif pendant l'infection (1-12 DPI) par chez les lignées tolérantes et sensibles. Chez CSR2 le nombre de cellules en gobelet infectées augmente et se déchargent dans la lumière de l'intestin alors que seules quelques cellules régénératives *nidi* se développent en nouvelles cellules en gobelet ou colonnaires ce qui conduit à des dommages physiologiques et une forte mortalité larvaire. Cependant, chez les lignées tolérantes le nombre de cellules en gobelet et cylindriques infectées est plus faible au fur et à mesure que l'infection progresse. Ceci peut être dû à la régénération de nouvelles cellules en gobelet à partir des cellules *nidi* ce qui induit des réparations physiologiques. Nous discutons du statut des cellules tolérantes/sensibles vis-à-vis de BmIFV.

Mots clés: BmIFV, *Bombyx mori* L., histopathologie, tube digestif, souches sensibles/tolérantes.

TRAITEMENT DES EAUX USEES POUR ELIMINER LES COLORANTS RESIDUELS DANS LES UNITES DE TEINTURE DE SOIE

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ABSTRACT

L'industrie de teinture de la soie présente des risques environnementaux associés au largage de colorants résiduels dans les eaux usées rejetées. Les effluents des unités de teinture méritent donc un traitement approprié avant d'être largués pour assurer une sécurité biologique de l'environnement. Les colorants utilisés sont généralement dispersables et le surplus des colorants résiduels est éliminé en utilisant diverses techniques physiochimiques, chimiques, biologiques et électrochimiques. Toutefois l'élimination complète à partir des eaux usées reste difficile. Beaucoup de chercheurs ont travaillé pour obtenir des méthodes plus efficaces et peu coûteuses pour éliminer les colorants. Notre étude a été entreprise avec cet objectif et nous avons adopté une nouvelle technologie en utilisant une chaudière fermée à haute température de 800 sans perte d'eau. Les colorants commerciaux donnent des aryl-amines détectées par chromatographie liquide à haute performance (HPLC). Le traitement de l'eau avec des déchets de colorants à 800°C pendant 3 minutes pour les colorants connus (nombre de groupements chimiques connu et produits par des fabricants certifiés) et à 800 °C pendant 9 minutes pour les colorants commerciaux (obtenus d'un marché local et dont la composition est difficile à connaître) est efficace pour une disparition effective de la couleur et l'évaporation de l'eau usée de colorants. La calorimétrie à balayage différentiel-thermogravimétrie (TG-DSC) et la chromatographie en phase gazeuse – spectrométrie de masse (GC-MS) ont été utilisées pour détecter les composants des résidus. Les résultats montrent qu'à 800 °C, ils sont réduits avec la formation de nombreux composants gazeux tels que le 3-(2,2-diméthylpropylidène) bicyclo[3.3.1]nonane-2,4-dione, hydroxytoluène butylé (BHT) *etc.*

Mots clés: Colorant acide, eau usée avec colorant, GC-MS, soie, TG-DSC.

VERS LA CONSTRUCTION D'UN SYSTEME NATIONAL INNOVANT DE SERICICULTURE (MURIER) EN INDE – POSSIBILITES ET PERSPECTIVES

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ABSTRACT

La sériciculture est une agro-industrie importante en Inde avec de nombreuses implications socio-culturelles. La soie est un produit d'exportation important et la nation a compris l'importance du secteur dès le début. Au cours des années le secteur a connu des changements technologiques importants avec des innovations principalement concentrées sur l'amélioration du produit des fermiers c'est à dire le cocon. Les efforts innovants n'ont pas été reçus par le secteur de transformation immédiat à savoir la filature, ce qui a affecté la qualité de la soie grège. Cet article tente d'établir que la sériciculture indienne a tous les ingrédients nécessaires et est caractérisée par un réseau et des liens complexes par la voie de facteurs économiques, sociaux, politiques, organisationnels et institutionnels qui influencent le développement, la diffusion et l'utilisation des innovations ; ainsi se qualifie un système d'innovation sectoriel. Cependant, sa progression et son développement sont limités par la faiblesse inhérente au système. Cette étude identifie une importante faiblesse du système et suggère des moyens d'amélioration. Les deux aspects importants identifiés sont la faible participation du secteur privé dans la R&D et la sur représentation du côté agricole de la sériciculture. La majorité des efforts d'innovation ont été concentrés sur le secteur fermier sans liens avec la modernisation du secteur filature. Ceci a rendu les efforts d'amélioration du grade de la soie grège inefficaces.

