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Ishita Roy
Secretary General
International Sericultural Commission

Message

This is a proud moment for the International Sericultural Commission to bring out the first issue of the new-look *Sericologia* in a relatively short span of time after the headquarters of the Commission moved from Lyon, France to Bangalore, India.

Publication of a scientific journal with a periodicity as short as three months is no mean task. *Sericologia* has been reaching its wide spectrum of readers since 1948, across the globe where sericulture is heard, read, taught or practised. Those who toiled behind the curtain, led by the towering scientific personalities, Dr. Gérard Chavancy and Dr. Bernard Mauchamp deserve applause for their unstinted efforts for all these years. Team *Sericologia* is committed to retain its rich legacy for the years to come.

Sericologia has now entered a new phase of its long existence. Change for sure is refreshing and it cannot be different for *Sericologia*. In consonance with the change in the leadership and the headquarters of ISC, we have ventured into offering a facelift to the journal along with an effort to make the content more scientifically appealing, with a firm belief that change is always for better.

Sericologia as a scientific publication with a global readership has now become more relevant than ever before because, many countries away from the Asian continent have started thinking seriously about sericulture as one of the livelihood options for their people. I am confident that the journal would disseminate knowledge, scientific and technical in nature, to a larger populace and the potential impact could be enormous. The journal would also serve as the one stop for researchers to publish their findings in frontier research areas.

The Commission believes that *Sericologia* should garner wider readership and serious citations. No efforts by the editor and the editorial management can replace the confidence the contributors and readers collectively repose on a journal to make it grow in its stature and receive focused attention among the umpteen journals coming out from reputed publishing houses.

I take this as an opportunity to appeal to all those who lay their hands on this issue to spend a minute to go through this and resolve that we will collectively make *Sericologia* worth its name.

Ishita Roy

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ERI CULTURE WITH SPECIAL REFERENCE TO REARING AND SEED TECHNOLOGIES

Y. Debaraj, Ravindra Singh¹, T. K. Biswas and B. B. Bindroo²

Regional Sericultural Research Station, Jorhat - 785 005, India.

¹Silkworm Seed Technology Laboratory, Kodathi, Bangalore - 560 035, India.

²Central Sericultural Research and Training Institute, Berhampore - 742 101, India.

E-mail: yumnamdebaraj@yahoo.in

ABSTRACT

Literature on the key areas of eri culture viz., silkworm rearing on different food plants, seasonal performance, interchange of food plants and suitability, combination food, rearing methods and economics, influence of castor genotypes, potential secondary food plants, aspects on seed production technology such as emergence, mating, oviposition behaviour, egg laying device, egg incubation, hatchability, egg refrigeration etc. are reviewed and discussed.

Key words: Eri silkworm, rearing, seed production, technologies.

INTRODUCTION

Eri silkworm, *Samia ricini* Donovan has also been domesticated like mulberry silkworm. It is polyphagous and multivoltine in nature and hence can be reared 5-6 times all through the year. In India, the primary information on eri silk may be quoted as of Lafroy and Ghosh (1912). Several varieties of food plants have been reported for eri silkworm (Jolly *et al.*, 1979; Chowdhury, 1982; Sarkar, 1988; Patil, 2004, 2011) which are grouped into primary, secondary and tertiary food plants. The most preferred food plant of eri silkworm is castor and the other food plants are exploited when food is scarce. The quality of eri cocoons depends on the quality of host plant.

Eri silkworm rearing technology

Realizing the potential of any sector of sericulture is a pre-requisite to exploit its contribution towards the growth of the industry. Due to lack of sufficient scientific knowledge on eri silkworm rearing, the economics of eri silkworm rearing was not well understood till 1970s when some studies were initiated. Rao *et al.* (1975 a) in their attempt to improve the effective rate of rearing (ERR), worked out the average

leaf cocoon ratio for castor (7.8 : 1) and Kessuru (8.3 : 1). This is the ratio of the weight of leaves consumed by a single larva during the whole larval period to the weight of a single cocoon. Later, Rao and Choudhury (1977) could observe that feeding early instars of eri silkworm on tapioca leaves and later instars on castor leaves was a better option for a number of economic characters except ERR, than doing *vice versa*. These observations proved useful in enhancing the economics of eri culture.

In order to assess the impact of different food plants on eri silkworm rearing, Vishwakarma and Thangavelu (1981) considered their overall effect on ERR, larval period, larval weight and cocoon characters. They could conclude that castor is the most ideal food plant followed by kessuru and tapioca. The ERR ranged from 82 to 95 % in castor, 68 to 96 % in kessuru and 32 to 77 % in tapioca. Further, the suitability of different food plants for eri silkworm rearing in different seasons was also worked out by Vishwakarma (1982a) who recommended castor as more suitable during April-May to June-July seasons whereas kessuru as suitable during July-August, September-October and November-December seasons.

Table 1: Commonly accepted food plants of eri silkworm

Plant	Scientific name
Castor	<i>Ricinus communis</i>
Kesseru	<i>Heteropanax fragrans</i>
Cassava	<i>Manihot esculenta</i>
Payam	<i>Evodia flaxinifolia</i>
Borpat	<i>Ailanthus grandis</i>
Borkesseru	<i>Ailanthus excelsa</i>
Champaca	<i>Michelia champaca</i>
Fountain tree	<i>Spathodea campanulata</i>
Kindal	<i>Terminalia paniculata</i>

Since the eri silkworm is polyphagous, its diet has been tried as different combinations of food plants for different larval instars. On interchange of food plants, Joshi (1985) observed that feeding of eri worms with tapioca till the 3rd instar and thereafter on castor gave better results. He recorded higher fecundity for castor (440) followed by tapioca-castor (400), castor-tapioca (278) and tapioca (197). Borgohain *et al.* (1987) studied the rearing performance of eri silkworm on 10 varieties of tapioca and recorded high hatchability (84.13 %) and fecundity (329) for CO-1, while the highest ERR was registered for H-2304 variety. Devaiah *et al.* (1988) while studying the effect of castor, tapioca and their combinations on the rearing performance of eri silkworm observed that all the economic parameters were superior when fed with tapioca up to 2nd instar and subsequently on castor. Govindan *et al.* (1992) reared *Samia cynthia ricini* on different combinations of food plants and obtained the highest pupation rate of 85.33 % when reared on castor alone followed by 81.33 % for castor (1-4 instars) and tapioca (5th instar) combination.

Khan and Haque (1987) tried the combination of castor-papaya leaf and observed higher rate of oviposition in the lot reared on castor than on papaya leaf. Similar observations were also made by Chowdhury (1960), Gomma (1972) and Rahman *et al.* (1985) in other eri worms. Joshi (1987) while working on the progression factor in *Philosamia ricini* in relation to four dietary regimens concluded that castor can be substituted with tapioca for rearing 1-3 instars to have the growth rate similar to that obtained with castor fed throughout. Thangavelu and Joshi (1982) observed the effect of larval population density on eri silkworm rearing

and indicated that lethal effect due to crowding caused higher larval mortality up to 48.9 % but had no influence on larval duration. They also provided a clue that 100 to 200 larvae required a space of 7.5 sq. ft. (2.5' x 3' size) for proper larval growth.

According to Saratchandra and Joshi (1983), bunch feeding method of rearing was found to be advantageous over tray feeding with respect to all economic characters and also in view of conserving the manpower utilized in cleaning the beds. They further opined that rearing during dry and colder seasons (September- February) irrespective of food plants or the method of feeding, yielded better crop than that in other periods. Debaraj *et al.* (2003 a) devised a new method of rearing for eri silkworm, *i.e.*, tier system of platform rearing (improved device, size 1 m x 2 m with 3 tiers) which performed better with regard to ERR (87.57 %) and shell percentage (14.12) than bunch rearing and tray rearing methods. It also requires less space and labour for feeding and bed cleaning. They have worked out the economics of improved device over traditional tray rearing device per unit area per annum considering four crops per year and found that the BCR for improved device was 1.32:1 while it was 0.73:1 for tray rearing.

Among varieties of castor, Saratchandra and Joshi (1984) reported that non-powdery ones are better than powdery varieties for eri silkworm rearing. They could roughly estimate that 650-750 kg of castor leaves is required to rear 100 dfls of eri silkworm. More or less similar information was also reported by Patil and Savanurmah (1994) for *Samia cynthia ricini* on castor. The leaf chopped into bits of about 1 cm² size is ideal for feeding young worms. They observed that the moulting period is about 20-24 h between each instar. Care is to be taken to avoid overcrowding since it leads to competition among the worms for food and space which ultimately results in undernourishment followed by retarded growth. A tray of size, 7.5' x 2' (15 sq. ft.) provides sufficient space to rear 10 layings (3000 worms) until 2nd instar and afterwards, 600 larvae can be reared up to 4th instar and only 300 in the final instar in the same tray.

Srivastava *et al.* (1981) studied the food deprivation during feeding hours of eri silkworm, *Philosamia ricini*

and reported that the commercial characters of cocoons are adversely affected with the longer larval period. Joshi and Misra (1985) while studying the life tables of eri silkworm, *Philosamia ricini* with castor as food have worked out the value of life expectancy, net replacement and innate capacity. Possibility of judicious exploitation of castor leaves so as to utilize them for silkworm rearing and also to have a reasonable harvesting of castor beans in oil seed producing areas was also reported by Misra (1987).

Many attempts were undertaken to assess the dietary value of different food plants as reflected in the rearing parameters. Singh *et al.* (1988) evaluated the performance of three perennial varieties of castor for eri silkworm rearing and recorded maximum ERR in T-3 variety (93.33 %) followed by Tarai-4 (88.7 %) and Kalpi-6 (87.33 %) which are superior to the local variety (71 %). Reddy *et al.* (1989) studied the influence of the food plants on the development and silk yield of eri silkworm and found that castor is the most suitable and Borkesseru (*Ailanthus excelsa*) is the least suitable food plant based on the rearing parameters. However, Khanikor *et al.* (1997) while studying the feasibility of substituting castor during winter seasons was of the opinion that *A. excelsa* can be successfully utilized as a substitute of castor for eri silkworm rearing. Saha *et al.* (1992) conducted an experiment on suitability of different food plants for eri silkworm rearing in different seasons and concluded that rearing of eri silkworm can be done throughout the year on castor, while on kesseru in June-October, on tapioca in May and August-October, on gulancha in May-August and on payam in May and August-September. Hazarika *et al.* (2003) studied the effect of different food plants on the rearing performance of eri silkworm and reported that kesseru has higher potential than castor in terms of leaf yield per hectare plantation and rearing performance. Different genotypes of castor were evaluated for yield parameters and grainage traits of eri silkworm (Sannappa and Jayaramaiah, 1999; Sannappa *et al.*, 2000; Govindan *et al.*, 2002, 2003; Ramakrishna Naika, 2003; Patil and Kenchanagudar, 2010). Jayaramaiah and Sannappa (1998) reported that among castor varieties, Aruna and

RC-8 are best suited for eri silkworm rearing in terms of economic parameters. Later, Sannappa *et al.* (2007) also confirmed the superiority of Aruna and RC-8. Patil *et al.* (1998) also worked in similar line and opined that the castor genotypes, RG-323 and SKI-80 are superior over 24 other genotypes for rearing performance. The SKI-80 being a high yielding variety, can be exploited for both castor seed and silkworm rearing. Govindan *et al.* (2005) evaluated the feeding efficiency of eri silkworm, *Samia cynthia ricini* on different castor varieties and concluded that the castor variety DCH-177 was found to be superior than others to harvest good cocoon crop.

Among the secondary food plants of eri silkworm, payam (*E. flaxinifolia*), a tree host available in Nagaland and its adjoining areas, is observed as good as the primary host, castor. Debaraj *et al.* (2003 b) attempted rearing of eri silkworm on 4 host plants including payam and confirmed that the performance on payam was almost at par with that of castor. Studies on the development and economic cocoon parameters of eri silkworm, *S. cynthia ricini* Boisduval were conducted on some new hosts including castor and higher survival rate, growth index, larval and cocoon characters were recorded when reared on castor (Manjunatha Naik, 2008; Manjunatha Naik *et al.*, 2010). Recently, Patil (2011) reported 4 new accepted tree hosts of eri silkworm and found that the rearing and cocoon characters of eri silkworm when reared on *M. champaca* was at par with that of castor.

Saha and Chanda (1993) assessed the optimum density of worms per unit area for eri silkworm rearing for better growth and yield. Rearing of 300 worms per one metre diameter bamboo tray has been found to be optimum for better growth and yield with 96 % ERR, 3.54 g cocoon weight and 0.48 g cocoon shell weight. Patil and Savanurmah (1994) described different types of mountages for eri spinning, *viz.*, bamboo basket filled with dry straw in layers, split bamboo type, mounting on folded cloth by suspending over bamboo forming a vertical fold and bamboo chandraki, *etc.* Debaraj and Sarmah (2001 a) evaluated the different mountages for cocooning of eri silkworm and revealed that bamboo

strip mountage enhanced the good cocoon recovery (98.9 %) and silk percentage (13.94 %) in comparison to other mountages.

Eri silkworm seed technology

Seed technology is one of the most important aspects in the sericulture industry in general as the quality of the seed is a deciding factor for the crop success. Information pertaining to seed preparation technology of eri silkworm is very scanty (Govindan *et al.*, 1981; Kotikal *et al.*, 1989; Debaraj and Sarmah, 2001 b). Preliminary investigations on the aspects of seed technology in eri silkworm, *S. cynthia ricini* were carried out by Nagalakshamma (1987). No information was available about the behavioural aspects of moth emergence in eri silkworm except general records in the books (Jolly *et al.*, 1979; Chowdhury, 1982; Sarkar, 1988).

Moth emergence starts in the early hours of the dawn and lasts up to noon. It's an advantage that they emerge in no time as the cocoons have open end unlike in other sericigenous insects. As a phenomenon common in many lepidopterans, males emerge earlier than the females. After emergence, the moths take rest for some time before mating. In eri silkworm, mating takes place during late afternoon. It has been reported that a temperature of 22 °C with moderate humidity is ideal for coupling and hatching in eri silkworm (Chowdhury, 1960). Rao and Kakaty (1975 a) were the pioneers to investigate the effect of mating duration on oviposition of eri silkworm and reported that 12 h mating duration has registered maximum number of eggs (96.89 %) laid by female moth. Further, Misra and Joshi (1991) also studied the effect of mating on oviposition and hatching in *P. ricini*. They found that short mating time up to 2 h drastically reduced the number of eggs laid (21- 60 eggs) and hatchability (0-18 %), while 3-5 h of mating resulted in 150-350 eggs and 70-93 % hatchability. They were however of the opinion that more than 4 h of mating helped to have uniform and compact egg laying pattern resulting in an egg mass.

"Khorika" a traditional device made up of a bundle of straw has been in use since long for oviposition where the fertilized female eri moths are tied with a string

passing under the shoulder joint of the right wing. Rao and Kakaty (1975 a) also assessed the oviposition performance in Khorika and noticed its disadvantages as it is laborious and time consuming causing considerable wastage of eggs that fall on the ground and also demands more space for a large scale grainage. Regarding the preference of vertical position by female moths for oviposition, Vijayaraghavan *et al.* (1983) conducted an experiment on oviposition of eri moths under different conditions and concluded that vertical position is not a pre-requisite for efficient oviposition in eri moths.

Srivastava and Misra (1985) reported that higher the moth density the lower the oviposition rate which decreases even up to 287.4 eggs per female. The number of eggs laid per female was inversely proportional to the number of pairs kept per container where the maximum efficiency of oviposition was rendered when only one pair was kept. Rao *et al.* (1975b) studied the performance of eggs laid on successive days by eri silk moth and found that first day laid eggs performed better with respect to ERR, cocoon weight and shell weight. The correlation between traits viz., pupal weight, cocoon weight, fecundity and hatching in eri silkworm have been worked out (Singh and Prasad, 1987; Nagalakshamma *et al.*, 1988; Kotikal *et al.*, 1989). The fecundity exhibit a progressive increase corresponding to the increase in pupal weight and pupal measurement (Kotikal *et al.*, 1989). The pupae with minimum average weight of 1.40 g and minimum body length of 2.34 cm had minimum number of eggs (186.8) while the pupae with maximum weight of 1.97 g, 2.74 cm in length and 1.14 cm in width had the highest fecundity (359.4). However, Nagalakshamma (1987) noticed that the pupal weight ranged from 0.97 to 1.45 g with the corresponding fecundity of 193.33 to 284 in light pupae and 327.67 to 388 in heavy pupae but the relationship with the pupal size parameter could not be established.

Prasad and Sinha (1980) studied eri egg incubation and indicated that 26 °C is ideal for incubation leading to 95 % hatching after an embryonic period of 9-10 days. Later, Vishwakarma (1982 b) also confirmed 26 °C as the optimum temperature for egg incubation resulting in

96.46 % hatching. While highlighting the status of development of ericulture, Thangavelu (1989) mentioned that the temperature above 32 °C is detrimental to egg development. Patil and Savanurmah (1994) could state 24~26 °C and 75~85 % as the optimum temperature and relative humidity for eri egg incubation. In 1981, Vishwakarma and Prasad studied the hatching behaviour of eri silkworm eggs and reported that all the eri eggs hatched exclusively between 6-8 o'clock in the morning with a peak at 8 a.m. They are also of the opinion that favourable brushing time is between 8 and 10 a.m. They further observed the vigour of eri worms hatched on different days for raising seed cocoon stock.

Debaraj *et al.* (2003 c) studied the different aspects of eri silkworm seed production technology in order to improve it at commercial level. They worked out the percentage of eggs laid during first three days and subsequent days, mean value of the number of eggs, co-efficient of egg laying, eggs per gram, weight of one dfl, *etc.* (Table 2). The seasonal ovipositional

Table 2: Oviposition performance of *S. ricini*

Parameter	Mean value
Number of eggs laid during the first 3 days (no.)	386.85
Eggs laid after 3 rd day oviposition	81.89
Total number of eggs laid	468.74
Eggs retained in the ovariole	12.60
Potential fecundity (eggs laid + unlaid)	481.34
Co-efficient of egg laying (%)	80.36
Eggs per gram (no.)	566.42
Weight of one dfl (g)	0.68

Source: Debaraj *et al.* (2003 c)

performance (Table 3) and performance in different oviposition devices were also studied and recommended the nylon net bag (15 x 20 cm size) for race and stock

Table 3: Seasonal effect on the oviposition performance of *S. ricini*

Season	Number of eggs laid	Fecundity	Co-efficient of egg laying	Eggs per gram	Weight of a dfl (g)
Feb-Mar	317	435	72.87	477	0.66
April	360	430	83.72	555	0.68
May	380	438	86.75	629	0.61
Jun-Jul	397	467	85.01	610	0.65
Sep-Oct	379	477	79.45	564	0.68

Source: Debaraj *et al.* (2003 c)

performance (Table 3) and performance in different oviposition devices were also studied and recommended the nylon net bag (15 x 20 cm size) for race and stock maintenance to save time, labour and space. On the other hand, Somaprakash and Sathyaprasad (2008) studied the impact of substrata on ovipositional behaviour of eri silkworm, *S. cynthia ricini* and found that the bamboo strips was the most suitable substratum for maximum egg recovery among six different substrata tried. The reproductive and commercial productivity of eri silk moth, *S. ricini* was studied in Orissa and found that winter season seem to be the most favourable in order to produce both qualitative and quantitative eri silk (Kar *et al.*, 2004). They were of the opinion that the combined effect of temperature, humidity and photoperiod as well as variations of these factors tend to regulate the process of grainage in eri silk moths. The grainage performance was also found to be the best during winter followed by autumn and spring (Kar *et al.*, 2005).

According to Rao and Kakaty (1975 b), the eri silkworm eggs can be refrigerated successfully up to 10 days at 4-5 °C from the 6th day of oviposition which show good hatching (79.2 %). It has been observed that refrigeration of *S. cynthia ricini* eggs at 3 °C beyond 5 days adversely affects hatching and that even within 5 days after oviposition if the eggs are refrigerated beyond 48 h, it results in poor hatching (Govindan *et al.*, 1980). Similar studies on *P. ricini* revealed that preservation of 1-3 days old eggs during summer and 1-5 days old eggs during winter at 7 °C delayed hatching by 4-5 days without any detrimental effect. The study also showed that 3-5 days old eggs are most suitable for refrigeration depending upon the season (Vishwakarma, 1983). While confirming the above findings, Nangia and Nageshchandra (1988) also concluded that the three days old eggs of *S. cynthia ricini* can be stored at 0 °C for 15 days with a good hatchability of 74 to 85.3 % beyond which egg mortality was high (57 to 73.2 %). Recently, Somaprakash and Sathyaprasad (2009) observed that 1 to 2 day old eggs of *S. cynthia ricini* can be refrigerated at 5 °C for 5 days and 2 day old eggs can also be refrigerated at 15 °C for 5 to 10 days without affecting hatchability.

In order to raise disease free layings and also to prevent secondary contamination, sample moth examination is a must followed by disinfection of the seed in 2 % formalin for 2 minutes and thereafter washed in cold water before incubation or commercial supply. Presently, eggs are supplied in a small packet made up of porous paper in the form of bag of 10 dfls each in capacity.

Future strategies

Although the different areas of eri culture has been explored by many and practiced since long back, the present trend of this culture in commercial level is far below expectation. However, with the background information generated through the above studies and research and development support being offered by the government agencies during the recent years, eri culture has been picking up to some extent. In view of the constraints faced in this sector and the limited knowledge accumulated so far, it is high time to initiate and implement need-based research programmes in eri culture industry with the following thrust areas.

- Maintenance of high quality commercial silkworm seed through provision of superior quality and suitable food plants all through the crops.
- Improved techniques for hygienic mass rearing to save time, space and labour and for assured crops.
- Improved techniques and suitable package of practices to ensure high quality leaf yield.
- Initiation and implementation of financially supported programmes and creation of technical and infrastructural facilities.
- Organized commercial silkworm seed production system to meet the demand.
- Formulation of seed cocoon and seed preservation techniques to meet the demand and slackness during adverse seasons.
- A complete package for cost effective and improved grainage operations for large scale seed production.
- Loose egg preparation and supply system.

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Technical Paper

SUSTAINABLE DESIGN IN THE BRIDALWEAR INDUSTRY OF IZMIR THROUGH REUSE OF LOCAL SILK FABRICS

E. O. Adanir, S. Kuleli, O. D. Göknur and A. Kuleli¹

Faculty of Fine Arts and Design, Department of Fashion and Textiles, Izmir University of Economics, Turkey.

¹Graduate School of Natural and Applied Sciences, Department of Engineering Sciences, Aegean University, Turkey.

E-mail: elvan.ozkavruk@ieu.edu.tr

ABSTRACT

Seventy per cent of the bridalwear production of Turkey is met by Izmir. The city is already starting to be recognized as a mass producer of the bridalwear like Milan or Barcelona. At the same time, Izmir's bridalwear industry is strenuously growing in production, marketing and branding internationally. Bridalwear sector in Izmir is continuing to increase its importance as a creative industry. This situation is bringing Turkey to an important position as a supplier for Europe and Middle Eastern countries. According to the data of Istanbul Bridalwear Exporters' Association, between 600,000 and 700,000 marriages take place every year. 350,000 of these mass produced wedding gowns are rented, 250,000 are bought. With these numbers, the bridal gown sector's value in Turkey is reaching close to 650 million US dollars. The fact that bridalwear sector is clustered in Izmir has facilitated the use of locally produced fabrics in this industry. There are also silk weaving firms among local fabric producers around Izmir. The silk fabric producers are applying experimental finishing techniques to extend their market. Some of the fabrics are being damaged due to this process. In the content of the research, a proposal for the reuse of the damaged silk fabrics is developed. In this paper, it is intended to present the examples of machine producible embroidery designs of these surplus silk fabrics.

Key words: Bridalwear, silk, sustainable design.

Fashion reflects current trends of contemporary living, and ecology and sustainability are becoming important issues in today's society (Hallett and Johnston, 2010). Different solutions as sustainable design strategies are preferred by companies which operate in eco-fashion industries (Vinken, 2006). Sustainability thrives on a system which is expected to be supported continuously in terms of environmentalism and social responsibility. While environmentalism in the fashion world is developed through donations of a percentage of sales to a charitable cause, fashion designers are now re-introducing eco-conscious methods at the source through the use of environment conscience materials and production. Sustainable fashion's principles are to reuse - not buying new; to reduce - by choosing products made with environment-friendly production processes and to recycle - making garments from a previously existing item (Fletcher, 2008). Sustainable fashion, which started as a trend, will become a real part of the market that affects

designers, retailers and consumers in a short time (Hallett and Johnston, 2010).

"Yesterday's textiles are tomorrow's toxins" says Quinn (Quinn, 2010). He explains that fabrics like fleece, flannel, corduroy, cotton, nylon, denim, wool, and linen may be donated to charitable organizations when they are no longer fit to use. The remainder of the used textiles goes either to a textile recovery facility or ends up in landfills. Using textiles creating harmful emissions, and using chemical processes to finish the fabrics are discouraged in fashion industry. Large fashion companies encourage over production of garments in order to reduce unit cost which results in a considerable amount of unsold garments, which are afterwards discarded as waste (Quinn, 2010). According to Quinn, estimated 1 million tonnes of fabric waste finds its way to landfills each year. He adds that clothing can take decades to decompose, leaving behind hazardous chemicals and harmful gases (Quinn, 2010).

The growing movement to produce sustainable textiles advocates environmentalism, economics and social responsibility. Textile production can have considerable impact on the environment. This realization prompts the use of new production methods that reduce the industry's carbon footprint (Quinn, 2010). Some designers are supporting sustainability because the production of more materials is not a viable solution. Textile specialists and fashion designers are working together to encourage manufacturing of environment friendly materials and developing socially responsible methods for clothing production. The most important challenge for designers is, to transform discarded industrial fabrics into textiles that are as beautiful as they are sustainable and this process is known as 'up-cycling' which means converting waste materials or useless products into new materials or products of better quality or of better environmental value (Hallett and Johnston, 2010). On the contrary, down-cycling is the process of converting materials and products into new materials of lesser value or quality. Most recycling involves converting or extracting useful materials from a product and creating a different product or material. This study is intended to find ways to transform discarded industrial silk fabrics into valuable, desirable and sustainable products by using fabrics of production failure, in adherence to industrial production methods.

Natural fabrics have always been fashion designers' first choice, but silk has remained a designers' dream. Silk is such a seductive, luxurious and desirable fiber that its price has, at times exceeded that of gold (Hallett and Johnston, 2010). "Nothing will ever replace silk", says designer Julien Macdonald. "It can look tenderly feminine or high-tech, timeless or cutting edge", he adds. Silk is a precious natural material used for high value garments such as evening dresses and wedding gowns (Datta and Nanavaty, 2005).

The bridal wear industry of the Izmir metropolis in Turkey is popular. This growing industry which is settled around Izmir is considered as a potential market for the sustainable value added fabric designs. Seventy per cent of the bridal wear requirement of Turkey is produced by Izmir. Interestingly, Izmir's bridal wear industry is

rapidly growing in production, marketing and in international branding. This growth is recognizing Turkey's important position as a supplier of quality bridal wear to Europe and Middle Eastern countries (Gülsoy, 2011). As per Istanbul Bridalwear Exporters' Association, 600,000 ~700,000 marriages take place in Turkey every year. For 350,000 of these weddings, mass-produced wedding gowns are rented and for 250,000, new wedding gowns are bought. In other words, Turkey's bridal gown industry is valued approximately at 650 million USD. About 80,000 employees work in Turkey's bridal wear industry. The products are partly consumed in national market and the remaining is exported to Spain, Italy, Portugal and Russian Federation. Turkey exported an impressive 400,000 units of wedding dresses excluding the shuttle trade, in 2011 (ISEID, 2012).

The growth prospect of Izmir's bridalwear industry is encouraging. The demand for Turkish wedding gowns is steadily growing especially in the Middle East and European market (ISEID, 2012) despite the recent European economic crisis. It could be assumed that the European economic crisis caused a shift in preferences for global wedding gown brands towards Turkey (EGSD, 2013). This scenario provides the Turkish bridal wear industry a prospect to expand the production base, to increase employment opportunity and to promote the brand in the international markets (ISEID, 2012). This is evident from the fact that Aegean Clothing Manufacturers' Association, and Turkey Federation of Fashion and Apparel have been organizing the largest bridalwear, groom suits and evening dress fair of Turkey known as "IF Wedding", since 2006. "IF Wedding" has become the 3rd biggest wedding fair of Europe in 2012 reiterating its soaring popularity. International wedding gown companies participate in IF wedding through their distributors, providing a professional international environment for local companies. Diverse representatives of the industry such as retailers (chain stores, boutique owners), producers, whole sellers (agencies & distributors), designers, exporters and importers, textile and apparel associations and public textile institutions, fashion design departments of universities and fashion media participate in the fair (IZFAS, 2012). Table 1 shows statistics about the fair.

Table 1: Izmir's international IF Wedding Fair statistics

Participants/Visitors/Area	Year					
	2007	2008	2009	2010	2011	2012
Domestic participants	75	160	138	156	188	188
Foreign participants	0	0	0	0	0	14
Domestic visitors	4687	14356	16400	13541	13375	14053
Foreign visitors	177	339	504	556	410	902
Visiting countries	21	34	42	47	59	59
Total area (m ²)	4000	20000	15000	11133	12754	26600

Resource: EGSD secretary.

The impressive statistics underlines the fact that the bridal wear industry concentrated around Izmir is a potential area of consuming large volume of textiles. The majority of the companies prefer to use PES or Viscose fabrics. This study proposes the methods for the reuse of damaged silk fabrics. It is aimed to raise the quality of the fabrics that are presented to customers without changing the prices while saving the wasted fabrics and reusing them with added value.

The use of locally produced fabrics in this industry is facilitated as the bridal wear sector is clustered in Izmir. There are some silk weaving firms among local fabric producers in and around Izmir which weave silk traditionally for centuries in Odemis and Kızılcaboluk towns near Izmir. The silk fabric producers apply experimental finishing techniques to increase fabric variety in order to extend their market. However, some of the fabrics are damaged during these experiment processes. Such damaged silk fabrics formed the test sample for this study.

The first sample selected for this research was wasted silk (Figure 1) damaged during removal of sericin and the second sample (Figure 4) was the one damaged during the dying process. As they became useless in terms of industrial processing in classical understanding, and lost a percentage of their value, these damaged silk fabric samples were suitable for up-cycling purpose in order to achieve higher quality of products.

One of the up-cycling methods employed in this study was decorating fabric surface by using embroidery

machines that lays piping pieces on tulle fabric that were cut and wound on reel formerly. Another one was constructing a new surface using same sort of piping and same embroidery machine embroidering the piping on heat-n-gone (melted with heat of press) or wet-n-gone (water soluble) stabilizers. After the removal of the stabilizer, the new lace-like fabric is obtained. In this research, we offer industrial embroidery techniques which developed in the last decade considerably.



Figure 1: Damaged silk fabric (sample 1)

The selected piece of damaged silk fabric supplied from Kızılcaboluk, was cut diagonally into parallel pieces in order to obtain piping material. The piping was applied on a tulle fabric via embroidery machine. The principle of this embroidery machine is laying pipes on

the fabric as programmed in the design and applying them onto the fabric using stitches. This machine allows designers to lay pipes up to 5 cm of width. The width of the pipes used in this project was set as 1.5 cm due to the pattern design. Pipes were cut with bias cutting machine.