Mots clés: Capacité d'absorption, Inde, système sectoriel d'innovation, sériciculture.

Mr. Rajit Ranjan Okhandiar, India elected as the Secretary General of ISC

During the XXV ISC Conference held at Guwahati, India on 25th January 2018, Mr. Rajit Ranjan Okhandiar, nominated by the Government of India has been elected as the Secretary General of International Sericultural Commission for a period of three years starting from 1st January 2019. Currently, Mr. Okhandiar is the acting Secretary General of ISC as well as the Chief Executive Officer of Central Silk Board, which is the national agency for sericulture development in India.



XXV Conference of ISC held at Guwahati, India on 25th and 26th January 2018

The XXV Conference of ISC was held at Hotel Radisson Blu, Guwahati, India during 25th to 26th January 2018. Apart from conducting the election for the post of Secretary General, ISC, the Conference also approved the various activities of ISC proposed for the year 2018. The Conference also approved to organize a 10 days training on "Silkworm Seed Production" during 17-26 September 2018 at Bangalore, India for the candidates nominated by the ISC Member Countries. The training would be organized by Central Silk Board in its Silkworm Seed Production Centre (SSPC) at Bangalore.

The Conference witnessed the participation of 22 delegates from 8 countries; Bangladesh, Egypt, India, Japan, Kenya, Romania, Thailand and Uzbekistan.



8th International Conference on Wild Silk Moths held at Guwahati, India during 22nd to 24th January 2018

Central Silk Board, Ministry of Textiles, Bangalore, India and International Society for Wild Silk Moths, Japan have jointly organized the 8th International Conference on Wild Silk Moths at Hotel Radisson Blu, Guwahati, India during 22nd to 24th January 2018. The Conference witnessed the participation of 300 delegates from 16 countries; Bangladesh, Egypt, Japan, India China, Kenya, Ethiopia, France, Ghana, Turkey, Ethiopia, Rwanda, Romania, Thailand, Paraguay, and Brazil. 185 scientific papers were presented during the Conference as oral and poster presentations of 6 sessions. Each of the Sessions were chaired by eminent scientists drawn from different parts of the world. The final outcome of the Conference was presented by the respective Chairpersons in the Plenary Session for adoption among the participating countries.



The last day of the event, 24th January 2018, was devoted for field visit to the sericultural areas in Udalguri, a soil to silk project area in Bodoland Autonomous Region of Assam Province. The delegates were exposed to Mulberry, Eri and Muga sericulture activities practised in North Eastern part of India.

An international exhibition on silk and silk products, with special focus on wild silk products, was also organized as a side-line event of the Conference. The delegates have been provided with an opportunity to experience the varied type of silk products originated from the different geographical regions of India.

Visit of Scientists from National Agriculture and Food Research Organization (NARO) to ISC

Dr. S. Tomito, Leader of New Silk Research Unit and Dr. N. Komoto, Senior Researcher from NARO, Japan visited the office of the International Sericultural Commission on 6th February 2018. ISC facilitated the meeting between the Japanese researchers and scientists of Central Silk Board to finalize the proposed international collaborative project between Central Silk Board and NARO for the development of sericulture and silk industry in both the countries.





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INFORMATION TO CONTRIBUTORS

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

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

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

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