There are three ways of cutting pipes out of fabric such as soldering, bias cutting (processing fabric by a machine with cold knives) and laser cutting. Soldering is preferred with synthetic fabrics. The pipe edges, which are trimmed using heated soldering iron along warp direction, are clean. This method prevents fringes but the touch of the fabric becomes stiff. Bias cutting machine operates with a (cold) knife and it is usually preferred with natural fabrics. After bias cutting, fringing may be observed (Figure 2) and this method is preferred for it does not cause stiffness or burnt edges. Laser cut is the most flexible method in cutting out piping as it enables variety of forms. Either natural or synthetic based fabrics can be cut into pipes using laser. The edges are neatly trimmed. Nevertheless, the amount of investment required is relatively high; it necessitates higher skills for operating and it may result in burnt edges due to faulty operation.

Silk piping used in this study is obtained using bias cutting method at an angle of 45°. Although the loose weave of the fabric caused fringing, these fringes helped to get a different surface design. The pattern selected for embroidering piping on tulle fabric (Figure 3) gives



Figure 2: Bias cut silk piping with fringes

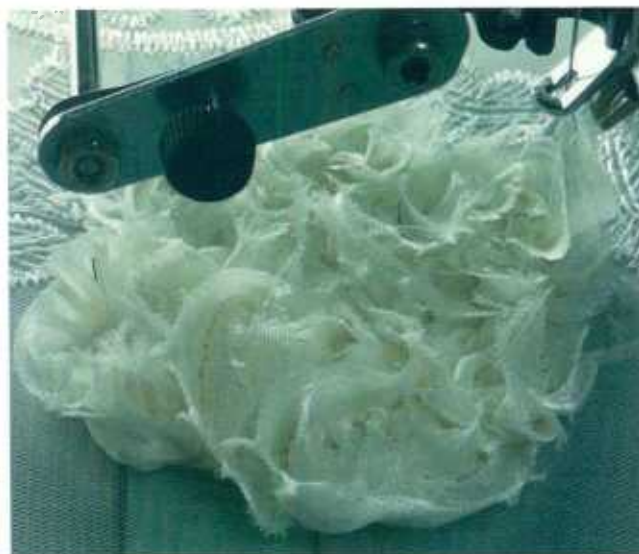


Figure 3: Silk piping embroidered tulle fabric

users the opportunity of using the fabric as a whole or cut into the repeats in order to be used as an appliqué on a garment. When using as appliqué the tulle fabric was used as basement which holds the pipes together. The tulle fabric will not appear as a part of the pattern. Bias cut pipes created using silk fabric gives a far softer touch when it is compared to the polyester piping obtained by soldering, which is mainly preferred in the market.

For the first fabric prototype for this study, 1.4 m of new tulle fabric was obtained from 1 m of damaged silk fabric which was cut diagonally for piping. The price of the new fabric per meter was calculated around 25 EU. Usual PES version of this pattern is sold at the price of 19 EU. The price of damaged silk fabric was about 3.5 EU per meter while PES is 2.5 EU. Tulle fabric costs less than 1 EU per meter. The rest of the value was added with embroidery process, pattern and seasons piping trend. For the second fabric prototype constructed for this study, 1 m of damaged silk fabric which was cut diagonally for piping was used. The price of the new fabric per meter was calculated to be around 50 EU. Usual PES version of this pattern is sold at the price of 17 EU. The price of damaged silk fabric was about 10 EU per meter while PES was 2 EU. The rest of the value was added with embroidery process, pattern and seasons piping trend (Table 2).

Table 2: Added value comparison of silk and PES fabric samples (in Euro)

Sample	Price of the piping fabric per meter	Embroidery cost	Total cost	Price of the newly constructed fabric per meter
Sample I	3.5	6.0	9.5	25
Sample I PES version	2.5	6.0	8.5	19
Sample II	10.0	8.5	18.5	50
Sample II PES version	2.0	8.5	10.5	17

The technology gives us possibility of using a combination of sequin or other embroidery techniques together with piping.

Conscious consumers are increasingly responding well to the sustainable and ethical developments in textile and fashion industry. With consumers making more informed and sensible choices, the companies which don't develop their sustainable strategies face risk of

**Figure 4: Bias cut strips of fabric, machine embroidered**

losing market share (Hallett and Johnston, 2010). The results of this study show more meaningful ways for the damaged silk fabrics which otherwise would end their life cycle in the waste, to reconsider and reuse in a wider context than the primary creative and technical processes and to up-cycle them into acceptable textile products.

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SILK PRODUCTION IN LATIN AMERICAN REGIONS – CONSTRAINTS & THE WAY FORWARD

J. G. Berdu Jr¹ and M. F. Pereira²

¹Instituto Vale da Seda, Parana, Brazil

²State University of Maringa, Parana, Brazil

E-mail: jberdu@bisaoverseas.com.br

ABSTRACT

Brazil is world's second largest exporter of raw silk that provides direct employment to one man year per hectare of mulberry plantation. During 2011, 10000 persons could get employment under sericulture industry. In Latin America, though several government initiatives were launched aimed at developing sericulture as an economic alternative for small farms, the results were not at the expected level. The major constraints faced were the high investment required in the silk production chain and the existence of different barriers for the entry of new entrepreneurs. In this context, this paper intends to provide an account of the silk production status and the strategies formulated in various Latin American countries *viz.*, Argentina, Bolivia, Chile, Colombia, Cuba, Ecuador, Mexico, Paraguay, Peru and Venezuela, that proposes to develop a cooperative network based silk industry to resolve many of the existing obstacles. The proposed network aims at providing coordination and guidance to produce and trade high quality cocoons, to overcome the constraints that so far have prevented the growth of sericulture sector in Latin American regions.

Key words: Cooperation network, Latin America, silk.

INTRODUCTION

Brazil occupies a prominent position in the international silk market due to the superior quality of raw silk produced (Thomas, 2009) in different production bases of the country. Besides Brazil, several Latin American countries have initiated the development of sericulture as an alternative economic activity for the small farms. Each one of the Latin American countries that invested in sericulture has considerable number of farmers who could benefit from this labour intensive avocation.

However, it is sad to note that many of these government actions to support private initiatives of silk cocoon production as an economic alternative for small farms have not achieved the desired results. Among the many reasons that contribute to this scenario, the high investment required in the silk production chain and the

existence of different barriers for the entry of new entrepreneurs to take up sericulture are some of the major constraints. In order to overcome these obstacles, this paper presents a proposal to bring the silk industry of Brazil under a cooperative network where the responsibilities and benefits are distributed among the stakeholders of the silk value chain. Such cooperation network will have governance based on institutional trust that allows coordination of efforts leading to increase in cocoon production among the countries of Latin America.

The proposal is presented in two sections, the first one is a theoretical framework on the institutional aspects that may have influenced the projects carried out in Latin America in recent decades, followed by the second one, which is a brief history and current situation of sericulture in some Latin American countries.

1. Institutional Aspects

1.1. Industry and Competitiveness

While introducing a new industry, similar to a group of companies manufacturing common products, various aspects such as competitiveness, infrastructure requirement and the barriers for the entry of new entrepreneurs play a vital role (Porter, 1986). The establishment of a cooperative network, in many cases, would address these difficulties. Mutual trust is the key factor on which such networks are built and proper governance determines its consolidation and sustenance.

According to Porter (1986), competitive industries are those whose companies have the capacity to improve and innovate to maintain a competitive advantage. The author identifies the existence of suppliers, distributors and competitive customers, as one of the key elements of competitive advantage stressing the fact that vertical relationships of dependency have great influence on the performance of companies. Also, according to Porter, in a systemic environment, competitiveness is not only related with individual capabilities, but also the perception of interdependence and interrelatedness among the actors in the chain of activities.

1.2. Asset Specificity

Williamson (1996) says that interaction between different actors in a chain of activities is strongly impacted by the specificity of assets involved in the transactions. The asset specificity refers to the ability to use assets for other purposes without reducing its value. Thus, the higher is the specificity, the lower is asset's value to other uses and therefore the greater the risk involved in a transaction. For Williamson, the specificity happens in six distinct types: a) locational, involving the distances between companies, transportation and storage costs, b) physical, concerning the use of the asset, c) human, related to training of manpower, d) brand specificity, e) dedicated assets, where existing assets do not have alternative uses and f) temporal specificity, which refers to the period in which the transaction occurs.

If the level of asset's specificity in the production of an item is low, transactions between agents can occur

via market, governed by relative prices. As the level of specificity increases, costs are added to the renegotiation process, and the use of market governance results in inefficiency (Williamson, 1996). The increase in asset's specificity favors the emergence of cooperation networks, which are forms of relationship based on lasting and intensive cooperation between companies, different than anonymous market relations, without reaching the level of formalized hierarchical relationships. According to Williamson (1996), intermediate forms of governance allow the reduction of transaction costs without losing the dynamism and flexibility through market relations.

1.3. Cooperation Networks

Among different forms of organizational flexibility described by Castells (1999), there is the model of multidirectional cooperation networks that is implemented between small, medium and even large companies. According to the author, small and medium enterprises often take the initiative of establishing relationships in networks with several companies of different sizes, finding market niches and cooperative ventures.

The settlement of a cooperation network implies the need for coordination. Coordination is not an intrinsic characteristic of supply chains, but the result of economic agents' actions (Williamson, 1996). In order to reduce transaction costs, agents make use of appropriate mechanisms to regulate a particular transaction, establishing a governance structure. Governance, according to Williamson (1996) is the driving structure that aims at achieving reliable and efficient contracts in a continuous process by which it is possible to accommodate conflicting interests in order to overcome difficulties presented by the market.

1.4. Barriers to Entry

Porter (1986) points out that among difficulties faced in market, there are the barriers to entry for newcomers in a particular industry. Based on the analysis of the determinants of their existence and their magnitude, the barriers to entry can be classified into five basic types: a) product differentiation, b) access to distribution channels, c) training of qualified human resources, d) economics of scale, and e) high initial investment.

1.5. Reliability

Trust plays a key role in overcoming the barriers to entry and difficulties related to assets' specificity, as well as on the accommodation of conflicting interests between companies within cooperation network. Coleman (1990) says that social actors are completely motivated by self-interest and argues that decision to trust or not is constructed by a rational calculation. By making this calculation, social actors determine the gain and potential loss arising from the act of trust and the probability that gain outweighs loss makes it possible to assume the risk to invest in trust. The risk of trust is related to the return obtained by the actor who trusts. If this perspective does not leave a clear return for these players, they will not invest in trust (Coleman, 1990).

According to Zucker (1986), trust can be of three forms: a) process based: arises when the relationships are shown stable over time, b) based on characteristics: it assumes that shared characteristics such as family ties, religion or ethnicity may be good reasons to trust and c) institution-based trust: comes into operation when trust is tied to the existence of formal structures in society, regardless of momentary preferences and actions of individuals. The existence of institutions and agents in a local production system with strong credibility among companies contributes to the development of this type of trust.

2. Silk cocoon production in Latin America

According to the International Sericultural Commission (ISC 2012), world cocoon production in 2010 was 789,313 MT. Of this, China, India, Thailand and Brazil accounted for 99.95 % of production. The world's largest producer, China, was responsible for 82.2 % of production followed by India with 16.6 %. Thailand with production of 4655 MT and Brazil, with 4439 MT accounted for 0.59% and 0.56 % of world production, respectively.

Sericulture has great potential to generate jobs and income among small farmers. In Latin America, a network called Red Andina de la Seda, presently known as Red Latinoamericana de la Seda was established in February 2001 to promote local and regional synergies,

enabling cooperation among Latin American countries to endorse concrete actions towards sustainable development of sericulture (RAS, 2001).

As shown in Table 1, there were a total of 306 silkworm rearing farmers spread across different countries belonging to the Red Latinoamericana de la Seda, with a production of 6528 kg of cocoon in 2010. Colombia accounted for the highest share of 79 % of this production.

Table 1: Silk cocoon production status of Red Latinoamericana de la Seda - Year 2010

Country	Craftsmen (No.)	Silkworm rearsers (No.)	Total (No.)	Cocoon production (kg)	%
ARGENTINA	15	30	45	-	-
BOLIVIA	12	3	15	42	1
COLOMBIA	155	180	335	5175	79
ECUADOR	25	10	35	517	8
PERU	49	78	127	794	12
CUBA	2	2	-	-	-
GUATEMALA	10	3	13	-	-
Total	266	306	572	6528	100

Source: Red Latinoamericana de la Seda (Cifuentes, 2012)

A brief account of the status of sericulture industry in Latin American countries is given below:

2.1. Argentina

In 2004, Argentine National Congress enacted the Law No. 25,747, regulated by Decree 526 in 2007, as a way to promote and accelerate sericulture activities in the country. The decree establishes the creation of tax incentives to encourage industrial scale of cocoon production in the country. Among provinces that joined the terms of Law No. 25,747, are Salta, Catamarca, La Pampa and Misiones. However, the combination of actions from state institutions and companies did not make a significant impact on the development of sericulture industry (Vieites *et al.*, 2010).

According to Vieites *et al.* (2010), lack of coordination and common goals, originating from ignorance or indifference to the potential of sericulture, and the existence of individual interests above the

collective interest have prevented cooperation among the players. This has created a situation wherein each sector becomes isolated from the other thereby disrupting sericulture development. The authors emphasized that under any circumstances, there would be people or companies that can bring success by finding the path at their own initiatives. However, for aiming the development of a sector, continuous efforts must be made to ensure the integration of the various activities of the value chain, but also ensuring that a fair price for each activity is equitably distributed.

2.2. Bolivia

Bolivia had their own sericulture projects financed by Propise - Pilot Proyecto Serícola del Centro de Investigación Tropical Agriculture (CIAT), through funding sources of the Bolivian government, resources of United States Agency for International Development (USAID PL480) and World Bank resources. From 1990 to 1997, two companies of Korean origin had operated in Bolivia for the production of silk cocoons (Cifuentes, 1997).

After the failure of these projects due to the 1998 crisis and in an attempt to explore new markets for sericulture, a silkworm cocoon drying unit was opened in the town of La Guardia in 2000 through a cooperation project by the silk rearing farmers on Government support. At the same time, city of Santa Cruz, through the Provincial Resolution No. 532/2000 created a three-year plan (2000-2003) for development of the Project, 'Technology Transfer Sericulture - PROTESE'. The objective of this project was to develop and transfer technology to farmers through specialized technical assistance for the implementation of mulberry cultivation and silkworm rearing as an alternative sustainable income generation for household farmers. In 2004, the production suffered a halt and subsequently farmers were supported by the establishment of a revolving fund, financed by IILA - Instituto Italo-Latino Americano, dedicated to finance the production and purchase of cocoons (Vieites *et al.*, 2010).

2.3. Colombia

During 1980s, two Korean companies established themselves in the cities of Pereira (Cokosilk SA) and Popayan (Cosedas). These investments were motivated by the high prices of raw silk in the international market. In 1992, the price of silk in the international market drastically declined, leading to the immediate closure of the Cosedas Company, and a complete change in the initial design of the Cokosilk Company in the city of Pereira (Cifuentes and Sohn, 1998).

In 1993, a bilateral agreement was signed between Colombia and the European Union (Project ALA 91/31), aiming to cultivate around 1,500 hectares of mulberry trees that would support the production of cocoons to be reeled on a reeling unit to be installed in the municipality of Santander Quilichao. In 1994, the Centro de Desarrollo Tecnológico de Sericulture - CDTs was created with the objective to develop a technology to promote sericulture through development of silkworm hybrids adapted to Colombia. Subsequently, silkworm eggs produced by CDTs were exported to Bolivia, Ecuador, Venezuela and the Canary Islands (Cifuentes and Sohn, 1998).

In 1998, the EU decided to terminate the support to sericulture department of Cauca, since the project did not progress as planned, causing frustration among silkworm rearing farmers. But one group remained motivated and in 2000, founded the Corporation for the Development of Cauca Sericulture - Corseda, which integrated silk producers and artisans of the region, as well as ten local organizations. Corseda aimed at self-sustainability to cope with any crisis encountered in the future. In order to reduce conflicts of interest between silkworm rearing farmers and artisans in an attempt of a continuous integration process, Corseda created quality standards for cocoon, and also a minimum selling price index for fabrics to prevent unfair competition between organizations and artisans in each one of their groups (Vieites *et al.*, 2010).

Corseda could coordinate 170 silkworm rearing farmers and 120 artisans in the municipalities of El Tambo, Timbío, Popayan, Piendamó, Morales, Caldono,

Santander and Quilichao Caloto (Vieites *et al.*, 2010). They were grouped into five associations of silkworm rearing farmers and five associations of artisans and farmers. Among the associates, the illiteracy levels were around 65 % with 75 % of families below the poverty line. The articulation process of Corseda substantially altered the relationship between producers and artisans. It made them realize the need for interdependence and the necessity of an organization that would mediate to resolve conflicts and provide services for the development of sericulture in Cauca. The involvement of affiliates in the Corporation enhanced transparency among the management and members. Corseda is also a place to meet friends, a guaranteed market for cocoon producers and a safe and close source of raw materials to artisans.

2.4. Cuba

Considering sericulture as one of the important modules for agricultural diversification within a sustainable regional development policy, Cuban government established "Indio Hatuey", a Programme for Sericulture Research, Innovation and Production in 2004 at the Experimental Station of Pastures and Forages. The main objective of the programme was to introduce and promote sustainable development through production and trade of silk items. Results obtained since 2006 at Indio Hatuey SCFE show that, on small scale, high quality cocoons can be produced in Cuba. Sericulture fits into the agricultural diversification policy that seeks alternatives to sugarcane cultivation. The growth of tourism is an attractive market for handmade silk products that can be produced in the country (Vieites *et al.*, 2010).

2.5. Ecuador

The silk cocoon production in Ecuador in 2010 was 517 kg (Cifuentes, 2012). The country had only ten silkworm rearing farmers and 25 artisans due to reduction in the number of silkworm rearing farmers since 2004. Red Latinoamericana de la Seda reported that in 2004, there were 500 trained farmers and more than 110 hectares of mulberry trees planted in 11 different provinces. There were a hatchery for silkworm eggs

and an acquisition cocoon unit at Penipe. At the distribution center, there were about 990 kg of first grade dry cocoon, 82 kg of second quality dry cocoon (produced in the years 2001, 2002 and 2003), along with a stock of processed yarn and finished piece goods. The center also has a wing for training in handicraft production, where about 95 craftsmen were trained in reeling, dyeing and weaving processes (Vieites *et al.*, 2010).

2.6. Mexico

In order to support sericulture among the vulnerable rural communities, the Ministry of Agriculture and Rural Development (SAGAR) implemented the National Sericulture Project in 1991. Since 2009, the Mexican Government, through the State System of Family Development (DIF), the Ministry of Rural Development (SEDER) and Ministry of Agriculture Livestock, Rural Development, Fisheries and Food (SAGARPA), supports sericulture, distribute young silkworms to silkworm rearing farmers and artisans of the regions of Sierra Norte Valle Central y Mixteca (Vieites *et al.*, 2010).

From 1995 to 2012, about 15 million heads of silkworms were delivered to the sector, which now has 100 ha of mulberry planted in different parts of the State of Oaxaca. The Silkworm production centers set up under the Project, provide extension services to small farmers in the region (AMIA, 2012).

2.7. Paraguay

The federal Government of Paraguay has been supporting sericulture activities in the country. During 2003, the Ministry of Agriculture and Livestock (MAG) proposed to implement the National Sericulture Plan for the diversification of family farming activities. The objectives of the Sericulture Plan was; to strengthen sericulture as a cost effective alternative for small farmers, optimize the use of resources available and involve the public and private sectors to improve the living standards of rural households involved in sericulture practice (Vieites *et al.*, 2010).

Earlier during 1988, a private company was set up by Italian investors aiming cocoon production and silk

reeling. The company, Seda y Fibras Srl started its activities of technology transfer, encouraging the development of sericulture in the region and also production of thrown silk. The supply of raw material *i.e.*, silk cocoons and raw silk was mostly from Brazil and Turkey, since the raw silk production could meet only 6 % of thrown silk produced by Seda y Fibras (Vieites *et al.*, 2010).

In 2011, Seda y Fibras Srl signed a cooperation agreement with the Brazilian University, the State University of Maringá – UEM located in the State of Paraná. The agreement's objective was the maintenance of University's silkworm germplasm bank and also the development of a breeding program to improve silkworm hybrid races belonging to the University. The research project also aimed at the development of stronger and more productive hybrids (Woehl, 2011).

2.8. Peru

In an attempt to promote sericulture as an alternative to diversify the activities of small farmers, on May 5, 2005, Peruvian government promulgated the law on the Promotion and Production of Sericulture and Mulberry Cultivation. This law considered sericulture as an important economic activity and a priority among programs as alternative for cultivation of coca in Peru. In 2006, there were several on-going projects of different dimensions in Peru, and in the central jungle area, there was a total area of 10 hectares of mulberry, 50 silk rearing farmers and ten artisans. In 2007, the Regional Government of Cusco and Peru held a workshop on sericulture, aiming to sensitize official authorities, heads of public institutions, regional and local members of private sector to support this initiative.

In 2008, the governments of Peru and China have entered into a Memorandum of Understanding establishing guidelines for cooperation, which includes the implementation of a pilot project with the cultivation of two hectares of mulberry in the National Agrarian University of La Selva in Huanuco (Amazonia). The project aimed at cultivation of 14000 ha of mulberry in due course to produce silk for the Asian market, while promoting joint research and exchange of information

which are relevant to implementation and development of projects in areas of extreme poverty (Vieites *et al.*, 2010).

2.9. Venezuela

Sericulture in Venezuela began in the mid-nineteenth century in Merida, Venezuelan Andes. In 1983, a company, Veneseda was founded in Mérida, dedicated to the study and dissemination of processes and techniques of sericulture and silk weaving. Veneseda maintained a close contact with cultural and educational institutions in the country to disseminate sericulture and silk weaving technologies. In this direction, a cooperation agreement was signed between the Ministry of Agriculture, organizations devoted to regional development and with foreign companies of the sector (RAS, 2012).

In the early 90s, as an alternative activity for the development in different parts of the country, a project was designed based on the export of cocoon that later would be processed in the country itself. This initiative had faced serious setback due to the sharp decline in the price of raw silk in international market, making cocoon production not competitive in comparison to other farming alternatives (Vieites *et al.*, 2010).

Even during 1990s, the company resumed its initial orientation, promoting the entire production process that can generate handmade pieces needed for the domestic market in Venezuela. The search for international cooperation agreements has continued and in 2012, with the support of IILA - Istituto Italo-Latino Americano, Veneseda received, as a donation, a machine for silk yarn twisting from an Italian company named Torcitura di Domaso (RAS, 2012 a).

2.10. Brazil

According to the International Sericultural Commission (ISC 2012), Brazil is the second largest exporter of raw silk. China is by far the first. The State of Paraná accounts for 91.95 % of the Brazilian silk cocoon production and about 88 % of the Brazilian production of silk yarn is exported as raw silk or thrown silk. When the world market suffered an unfavorable

trend for export of raw silk, there was a disincentive attitude in rural areas, especially among producers who work under a partnership system, causing a decline in the number of Paraná silkworm rearing farmers, which reduced from 7914 in 1998 to 3947 in 2010 (SEAB-PR, 2010). Table 2 depicts the data on cocoon production in Brazil between 1991 and 2012.

Subsequent to the reduction in silk cocoon production, Brazilian silk reeling industry became almost idle as the production level was not enough to meet the increased demand for raw silk. The fluctuation in raw silk price in the international market had a direct influence on prices paid for the cocoons produced in the country. In 1989, when the international market flourished, the average price paid to the producer in Brazil was US\$ 3.51/kg of fresh cocoons. Decline in the price of silk yarn in the international market in early 90s had

kept the price paid to fresh cocoons from 1991 to 2000 around US\$ 2.19/kg of fresh cocoons. From May 2010 to January 2011, the average price paid was US\$ 2.51/kg of fresh cocoons (SEABR-PR, 2010a).

There was a hike in cocoon price during the season in 2011-2012, influenced by the bullish international raw silk rate, wherein average price of R\$ 10.89/kg was paid to Brazilian producers for first grade fresh cocoons. During the season 2012-2013, which started in September, 2012, the price fixed for first grade cocoons with 15 % silk content was R\$10.00/kg (US\$ 4.90/kg) and the estimated average price paid during the 2012-2013 crop was R\$ 11.90/kg (US\$ 5.83/kg) for first grade fresh cocoons, according to BRATAC (2012).

The above developments show that the prospects of exporting Brazilian raw silk to the international market is quite optimistic, however it is necessary to firm up

Table 2: Silk cocoon production (Tons) by Brazilian companies (1991 to 2012)

Company/ Year	Bratac	Kanebo/ Fujimura	Cocamar	Kobes	Shoei	Cooperseda	Total
1991 - 92	7865	3603	2663	1460	1514	481	17586
1992 - 93	8784	3909	2777	1464	1779	421	19134
1993 - 94	9048	3716	2299	1200	1719	278	18260
1994 - 95	8477	3454	1727	1075	1527	CD	16260
1995 - 96	9046	3185	1293	1111	733		15368
1996 - 97	8999	3332	1376	1104	CD		14811
1997 - 98	9175	3792	1627	CD			14594
1998 - 99	6603	2669	1033				10305
1999 - 2000	5495	2343	635				8473
2000 - 01	6290	2900	726				9916
2001 - 02	6897	2381	960				10238
2002 - 03	6871	2204	891				9966
2003 - 04	5504	1853	648				8005
2004 - 05	4833	1767	546				7146
2005 - 06	5609	1877	565				8051
2006 - 07	6516	2101	CD				8617
2007 - 08	4709	1557					6266
2008 - 09	3610	1225					4835
2009 - 10	3368	1071					4439
2010 - 11	3037	CD					3037
2011 - 12	2601						2601

Source: BRATAC, 2012; CD - Closed Down.

close partnerships with producers, producer groups and Government departments like; Municipal, State and Federal agencies. In this line, IAPAR, EMATER and Federal and State Universities of Paraná promoted several courses throughout the 2009-2010 crop season, for the implementation of research projects aiming to modernize the silkworm rearing sector in Paraná (SEAB-PR, 2010).

According to SEAB-PR (2010), the highlights of the Projects were the improvement of Brazilian silk production chain and boosting the production of silk products domestically so that the export of raw silk could be reduced considerably. In order to realize this, the Project Vale da Seda, proposed by Technology Incubator of Maringá emphasized sustainable regional development and hence enabled the creation of a Cooperative of Silk Handicraft Producers - Artisans Brazil. This cooperative, formed by 40 women belonging to rural areas of Nova Esperança city, exported scarves and other handmade silk items to fair trade network called Artisans Du Monde, in France.

CONCLUSION

Despite various efforts made by the Federal Governments in Latin American countries, it was not possible to ensure the progress or sustain the developmental initiatives undertaken by small-scale producers. In Brazil, sericulture ensures provision of job to one person for each hectare of mulberry plantation (ABRASSEDA, 2002). Although the sericulture industry in Brazil is supported by the reeling sector which is very well positioned to cater to the requirement of the international raw silk market, the same is forced to work in idle capacity due to reduction in silk cocoon production.

Sericulture equipment and machineries are exclusive, having no value if intended to utilize for other activities. Asset specificity of silk production chain is also observed on manpower training and qualification. The skill development training needed for human resources, including farmers, is also a barrier for the entry of new participants in the silk production chain. These issues can be pointed out as the major reasons

that significantly influenced on the failure of sericulture initiatives in several Latin American countries. Lack of trained cocoon producers able to assure supply of regular and substantial quantities of cocoon prevented the operation of silk cocoon reeling units on industrial scale. On the other hand, lack of stable demand for cocoons as per norms prevented the training of producers to expand production.

Under such circumstances, it could be inferred that based on the current international raw silk market conditions and institutional environment in several Latin American countries, recent investments in sericulture may have a different result than investments made during the 1990s. This is due to the fact that the proposed cooperation network is based on institutional trust and governance among the stakeholders. This network should coordinate efforts towards increased production in different countries to meet the demand of Brazilian silk reeling industry, which has already achieved scale of production and has consolidated distribution channels through different agencies. This new proposed structure of cooperation would enable the development of the entire silk value chain in the region, mostly among the family farmers.

Further, it is proposed to study the technical and economic feasibility of deploying a cooperation network between the silk reeling industry in Brazil and entrepreneurs in Argentina, Bolivia, Chile, Cuba, Colombia, Ecuador, Mexico, Paraguay, Peru and Venezuela, seeking the production of silk cocoons on an industrial scale. It is worth noting that Vale da Seda project, developed at Technological Incubator of Maringá, points out that large scale cocoon production provides a favorable environment for development and support of silk handicraft production, which could gradually increase the consumption of silk cocoon consistently produced in the region.

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Research Paper

EVALUATION OF RESISTANCE MECHANISMS OF MULBERRY CULTIVARS THROUGH COMPONENT ANALYSIS OF AECIAL INFECTION CYCLE OF MULBERRY RED RUST (*AECIDIUM MORI* BARCLAY)

T. Gonzales Angelina¹ and S. Opina Oscar²

¹DMMMSU Sericulture Research and Development Institute, Banotan, La Union, Philippines.

²Plant Pathology Department, University of the Philippines-Los Banos, Laguna, Philippines.

E-mail:at_taduran143@yahoo.com

ABSTRACT

Component analysis of resistance of mulberry cultivars against the mulberry red rust disease caused by *Aecidium mori* Barclay showed that the resistant reaction conferred by resistant cultivars was due to their ability to limit or suppress sporulation capacity, prolong latent period and shorten the infectious period of the fungus. The cohort life statistics revealed that the survival rate, proportion of infection units of *Aecidium mori* Barclay at various infection stages and infection efficiency of mulberry red rust (MRR) did not vary significantly among resistant (Alfonso), moderately resistant (S_{13} and $SRDC_2$) and susceptible (Mlocal, S_{34} , S_{61} and Batac) mulberry cultivars. Regardless of cultivar, high mortality of infection units was recorded during the early stages of infection process. Sporulation capacity, infectious period and latent period of *A. mori* significantly differed among resistant, moderately resistant and susceptible cultivars. The infectious period of *A. mori* on susceptible cultivars was longer (20-32 days) compared to moderately resistant (12-28 days) and resistant (10 days) cultivars. *A. mori* produced abundant aeciospores in susceptible cultivars, less number in moderately resistant cultivars and very few in resistant cultivar. The latent period was longer in resistant cultivar compared with that of susceptible ones. The observed resistant reaction of cv. Alfonso can be attributed to its ability to limit or suppress sporulation capacity, prolong latent period and shorten infectious period of the fungus.

Key words: Aecial infection cycle, *Aecidium mori*, component analysis of resistance, infectious period, latent period, sporulation capacity.

INTRODUCTION

In the Philippines, the silk industry has been given much attention in recent years. The government adopted a collaborative system mandating concerned agencies and cooperatives to work for the promotion and development of silk industry. However, the silk industry is constrained with many problems related to mulberry and cocoon production. Occurrence of mulberry diseases is among the major limiting factors affecting cocoon production. The most destructive disease appeared to be the mulberry red rust (MRR) caused by *Aecidium mori* Barclay (Govindaiah and Gunasekhar, 1992; Biswas, 1992; Teotia and Sen 1994). It significantly decreases the amount of moisture, crude protein, reducing

sugars and total sugars of the infected leaves (Sundeswaran *et al.*, 1988). The disease is also known to cause 10-30 % leaf yield loss and also decreases the nutritive value of leaves, hastens yellowing, senescence, and defoliation (Biswas and Sengupta, 1994). Consequently, poor quality and quantity of mulberry leaves are the perennial problems for successful silkworm rearing and cocoon production (Philip *et al.*, 1994). It has been reported to infect mulberry during cool months to early summer seasons of the year (Ahmed, 1981).

The pathogen (*A. mori*) hibernates over unfavorable conditions as mycelium or aeciospores in aecium (aecia) on old living plants or in dead plant parts. Overwintering aeciospores act as sources of primary infection under

moist and moderate weather conditions. Aeciospores germinate at around the optimum temperature of 24°C at high relative humidity. Symptoms usually appear 20 days after inoculation. The aeciospores discharged from the cup are spread mainly by the wind and act as secondary sources of inoculum. The disease can appear during any period of the year, as long as the host (mulberry) is available.

It has recently been observed that MRR disease not only attack established mulberry garden but also mulberry nurseries. It is expected that the outbreak of the disease can lead to drastic decline in quantity and quality of leaves harvested per unit area. If MRR continue to develop unabated, silk production can be seriously affected. Mulberry diseases occur over a wide range of environmental conditions. The environment can affect the perpetuation or overwintering of the pathogen from one growing season to the next, the build-up of both primary and secondary inoculum and the dormancy, germination and host penetration of the inoculum. It can also affect the resistance or susceptibility of the host (Agrios, 1997).

In the Philippines, MRR is considered as an old disease of mulberry. Kobayashi and De Guzman (1988) reported the occurrence of *A. mori* on mulberry in Pederal Forest Nursery, Baguio City on February 1977. The same fungus was found on several species of *Morus* in Asia including India and the Philippines (Dizon and Kakishima, 1995). This study was intended to investigate the resistance mechanisms of mulberry cultivars against mulberry red rust caused by *A. mori* Barclay as no efforts were undertaken so far in this line.

MATERIALS AND METHODS

Mulberry cultivars from India (S_{13} , S_{61} , Mlocal and S_{54}), and local varieties (SRDC₂, Alfonso and Batac) with different reactions to mulberry red rust were used in the experiment. Cultivars, S_{61} , Mlocal, S_{54} and Batac were rated as susceptible (S); cv. S_{13} and SRDC₂ were moderately resistant (MR) and cv. Alfonso was rated as resistant (R). Cuttings were prepared from mature mulberry plants and were grown in sterilized soil. Each cultivar was replicated thrice. All recommended cultural

practices such as fertilization, irrigation *etc.*, were followed to give favorable conditions for the vigorous growth and development of the test plants. The methods of Opina and Valencia (1994) were adopted in conducting the experiment.

Inoculum preparation and inoculation technique: Heavily infected mulberry leaves showing symptoms of MRR were collected from the field. Aeciospores were extracted from infected plants using a spore collector connected to a vacuum pump (Figure 1). With the aid of improvised plastic settling tower, the spores were inoculated to the 3-month-old mulberry saplings late in the afternoon. The inoculation was done violently releasing approximately 1.0 gram of aeciospores on top of the settling tower. The tower provided an even distribution of aeciospores deposition on the leaves and also served as an incubation chamber for the inoculated plants. After 24 hours of incubation,

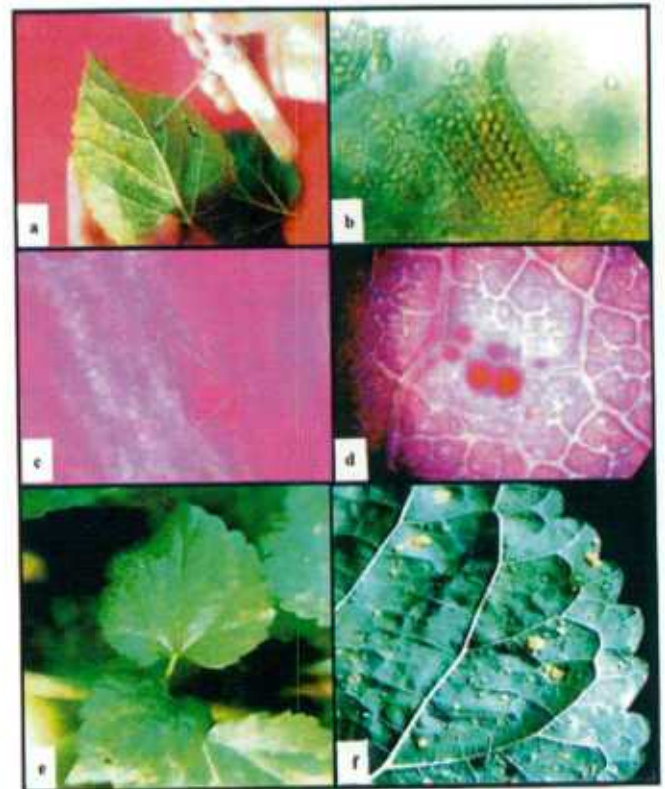


Figure 1: Inoculation preparation and aeciospore production: (a) spore collector attached to a vacuum pump; (b) active rust pustules releasing aeciospores (LPO); (c) germination process (HPO); (d) pustule formation (LPO); (e) early symptoms of MRR, 8-10 days after inoculation and (f) advanced symptoms of MRR with eruptive pinhead lesions under surface of the leaves.

the saplings were transferred from the settling tower to the greenhouse for disease development.

Stages of MRR infection: The aeciospores of *A. mori* on the leaves of seven mulberry varieties were studied as they underwent infection process. The different stages of infection cycle were monitored under a compound microscope based on observable ungerminated aeciospores, germinated aeciospores, germtube formation, appressorium formation and pustule formation. The densities of infection units passing through the identified infection stages were assessed at 3-day interval. These were the total aeciospores density (TAD), germinated aeciospores density (GAD), germ tube density (GTD) and surviving pustule density (SPD) (Table1).

Measurement of infection units: After inoculation, leaflets of each cultivar were randomly selected and detached at different time intervals. Leaf samples were carefully cut into pieces and were fixed in formalin-aceto-alcohol combination (FAA) for 24 hours. Leaf samples were decolorized for 24 – 48 hours in a Carnoy's solution and stained in an acid-fuchsin staining solution for 24 hours. The stained leaf samples were mounted on slides and were observed under a

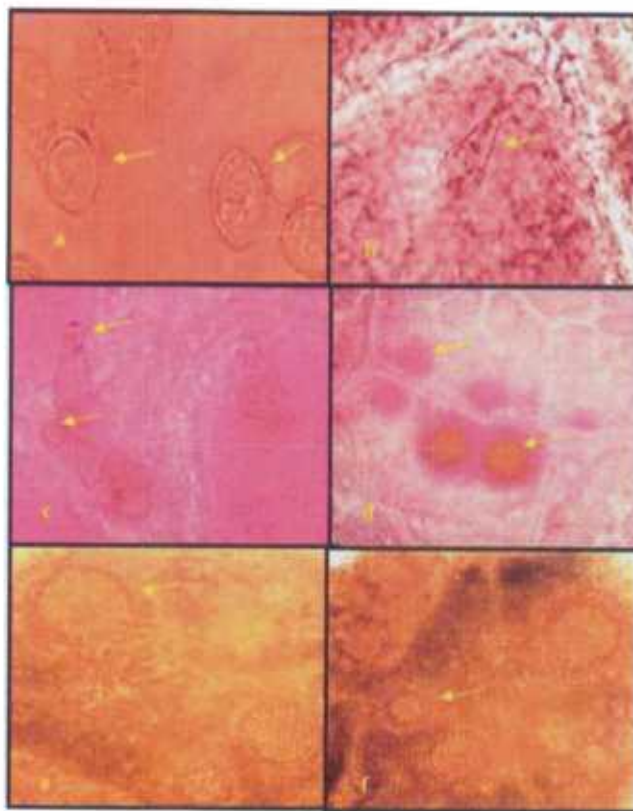


Figure 2: Different stages of infection cycle of *Aecidium mori* observed under the compound microscope: (a) aeciospores; (b) aeciospores with germtube; (c) aeciospores with distinct appressorium; (d) young and intact pustules and (e-f) top view of mature pustules with aeciospores.

Table 1: List of variables used in the construction of life and reproductive tables of *Aecidium mori*

Variable	Acronym	Definition
Total aeciospore density	TAD	Number of aeciospores deposited per unit leaf area
Germinated aeciospore density	GAD	Number of germinating aeciospores per unit leaf area
Germtube density	GTD	Number of germtubes produced per unit leaf area
Appressorium density	APD	Number of appressoria produced per unit leaf area
Pustule density	PUD	Number of pustules produced per unit leaf area
Surviving pustule density	SPD	Sporulating or aeciospores producing pustules per unit leaf area
Mortality ratio	q_i	Proportion of infection units dying at each stage of infection process
Survival ratio	$1 - q_i$	Proportion of infection units surviving at each stage of infection process
Age-specific reproduction rate	m_i	The number of aeciospores per pustule of age i
Proportion of survivor	l_i	Proportion of survivors at any i
Net production	R_0	The net reproduction rate per infection unit
Generation time	T_g	Length of disease cycle
Maximum relative growth rate	r_{max}	The maximum relative growth rate, which sets an upper limit to the rate of disease development

compound microscope. The number of ungerminated aeciospores, germinated aeciospores, germtube appressoria (LPO magnification) and pustules per 0.25 cm² of leaf surface were determined. The measurements of infection units were done in three replicates (Figure 2).

Data and analysis: The life table statistics, reproductive table and area under the sporulation progress curve (AUSPC) of *A. mori* on seven mulberry cultivars were constructed based on the parameters listed in Table 1.

Life table statistics: The life table statistics of MRR was determined for each cultivar. The mortality (q_1) and survival ($1-q_1$) ratios, proportion of surviving infection units (l_1) and survivorship curves of *A. mori* were established for the seven mulberry varieties.

Reproductive table: The reproductive table was estimated based on the aeciospores produced, 10 to 14 days after inoculation at 2 day- interval. Ten days after inoculation, aeciospore production on plants was determined. Leaflets with known number of rust pustules were tagged and aeciospores were collected using a spore collector attached to a vacuum pump. The collected aeciospores were suspended in 1.0 ml distilled water with a drop of Tween 40 to ensure even dispersion of aeciospores. The density of aeciospores was

determined using a haemocytometer. The measurements of aeciospores production were taken at 2-day interval till the unit pustules have stopped sporulation in three replications.

RESULTS AND DISCUSSION

The fate of the cohorts of infection units (aeciospores) as they passed the different infection stages on seven mulberry cultivars is shown in Table 2. Out of an average of 12.75 aeciospores per microscopic field (LPO) deposited on mulberry leaves, 9.68 aeciospores successfully germinated, 8.44 produced germ tubes, 4.56 produced appressorium and 1.87 developed into sporulating pustules. Of the infection units deposited on mulberry leaves, only 15 % managed to produce new rust pustules.

Survivorship curves: The survivorship curves showed that regardless of mulberry cultivars, *A. mori* infection units were dying at a higher rate during the early stages of infection process, but once the pustules were formed, they survived more efficiently and produced abundant aeciospores (Figure 3). The survival rate of infection units did not vary significantly among resistant and susceptible cultivars at early stages of infection. However, pustules developed on resistant (Alfonso) and moderately resistant cultivars (S_{13} and $SRDC_2$) survived for a shorter period and produced

Table 2: Number of infection units of *A. mori* at different age intervals and stage of infection process on seven mulberry cultivars

Age interval (Days)	Infection stage*	Resistant	Moderately resistant		Susceptible				Average
		Alfonso	S_{13}	$SRDC_2$	Mlocal	Batac	S_{54}	S_{61}	
0	TAD	11.20	14.34	10.36	9.86	15.32	15.22	13.00	12.75
1	GAD	8.60	5.55	9.74	7.44	10.21	14.68	11.55	9.68
2	GTD	8.23	5.23	7.78	6.52	10.17	11.52	9.62	8.44
3	APD	2.98	4.07	4.55	3.86	5.21	7.47	3.83	4.56
9	PUD**	1.75	1.58	2.60	1.42	2.08	2.19	1.50	1.87
44	SPD	-	-	-	-	-	-	-	-

Each figure is an average of infection units per low power objective (LPO) magnification.

*TAD = total aeciospores density; GAD= germinated aeciospores density; GTD = germtube density; APD = appressorium density; PUD= pustule unit density; SPD = sporulating pustule density.

**Each figure is an average of rust pustule on 0.25 mm² leaf surface.

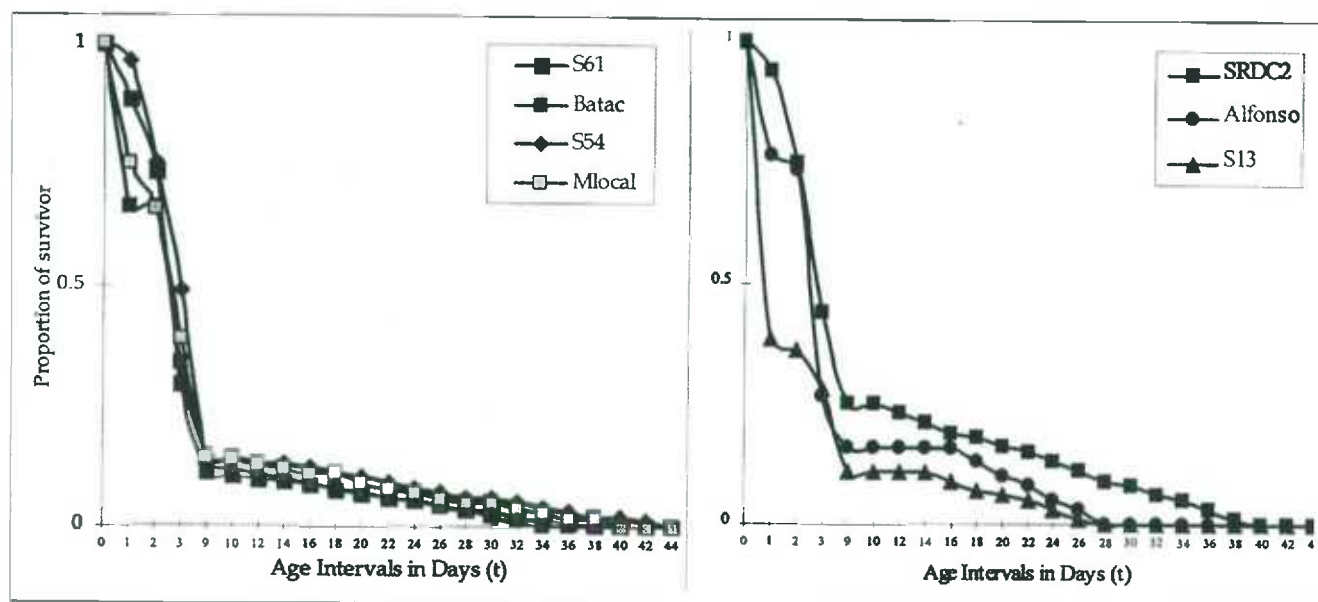


Figure 3: Proportion of surviving individual of *A. mori* on the leaves of mulberry cultivars

aeciospores only up to 26-28 days after aeciospores were deposited on mulberry leaves. Pustules developed on susceptible cultivars survived longer and ceased to sporulate 44 days after infection.

Survival ratios: The proportion of surviving infection unit of *A. mori* at the different stages of infection on the seven mulberry cultivars is indicated in Table 3. Results indicated that 76.7 % of the aeciospores deposited on mulberry leaves germinated; 88.3 % of the germinated aeciospores formed germ tubes; 53.3 % of the germ tubes was transformed into appressoria and 42.8 % of the appressoria produced sporulating pustules. Of the total infection units deposited on mulberry leaves, only 15 % managed to produce rust pustules. The data suggested that the most vulnerable stages of the infection process were germ tube to appressorium and

appressorium to pustule formation. The proportions of survivors were the highest during the stages of germination of aeciospores and germ tube formation and these did not vary significantly among the mulberry cultivars. SRDC₂ and S₅₄ appeared to allow germination of aeciospores freely, but S₁₃ seemed to block the aeciospores germination. Low survival rate was associated with appressorium and pustule formation stages which also did not significantly vary among the seven mulberry cultivars. The infection of *A. mori* did not vary significantly among seven mulberry cultivars while SRDC₂ gave the highest aeciospores to pustule ratio. *A. mori* appeared to have high infection efficiency on SRDC₂ which could be attributed to high proportion of aeciospores germination; appressorium and pustule formation compared with the other cultivars.

Table 3: Survival ratio of infection units of *A. mori* on mulberry cultivars

Ratio	Resistant	Moderately resistant		Susceptible				Average
	Alfonso	S ₁₃	SRDC ₂	Mlocal	Batac	S ₅₄	S ₆₁	
Germinated/Total aeciospore	0.767 b	0.387 c	0.94 ab	0.754 b	0.666 b	0.964 a	0.888 ab	0.767
Germ tube/Germinated aeciospore	0.956 a	0.942 a	0.798 a	0.876 a	0.996 a	0.784 a	0.833 a	0.883
Appressorium/Germ tube formed	0.362 a	0.778 a	0.584 a	0.592 a	0.512 a	0.648 a	0.399 a	0.553
Pustule/Appressorium formed	0.587 a	0.388 a	0.571 a	0.367 a	0.399 a	0.293 a	0.391 a	0.428
Pustule/Total aeciospores (Infection efficiency)	0.156 b	0.110 b	0.250 a	0.144 b	0.131 b	0.143 b	0.115 b	0.150

Means in a row followed by the same letter are not significantly different from each other at 5 % level of significance, DMRT.

Reproductivity of *A. mori* : The reproductivity of *A. mori* on seven mulberry cultivars was constructed on the bases of assessment of age-specific reproductivity rates and reproductivity statistics worked out is presented in Table 4. Reproductivity statistics indicated that a single pustule can produce an average of 6,229 new aeciospores on mulberry leaves during the infectious period. The maximum related growth rate ($r_{\max}$) or the maximum infection rate of MRR in mulberry was estimated to be 0.416 unit per day, while the generation time was about 18.93 days.

20.23 days and did not vary significantly among cultivars.

The reproductivity curves of *A. mori* on seven mulberry cultivars indicated that pustules of *A. mori* produced aeciospores as early as 10 days after inoculation, continued to sporulate up to 42 days and stopped sporulation 44 days after inoculation. Resistant (Alfonso) and moderately resistant (S_{13}) cultivars significantly suppressed sporulation and pustules ceased to sporulate as early as 28 days after inoculation. The susceptible (S_{61} , S_{54} , Mlocal) cultivars allowed early

Table 4: Estimated net reproduction rate, generation time and maximum growth rate of *A. mori* on mulberry cultivars

Statistics	Resistant	Moderately resistant		Susceptible				Average
	Alfonso	S_{13}	SRDC ₂	Mlocal	Batac	S_{54}	S_{61}	
Net reproduction ¹ rate, R_0 (no./pustule)	579.93c	612.86c	5,408.2b	5,731.71b	1,027.56c	5,988.66b	24,255.08a	6,229.134
Generation time, T_g ² (in days)	18.39	18.99	18.845	19.25	17.21	19.84	20.234	18.934
Maximum relative growth rate, $r_{\max}$ ³ (unit per day)	0.34	0.34	0.456	0.45	0.40	0.44	0.49	0.4165

Means in a row followed by the same letter are not significantly different from each other at 5 % level of significance, DMRT.

¹The total number of aeciospores produced per individual infection unit (original aeciospores) per generation.

²The total length of infection cycle in a polycyclic epidemic as affected by the cultivars, *A. mori* and environment.

³The intrinsic rate of increase, or the maximum rate possible under the condition of the experiment and was attained with the unrealistic assumption that all newly produced aeciospores would actually arrive on susceptible leaves.

The sporulation capacity of *A. mori* significantly differed among mulberry cultivars. Data revealed that an infection unit (pustule) was able to produce 580 new aeciospores on the most resistant cultivar (cv. Alfonso), 613 aeciospores on moderately resistant (cv. S_{13}) and 24,255 aeciospores on the most susceptible cultivar (cv. S_{61}). Cultivars, Batac, Mlocal and S_{54} sustained sporulation capacity of *A. mori* ranging from 1028 to 5989 aeciospores per pustule.

The highest rate of infection of MRR disease was estimated as 0.49 unit per day in susceptible cv. S_{61} . The lowest infection rate of MRR was 0.34 unit per day each in resistant cv. Alfonso and moderately resistant cv. S_{13} , while the infection rates for Batac, S_{54} , Mlocal and SRDC₂, were 0.40, 0.44 and 0.45 unit per day, respectively. The generation time ranged from 17.21 to

sporulation and maximum sporulation was attained from 16 to 24 days after inoculation (Figure 4). Cumulative age-specific reproductivity rates over time clearly described the differences in magnitude on sporulation capacity of *A. mori* on seven mulberry cultivars. The fungus produced abundant aeciospores on S_{61} , while there was 5-fold reduction of sporulation on resistant and moderately resistant cultivars, Alfonso and S_{13} . The reduced sporulation can be attributed to the shorter infectious period and reduced size of rust pustules on cv. S_{13} and hypersensitive response of cv. Alfonso compared to susceptible ones.

The reproductivity table clearly indicated that the difference in resistance conferred by the cultivars against *A. mori* can be attributed to the suppression of

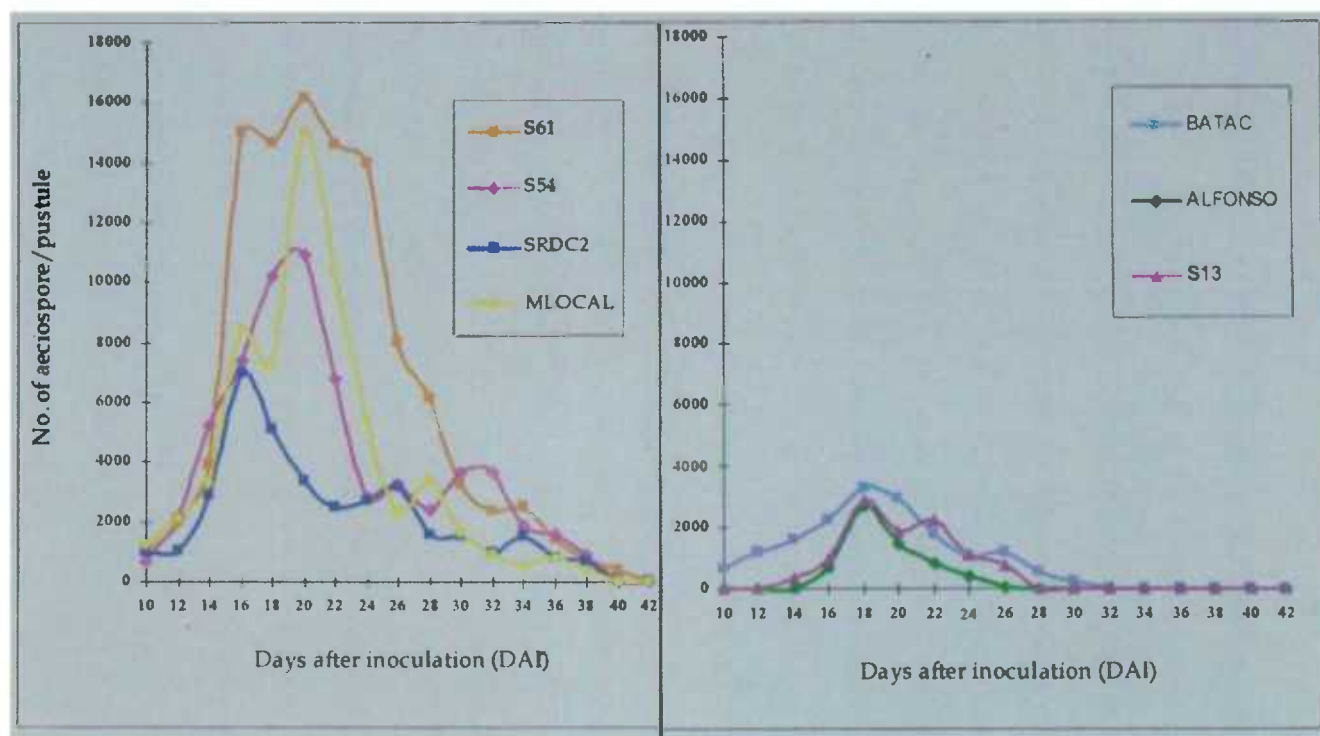


Figure 4: Aeciospores production of *A. mori* on the leaves of seven mulberry cultivars.

sporulation. The calculated net production rate (R_o) or sporulation capacity of *A. mori* on cv. Alfonso is related to the reduction in maximum related growth rate (r_{max}) that is similar to apparent infection rate. However, the length of infection cycle (T_g) did not vary among the cultivars suggesting that the resistance of cv. Alfonso is not related to T_g .

Latent and infectious periods and sporulation capacity of *A. mori*: Data from the cohort and reproductivity tables showed that *A. mori* pustule initiated aeciospores production at about 10 days after aeciospores were deposited on mulberry leaves. The

duration of sporulation (infectious period) was 22.85 days, while a single pustule in mulberry leaf can produce an average of 28,053 aeciospores during the entire duration of sporulation (Table 5). The rust fungus initiated aeciospores production as early as 9 days after inoculation on susceptible cultivars, 9-12 days on moderately resistant and 14 days on resistant cultivars. *A. mori* appeared to sporulate 5 days earlier on susceptible cultivars compared with the resistant cultivar (Alfonso). The duration of sporulation of *A. mori* on susceptible cultivars was longer compared to moderately resistant and resistant cultivars. A pustule can remain infectious 20 to 32 days on susceptible cultivars, 12-28

Table 5: Comparative evaluation of 7 mulberry cultivars based on epidemiological parameters of mulberry red rust (MRR) caused by *A. mori*

Parameter	Resistant	Moderately resistant		Susceptible				Average
	Alfonso	S ₁₃	SRDC ₂	Mlocal	Batac	S ₅₄	S ₆₁	
Latent period (days)	14	12	9	9	9	9	9	10.143
Infectious period (days)	10	12	28	28	20	32	30	22.85
Sporulation capacity (spore/pustule)	6,237	10,147	35,515.92	62,763	16,716	64,892.39	105,826.3	28,053

Each figure is an average of three replications.

days on moderately resistant and 10 days on resistant cultivars.

Results showed that *A. mori* produced abundant spores on susceptible cultivars. The rust pustules on susceptible cultivars can produce a crop of spores ranging from 16,716 to 1,05,826 aeciospores and from 10,147 to 35,515 aeciospores on moderately resistant cultivar, which were 5 to 17 fold lesser compared with susceptible cultivars. The results suggested that the degree of resistance conferred by mulberry cultivars against *A. mori* can be attributed to their ability to prolong the latent period and delay the onset of initial aeciospores production. The abundant number of aeciospores produced in S_{61} was due to higher sporulation capacity, bigger and aggregated pustules (more than one pustule is found in one pustule locus), while the lower aeciospores yield in cultivars Alfonso and S_{13} was due to hypersensitive response, minute pustules and shorter infectious period. This sort of a reaction to *A. mori* infection is a form of resistance against the rust disease. Hypersensitive response exhibited a pronounced and early dying/darkening of pustules indicating that the resistance genes in these resistant cultivar responded by inhibiting spore production of *A. mori* that led to short sporulation.

Prolonged latent period and limited spore or conidial reproduction of the pathogens would be more desirable traits and should be emphasized in a mulberry-breeding program. Prolonging the latent period could increase the mean generation time of the pathogens, and consequently reduce the probable number of disease cycles as that can be generated in the field (Panigbatan and Opina, 1992).

Lapis *et al.*, (1993) disclosed that evaluating the resistance components of host-pathogen interaction is an important step towards the selection of parents to use in the development of more durable and stable resistant varieties of hybrids. He discussed further that defoliation time, lesion size and density and sporulation capacity were the variables that best reveal the differences among the varieties in mungbean. The exact mechanism of resistance is uncertain. But in peanut, the

uredospores of *Puccinia arachidis* were sensitive to methyl *cis* 3, 4-dimethoxy cinnamate, an inhibitor of germination. These claims were supported by the study of Opina and Valencia (1994) that UPL-Pn4 variety possesses some biochemical substances that inhibit spore germination. It can be the same principle that works in mulberry against *A. mori* but so far no studies were conducted to verify that mulberry indeed possesses substances, which inhibit appressorium formation and sporulation. Biochemical studies must be undertaken to support the above results. On the other hand, morphologically, S_{61} is coarser in texture and pale green in color, S_{54} is softer and thinner, while S_{13} and Batac and Alfonso are dark green, Alfonso being smooth and trichome free too. Valencia and Opina (1994) cited that in peanut, germination and appressorium formation were the most vulnerable infection stages of peanut rust fungus. However, in this study, the most affected infection stage was sporulation and spore production.

CONCLUSION

Component analysis of resistance of the identified resistant and moderately resistant mulberry cultivars was further undertaken to determine the mechanisms of resistance. The cohort life statistics revealed that the survival rate, proportion of infection units of *A. mori* at various infection stages and infection efficiency of MRR did not vary significantly among resistant (Alfonso), moderately resistant (S_{13} and SRDC₂) and susceptible (Mlocal, S_{54} , S_{61} and Batac) mulberry cultivars. Regardless of cultivar, high mortality of infection units was recorded during the early stages of infection process.

Sporulation capacity, infectious period and latent period of *A. mori* significantly differed among resistant, moderately resistant and susceptible cultivars. The duration of sporulation (infectious period) of *A. mori* on susceptible cultivars was longer (20-32 days) compared to moderately resistant (12-28 days) and resistant (10 days) cultivars. *A. mori* produce abundant aeciospores in susceptible cultivars, less number in moderately resistant cultivars and very few in resistant cultivar. The latent period or the time a pustule initiate sporulation is longer in resistant cultivar compared with susceptible

cultivars. The observed resistant reaction of cv. Alfonso can be attributed to its ability to limit or suppress sporulation capacity, prolong latent period and shorten infectious period of the fungus.

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SUSCEPTIBILITY OF SILKWORM RACES TO *BOMBYX MORI* NUCLEOPOLYHEDROVIRUS

R. Murakami and K. Miyamoto

National Institute of Agrobiological Sciences, 1-2, Ohwashi, Tsukuba, Ibaraki 305-8634, Japan.

E-mail: mritsuko@affrc.go.jp

ABSTRACT

Twenty-eight silkworm races were screened for their susceptibility to *Bombyx mori* nucleopolyhedrovirus (BmNPV) by peroral infection with inclusion bodies of BmNPV. Among the tested races, J137 x C146 was the least susceptible and Kanoh was the most susceptible. The degree of susceptibility between the least and the most susceptible races was 128 times based on LC_{50} . In certain combinations of hybrids, heterosis was observed for BmNPV resistance.

Key words: *Bombyx mori* nucleopolyhedrovirus, LC_{50} , silkworm, susceptibility.

INTRODUCTION

The disease caused by *Bombyx mori* nucleopolyhedrovirus (BmNPV) is the most serious one in sericultural industry. NPV has two virion phenotypes in their life cycle. One is occlusion-derived viruses (ODVs) and the other is budded viruses (BVs). ODV particles are packed in the viral polyhedral bodies. Silkworm larvae ingest ODVs along with food and the polyhedral bodies get dissolved under the alkaline environment in their midguts leading to the production of BVs. Infection pathways of BmNPV, control methods and resistance mechanisms are well established. Many mechanisms of defense against BmNPV infection in silkworms *viz.*, inducing apoptosis of silkworm cells (Rollie *et al.*, 1991; Ishikawa *et al.*, 2003), lipase (Ponnuvel *et al.*, 2003), serine protease (Nakazawa *et al.*, 2004) and NADPH oxidoreductase (Selot *et al.*, 2010) and chitin synthesis in midgut (Arakawa, 2002) were reported. Moreover, the environmental factors also influence the occurrence of the disease caused by BmNPV (Kobayashi *et al.*, 1981). RNAi (Isobe *et al.*, 2004) and transgenic technology (Kanginakudru *et al.*, 2007; Liang *et al.*, 2012) are reported with silkworms to control the disease caused by BmNPV. However, a complete control of the disease caused by BmNPV is difficult.

The genome of silkworm was analyzed and the genes related to susceptibility to BmNPV were determined (Ito *et al.*, 2008; Atsumi *et al.*, 2012). To study genes related with susceptibilities of silkworms against BmNPV, we tried to identify characteristic silkworm races against BmNPV by per oral inoculation with BmNPV employing 28 silkworm races.

MATERIALS AND METHODS

ODVs of BmNPV: BmNPV supplied by Dr. Y. Furuta was preserved at 4 °C. For inoculation purpose, BmNPV ODVs were purified by 45-85 % (w/v) sucrose density-gradient centrifugation.

Silkworm races: Twenty-eight races of silkworm (Table I) have been reared at National Institute of Agrobiological Sciences and larvae fed on artificial food (Silkmeito[®], Nihon Nosan Kogyo K. K., Yokohama). Larvae fed on the artificial food were selected in I and II instar for their adaptation to food. All the larval batches were reared at 25 - 27 °C.

Susceptibility test: The tests were performed during May 2006 to December 2007. Each larva was fed on the artificial food with $2.5 \times 10^5 \times 10^8$ ODVs/g containing 50 ppm of chloramphenicol. Each larva and the food was kept in separate cups (diam. 4.3 cm) capped with

Table 1: Susceptibility of silkworm races against *Bombyx mori* nucleopolyhedrovirus

Race	Slope $\pm$ SE	LC ₅₀ *	95 % CL		Race	Slope $\pm$ SE	LC ₅₀ *	95 % CL	
			LL	UL				LL	UL
J137 x C146	0.39 $\pm$ 0.15	7.09	6.34	9.77	Koishimaru (sanshi)	0.88 $\pm$ 0.18	6.00	5.57	6.36
TC62	0.97 $\pm$ 0.20	6.88	6.54	7.33	TN44	1.28 $\pm$ 0.24	6.00	5.69	6.29
Oh1	0.84 $\pm$ 0.18	6.82	6.44	7.33	C134	1.11 $\pm$ 0.22	5.89	5.52	6.20
C605	1.56 $\pm$ 0.29	6.77	5.44	7.05	TN40	0.91 $\pm$ 0.19	5.84	5.40	6.20
TCS37	2.33 $\pm$ 0.52	6.73	6.72	6.96	Murasakiko	2.16 $\pm$ 0.44	5.84	5.62	6.08
TN43	1.19 $\pm$ 0.22	6.55	6.26	6.88	Torukoohken	3.22 $\pm$ 0.80	5.82	5.63	6.01
TCS59	0.79 $\pm$ 0.17	6.50	6.10	6.96	Kinkomaru	1.78 $\pm$ 0.36	5.79	5.54	6.04
CSL1	1.19 $\pm$ 0.22	6.39	-	-	Daizo	2.57 $\pm$ 0.59	5.75	5.53	5.96
Aojuku	1.69 $\pm$ 0.30	6.32	-	-	NSL1	2.38 $\pm$ 0.53	5.74	5.25	5.96
Ohha	1.00 $\pm$ 0.49	6.20	5.85	6.55	C145 x HekirenG	1.58 $\pm$ 0.33	5.62	5.34	5.88
TN39	0.96 $\pm$ 0.19	6.13	-	-	Serishinmayu	1.14 $\pm$ 0.25	5.53	5.12	5.84
J603	1.43 $\pm$ 0.26	6.12	5.84	6.39	Koishimaru (watari)	4.70 $\pm$ 2.62	5.52	-	-
C604	2.06 $\pm$ 0.43	6.03	5.80	6.27	Ryukyutasan (ayabe)	1.40 $\pm$ 0.32	5.42	-	-
Jinzohkeiran	2.32 $\pm$ 0.51	6.02	5.80	6.24	Kanoh	0.98 $\pm$ 0.72	3.65	-	-

* Polyhedral inclusion bodies per ml / larva, measured as the 50 % lethal concentration with 95 % confidence limits (CL).

a hole to facilitate air circulation. The larvae fed on the artificial food containing only 50 ppm of chloramphenicol were maintained as control. These larvae were reared for nine days, and number of dead larvae was recorded.

Statistical analysis: Lethal concentration 50 (LC₅₀) of each race was calculated by Probit method (SPSS software ver'. 7.5. I J).

RESULTS

Susceptibility test: Sixteen larvae each of 28 races were fed on the artificial diet containing $8 \times 10^{4-5} \times 10^7$ ODVs/g of BmNPV and silkworm mortality was observed three days after the inoculation. Highly susceptible races died earlier than less susceptible races. LC₅₀ of J137 x C146 race was the highest and that of Kanoh race was the lowest among the 28 tested races. When Kanoh race was fed on the diet containing 8×10^4 ODVs/g of BmNPV, 14 larvae died and all the larvae were died at $4 \times 10^{5-7}$ ODVs/g.

Along with Kanoh race, Koishimaru (watari) and Ryukyutasan (ayabe) races also did not have 95% confidence limits for LC₅₀ values because all larvae fed with the diet containing $2 \times 10^{6-7}$ ODVs/g of BmNPV died. On the other hand, CSLI, Aojuku and TN39 races also did not have 95% confidence limits value because many control larvae died (Table 1).

J137 x C146, C605 and TC62 were found to be less susceptible races against peroral infection of BmNPV, and Kanoh race was selected as highly susceptible one. The results were confirmed by second test in which 16 larvae of less susceptible races viz., J137 x C146, C605 and TC62 races and highly susceptible race, Kanoh were fed on the artificial diet containing $5 \times 10^{-5} \times 10^7$ ODVs/g of BmNPV. LC₅₀ of J137 x C146 race was the highest and LC₅₀ of Kanoh recorded the lowest among the tested races (Table 2).

Table 2: Confirmation tests for silkworm races having large differences in susceptibility

Race	Slope $\pm$ SE	LC ₅₀ *	95 % CL	
			LL	UL
J137 x C146	0.67 $\pm$ 0.14	7.50	7.05	8.03
TC62	1.40 $\pm$ 0.31	6.35	1.40	0.31
Kanoh	0.67 $\pm$ 0.14	3.21	-	-

* Polyhedral inclusion bodies per ml / larva, measured as the 50 % lethal concentration with 95 % confidence limits (CL).

Cross mating and parents test: Twelve larvae each were fed on the artificial diet containing $5 \times 10^{1-7}$ ODVs/g of BmNPV. J137 x C146 race was the least susceptible followed by C146 x J137. These being hybrids, were less susceptible than parental races. Kanoh race was found highly susceptible followed by TC62 (Table 3).

Table 3: Susceptibility of hybrids and parental races against *Bombyx mori* nucleopolyhedrovirus inoculation

Race	Slope $\pm$ SE	LC ₅₀ *	95 % CL	
			LL	UL
J137 x C146	0.46 $\pm$ 0.10	6.60	6.33	6.91
C146 x J137	0.57 $\pm$ 0.10	6.46	6.13	6.96
C146 x Kanoh	0.34 $\pm$ 0.06	6.49	4.64	9.12
C146 x C146	0.47 $\pm$ 0.85	5.67	5.34	5.98
J137 x J137	0.45 $\pm$ 0.76	5.30	4.96	5.62
Kanoh x C146	0.31 $\pm$ 0.59	5.37	4.79	5.94
J137 x Kanoh	0.29 $\pm$ 0.54	6.20	5.69	6.85
TC62 x Kanoh	1.13 $\pm$ 0.36	6.80	6.50	7.09
Kanoh x J137	0.40 $\pm$ 0.70	5.35	5.26	6.22
Kanoh x TC62	0.44 $\pm$ 0.90	5.02	4.57	5.51
TC62 x TC62	0.24 $\pm$ 0.62	5.18	4.10	5.80
Kanoh x Kanoh	0.50 $\pm$ 0.10	4.45	-	-

* Polyhedral inclusion bodies per ml / larva, measured as the 50 % lethal concentration with 95 % confidence limits (CL).

Differences of susceptibility of J137 x C146 and Kanoh race: J137 x C146 (less susceptible) and Kanoh (highly susceptible) were fed on the diet containing $2.5 \times 10^{-5} \times 10^7$ ODVs/g of BmNPV. Since 95 % confidence limits of Kanoh race was determined at 4.69, the degree of variation in LC₅₀ between J137 x C146 race and Kanoh race was 2.11, showing that susceptibility of Kanoh race is 128 times as that of J137 x C146 race (Table 4).

Table 4: Confirmation test of silkworm races having large differences in susceptibility

Race	Slope $\pm$ SE	LC ₅₀ *	95 % CL	
			LL	UL
J137 x C146	1.60 $\pm$ 0.25	6.80	6.06	8.00
Kanoh	1.46 $\pm$ 0.25	4.69	4.47	4.92

* Polyhedral inclusion bodies per ml / larva, measured as the 50 % lethal concentration with 95 % confidence limits (CL).

DISCUSSION

Susceptibilities of silkworm races against BmNPV have been studied by several workers (Furuta 1994 a, b; 1995; Sen *et al.*, 1997; Biabani *et al.*, 2005). The susceptibilities of silkworm races against inoculation with BmNPV varied and no resistant race for BmNPV was identified in Japan (Furuta, 1994 a). The present study shows that difference of LC₅₀ between the least susceptible race and the highly susceptible race was only 128 times. Furuta (1995) could record a difference of

about 100 times between the most susceptible and the least susceptible race against peroral inoculation with BmNPV. Kanoh race was the most susceptible race among the tested 28 races. The genetical studies on BmNPV of silkworms by Zhu *et al.* (1998) showed that resistance against BmNPV exhibited a patroclinal inheritance. The heredity of resistance of silkworm against BmNPV was controlled both by major dominant genes and multiple micro-effects genes (Yao *et al.*, 2003). Therefore, we consider that there are many genes concerning susceptibility against BmNPV or resistance against BmNPV in silkworms. This paper shows that susceptible genes confirmed in Kanoh race may be an important information towards studies on susceptibility/resistance against BmNPV of silkworm.

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Research Paper

THE TAILORABILITY OF SOFT SILK FABRICS

Jameela Khatoon¹, T. H. Somashekhar², Arindam Basu¹ and Y. C. Radhalakshmi³

¹Central Silk Technological Research Institute, Central Silk Board, BTM Layout, Bangalore 560 068, India.

²Visvesvaraya Technological University, Belgaum, India.

³Central Sericultural Research and Training Institute, Central Silk Board, Mysore 570 008, India.

E-mail: khatoon.jameela@gmail.com

ABSTRACT

Soft silk fabrics in the weight range of 50-60 g/m² were subjected to testing of their physical and low stress mechanical properties using the FAST system with the objective of investigating their tailorability. The instrumentally measured properties of the soft silk fabrics are discussed in terms of fabric weight, thickness, relaxation shrinkage, hygral expansion, extensibility, bending rigidity, shear rigidity and formability. It is observed that the relaxation shrinkage and hygral expansion of these fabrics are under control as per the requirement in garment manufacture according to the standard guidelines. The main problem area is the low extensibility and low formability in both warp and weft direction, which may lead to tailoring problems during laying, cutting, sewing and fabric manipulation. This study is an effort to build up a database of the properties of silk fabrics which can be used to engineer new characteristics or attributes into the silk fabrics and also to provide a basis for appropriate process control during apparel manufacture and hence facilitate the conversion of these fabrics into garments.

Key words : Bending rigidity, extensibility, FAST system, formability, hygral expansion, shear rigidity, soft silk fabrics, tailorability.

INTRODUCTION

The main task of clothing manufacturer is to produce shell structures out of flat fabrics to match the shape of the human body. In all shape-producing methods, there will be an interaction between particular methods used and various mechanical and physical properties of the fabric. The mechanical properties of apparel fabrics are important from the point of view of stresses applied to fabrics in making up, as well as physical changes in the fabric as a result of application of forces in a garment during its use (Shishoo, 1991).

The pioneering research work on the objective measurements of mechanical properties of fabrics was carried out by Pierce (1930). Lindberg *et al.* (1960) were the first to apply the theory of buckling to textile fabrics in garment technology. Longitudinal fabric compression sustainable by a fabric in a certain direction before the fabric buckles is a fabric mechanical property that is

particularly important in tailoring *i.e.*, forming and sewing of flat fabrics into three-dimensional garments. Fabric formability is a measure of the degree of longitudinal compression. In the case of plate buckling, this compression limit is dependant on the product of fabric compressibility and fabric bending rigidity (Lindberg *et al.*, 1960).

Tailorability has been defined as 'the ease with which the fabric can be converted into the intended end product' (Bassett, 1981). Tailorability has also been referred to as 'making-up' properties by Morooka and Niwa (1978). The method of production and the quality of the finished garment is determined from the physical and mechanical properties of fabrics used for producing the garment. Therefore, an understanding of the properties and characteristics of the fabrics being converted becomes a prerequisite for controlling the apparel manufacturing processes.

Garment manufacturing processes are becoming more and more automated in the recent years. The demand for newer varieties and styles by the consumers has made the consumer market increasingly sophisticated demanding more choices for selection. Quality control in garment manufacturing is therefore becoming more difficult. With the aim of producing good quality products with high production efficiencies, clothing manufacturing companies have established advance laboratories for measuring fabric properties to control fabric quality, production processes and garment quality.

Silk fabrics are traditionally evaluated by subjective assessment by experts who are familiar with different quality or handle attributes of these materials. The development of fabric objective measurement has provided a scientific basis using instruments for the evaluation of finished fabric quality and performance attributes. This method has largely been applied to wool, cotton and synthetic materials and their blends. In order to use this method for the evaluation of silk fabrics, it is required to build up a database of the low stress mechanical, surface and dimensional properties of finished silk fabrics. This database can be used to ascertain whether it is possible to differentiate between and identify different known qualities of silk fabrics according to their objectively measured low stress mechanical properties and surface properties. This would also facilitate in determining the relationship between these instrumentally measured properties and various silk fabric finishing processes such as degumming, bleaching, dyeing and drying (Postle and Ping, 1994). Recently, techniques have been developed to measure the mechanical properties of fabrics and use these measurements to quantify handle attributes (Mahar *et al.*, 1982) and predict performance in both garment manufacture and appearance (Postle *et al.*, 1983).

The objective of this study is to investigate the tailorability of a range of soft silk fabrics in plain weave in the weight range of 50-60 g/m² using the FAST system. The instrumentally measured properties of the finished soft silk fabrics are discussed in terms of fabric weight, thickness and low stress mechanical properties such as tensile properties, shear, bending and dimensional stability.

MATERIALS AND METHODS

Six soft silk fabrics in the weight range of 50-60 g/m² were subjected to testing of their physical and low stress mechanical properties using the FAST system. The summary of the fabric construction parameters is given in Table 1.

Table 1: Construction parameters of soft silk fabrics

Sample	Mass per unit area (g/m ²)	Thickness (mm)
SS1	51	0.140
SS2	54	0.148
SS3	59	0.167
SS4	49	0.150
SS5	53	0.134
SS6	58	0.156

Fabric composition: 100 % silk; Weave: Plain.

The mass per unit area of the soft silk fabrics considered under the study varied from 49 to 59 g/m² and the thickness from 0.134 to 0.167 mm. There is a correlation between the thickness and weight of the fabric which is significant at 5 % with a correlation coefficient of 0.394.

Measurement of fabric properties relevant to tailorability

Relaxation shrinkage (RS)

Relaxation shrinkage is the irreversible change that occurs in the fabric dimensions when a fabric is wet or exposed to steam. Relaxation shrinkage is caused by the release of cohesive or temporarily set strains that are imposed on fabrics during textile processing. In the FAST system, relaxation shrinkage is defined as the percentage change in dry dimensions of the fabric measured after relaxation in water at 25 ± 5 °C for 30 minutes.

Hygral expansion (HE)

The reversible change in dimensions caused by the changes in moisture is called hygral expansion by Baird (1962). With FAST, hygral expansion is defined as the percentage change in dimensions of the relaxed fabric from wet to dry (De Boos, 1991).

Extensibility (E100)

The extensibility of a fabric measures the increase in fabric dimensions that occurs when it is subjected to an applied tensile load. The extensibility of the fabric is measured by using FAST-3 (extensibility meter). With FAST system, extensibility is measured as a percentage increase in length at a sample loading of 5 gf/cm, 20gf/cm and 100gf/cm width. The value quoted for fabric extensibility is that measured at 100gf/cm and the extensibility in warp and weft directions measured at 5 gf/cm and 20 gf/cm is used to calculate fabric formability (De Boos, 1991).

Bending rigidity (B)

The bending rigidity of the fabric was measured using FAST-2 (bending meter). The FAST system determines bending rigidity from the cantilever bending length of the fabric and the fabric mass:

$$\text{Bending rigidity} = \text{mass} \times (\text{bending length})^3 \times 9.807 \times 10^{-6}$$

where the bending rigidity is expressed in μNm , the bending length in mm and the fabric mass in g/m^2 .

Shear rigidity (G)

The shear rigidity of the fabric was measured using FAST - 3. In the FAST system, shear rigidity is calculated from the extensibility of the fabric under a load of 5gf/cm.

$$\text{Shear rigidity} = 123 \div \text{bias extensibility}$$

Where the shear rigidity is expressed in N/m and the bias extensibility as a percentage.

Formability (F)

The FAST system uses the derived parameter, formability, in analyzing the fabrics. Formability is a measure of the extent to which a fabric can be expressed in its own plane before it buckles. This parameter, as the product of the bending rigidity and the extensibility of the fabric at a low load, is defined in the FAST system as :

$$\text{Formability} = \text{bending rigidity} \times \text{extension (at 20gf/cm width)} - \text{extension (at 5 gf/cm width)} \div 14.7$$

where the formability is expressed in mm^2 , the bending rigidity in μNm , and the extension as a percentage (Wang *et al.*, 2003).

RESULTS AND DISCUSSION

The summary of the FAST test results is given in Table 2. The guidelines to determine the upper and lower limits of the test parameters are followed as per De Boos (1991).

Relaxation shrinkage (RS)

Both excessive and insufficient relaxation shrinkage can cause problems during garment manufacturing. If the relaxation shrinkage exceeds 3 %, shrinkage in the manufacturing process can be excessive and the final garment will be smaller than planned. If different panels of a garment are subjected to different preparations, the shrinkage of these panels can be different making the matching of checks or patterns difficult. In case of a fabric with insufficient relaxation shrinkage, *i.e.*, less than (0 %), there can be problems during sewing and pressing around the sleeve head, where some shrinkage is required to remove the residual fullness and to take up excess fabric.

As shown in Table 2 and Figure 1, the relaxation shrinkage in the warp direction ranges from a minimum of 1.1 to a maximum of 3.0 % which is within the guidelines *i.e.*, 0 – 3 %. For the relaxation shrinkage in the weft direction, the range is from a minimum of 0.0

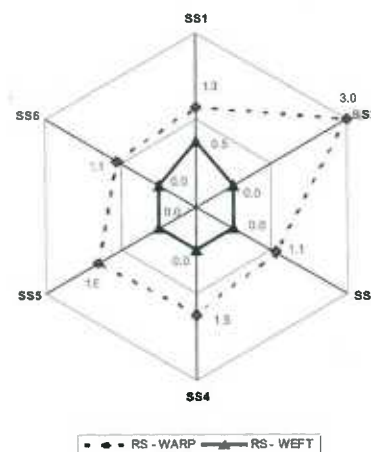


Figure 1: Warp and weft relaxation shrinkage of soft silk fabrics.

Table 2: The FAST test results

Sample	RS -1	RS -2	HE-1	HE-2	E100-1	E100-2	B-1	B-2	G	F - 1	F-2
SS1	1.3	0.5	1.4	0.5	0.70 ^b	1.70 ^b	8.91	1.97 ^b	44	0.061 ^b	0.040 ^b
SS2	3.0	0.0	-0.1	0.0	1.53 ^b	0.60 ^b	5.41	15.65	139 ^a	0.098 ^b	0.075 ^b
SS3	1.1	0.0	1.1	0.0	0.87 ^b	0.97 ^b	10.84	7.51	69	0.123 ^b	0.068 ^b
SS4	1.5	0.0	-0.4	0.0	1.53 ^b	1.47 ^b	2.91 ^b	10.32	53	0.059 ^b	0.164 ^b
SS5	1.6	0.0	0.3	0.0	1.03 ^b	0.90 ^b	7.43	9.72	176 ^a	0.101 ^b	0.089 ^b
SS6	1.1	0.0	-0.5	-1.1	1.37 ^b	0.73 ^b	6.23	12.96	93 ^a	0.070 ^b	0.117 ^b

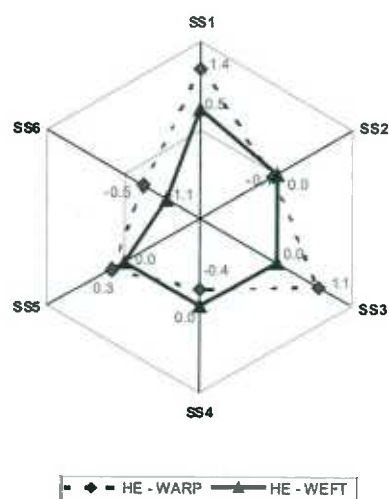
The suffixes 1 and 2 refer to the warp and weft directions, respectively. The suffixes 'a' and 'b' indicate that the corresponding value is above the upper limit and below the lower limit, respectively

to a maximum of 0.5 % which is also within the recommended limits of 0 - 3%.

Hygral expansion (HE)

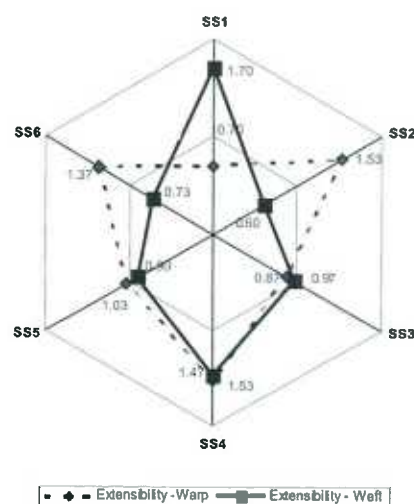
Excessive hygral expansion (>6 %) will cause poor appearance of garment in wear because the unsupported garment panels expand in dimensions as the moisture content of the fibers increase. This results in differential fabric expansion at the junction of supported (fused or seamed) and unsupported panels, which in turn cause rippling or puckering of the fabric. De-lamination of fusible interlining can also occur.

As shown in Table 2 and Figure 2, the hygral expansion in the warp and weft directions ranges from a minimum of -0.5 to a maximum of 1.4 % and from a minimum of -1.1 to a maximum of 0.5 %, respectively which is within the guidelines *i.e.*, <6 %. However, there is no specific lower limit for the hygral expansion parameter.

**Figure 2: Warp and weft hygral expansion of soft silk fabrics.**

Extensibility (E)

Both excessive and insufficient fabric extensibility will cause problems in garment manufacturing. If the extensibility is less than 2 %, it is difficult for the fabric to get stretched during seam-overfeeding. It is also difficult to create fullness at the sleeve head. If the extensibility is greater than 4 % in the warp direction, the fabric gets very easily stretched during laying before cutting. It is therefore difficult to lay each layer of the fabric in an unstrained state. If this is not achieved, the dimensions to which a garment panel is cut will not correspond to the stable dimensions of the fabric. Excessive fabric extensibility can also make the cutting process difficult unless the fabric is stabilized on a vacuum table. In addition to this, the sewing of long unsupported seams on patterned fabric is difficult with highly extensible fabrics and require a high level of expertise and control by the operator.

**Figure 3: Warp and weft extensibility of soft silk fabrics.**

The warp extensibility for the fabrics tested ranged from a minimum of 0.7 to a maximum of 1.53 % which is below the lower limit of guideline *i.e.*, <2 %. As for the weft extensibility, it ranged from a minimum of 0.6 to a maximum of 1.7 % which is also below the lower limit of guideline *i.e.*, <2 % (Table 2 and Figure 3).

Bending rigidity (B)

The major problems associated with bending rigidity occur in fabrics in which it is very low. When the bending rigidity is less than 5 μNm , it can be difficult to cut, handle and sew the fabric because of the ease with which it bends and folds.

In the present case (Table 2 and Figure 4), the warp bending rigidity ranged from a minimum of 2.91 to a maximum of 10.84 μNm . In the case of SS4 alone, it is 2.91 μNm , which is below the lower limit of the guideline *i.e.*, 5 μNm whereas in the case of the other five silk samples, it is above 5 μNm which is within the guidelines. As for the weft bending rigidity, it ranged from a minimum of 1.97 to a maximum of 15.65 μNm . In the case of SS1 alone, it is 1.97 μNm , which is below the lower limit of the guideline *i.e.*, 5 μNm whereas for the other five silk samples, it is above 5 μNm which is within the guidelines.

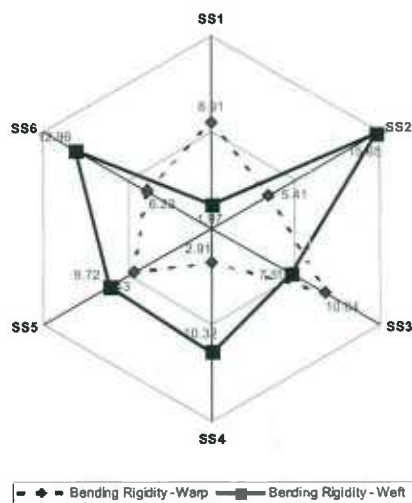


Figure 4: Warp and weft bending rigidity of soft silk fabrics.

Shear rigidity (G)

Too high or too low values of fabric shear rigidity with respect to the guidelines will also result in problems

during garment manufacture. If the shear rigidity is less than 30 N/m, the fabric is easily distorted and can skew or bow during handling, laying up, cutting or sewing. The skewing can lead to the formation of distorted panels. If the shear rigidity is more than 80 N/m, it will be difficult to form, mould or shape the fabric at the sleeve head and also to form into smooth three dimensional shapes.

As shown in Table 2, the shear rigidity values for three fabric samples *i.e.*, SS1, SS3 and SS4 fall within the range of the guidelines, whereas for the other three, *i.e.*, SS2, SS5 and SS6; it is above the upper limit of the guidelines.

Formability (F)

The lower limit of formability for light weight fabrics is set at 0.25 mm^2 and this can vary depending on the sewing thread, needle size, and thread tension as well as the skill of the operator. It can be seen from Table 2 and Figure 5 that the warp formability ranges from 0.059 to 0.123 mm^2 which is below the lower limit of the guidelines *i.e.*, 0.25 mm^2 .

As for the weft formability, the range is from 0.040 to 0.117 mm^2 which is also below the lower limit of the guidelines *i.e.*, 0.25 mm^2 . As the values of formability in both warp and weft are below the lower limit of the guidelines, these fabrics may cause problems in seam quality for sewing in all fabric directions.

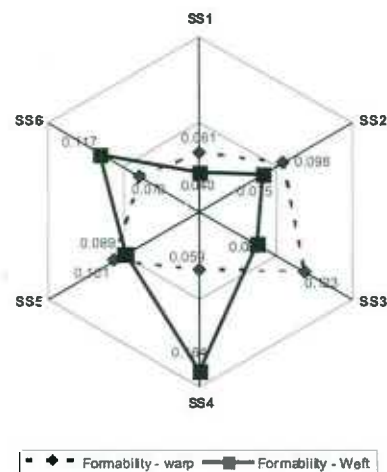


Figure 5: Warp and weft formability of soft silk fabrics.

CONCLUSION

In accordance with the results and observations made in respect of the soft silk samples tested under this study, some general conclusions can be drawn, which are as follows:

- The relaxation shrinkage and hygral expansion of these fabrics are under control as per the requirement in garment manufacture, according to the guidelines framed by De Boos (1991).
- The main problem area is the low extensibility and the low formability in both warp and weft direction, which may lead to tailoring problems during laying, cutting, sewing and fabric manipulation.

This study is an effort to build up a database of the properties of silk fabrics which can be used to engineer new characteristics or attributes into the silk fabrics and also to provide a basis for appropriate process control during apparel manufacture and hence facilitate the conversion of these fabrics into garments.

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IMPACT OF LEGUME GREEN MULCHING ON SOIL PHYSICO-CHEMICAL CONDITION OF RAIN-FED TROPICAL TASAR SILKWORM FOOD-PLANT FIELDS

R. Manohar Reddy¹, Ram Kumar², Suresh Rai², B. S. Angadi³ and V. Sivaprasad³

¹P2 Basic Seed Farm, National Silkworm Seed Organization, Central Silk Board, Parigi - 515 261, India.

²Central Tasar Research and Training Institute, Central Silk Board, Ranchi - 835 303, India.

³National Silkworm Seed Organization, Central Silk Board, Bangalore-560 068, India.

E-mail: dr.manohar1959@rediffmail.com

ABSTRACT

Rain-fed tropical fields of *Terminalia tomentosa* (W&A) have been evaluated for soil enrichment and sustainable leaf productivity through green mulching with legumes viz., sun hemp (*Crotalaria juncea*), daincha (*Sesbania aculeata*), green gram (*Vigna radiatus*) and black gram (*Vigna mungo*). The legume mulching has enhanced the water holding capacity, moisture retention, electrical conductivity, organic carbon, nitrogen (N) and potassium (K) contents and reduced the bulk density and pore space of soil. Among the four legumes, sun hemp has shown the highest improvement in water holding capacity (56.9 %), moisture content (68.5 & 37.9 % at 30 and 45 cm depth, respectively), electrical conductivity (0.30 mhos/cm), bulk density (1.12 g/cm³), pore space (50.4 %), organic carbon (0.61 %), nitrogen (109 kg/ha) and potassium (254 kg/ha) of the soil leading to better leaf yield of tasar food-plant (24.8 MT/ha). The study infers that the legume green mulching in rain-fed tasar fields can augment the physico-chemical properties and fertility condition of soil and leaf yield of *T. tomentosa*.

Key words: *Antheraea mylitta*, leaf yield, mulching, soil properties, *Terminalia tomentosa*.

INTRODUCTION

Application of green mulches has become an important practice nowadays for maintaining soil productivity though growing a legume crop to be worked into the soil has been in practice since long. The incorporated legume residues are the biological source of nitrogen (N) and reduce the N requirement for the following crop, besides favouring the soil physical properties with decreased bulk density, increased water infiltration capacity, organic C and recycling of N, P and K (Fischler *et al.*, 1999; Carter, 2002; Feichtinger *et al.*, 2004; Iqbal *et al.*, 2005; Khurshid *et al.*, 2006; Pervaiz *et al.*, 2009). The application of sun hemp as organic mulch was proved to have triple benefits of effective utilization of waste, improvement in soil quality and economic gain with low input of chemical fertilizers for sustainable silk cocoon production (Shashidhar *et al.*,

2009). In temperate regions, high organic matter inputs combined with slow decomposition rates (determined by climate) lead to high soil organic carbon (SOC), while in tropical regions, decomposition and the turnover of SOC tend to be faster (Alvarez and Alvarez, 2000; Ghuman and Sur, 2001; Jung *et al.*, 2005; Liu *et al.*, 2006). The tropical tasar food-plants, *Terminalia tomentosa* and *Terminalia arjuna* grown under the rain-fed conditions and in degraded soils with low nutrients (Suryanarayana *et al.*, 2005) are being exploited to rear tasar silkworm, *Antheraea mylitta* to produce vanya silk of high global demand. The optimal leaf productivity of tasar food-plant is the most essential factor which make tropical sericulture sustainable. The organic mulches help the soil from rapid warming and drying so that crop growing and harvesting periods are extended (Wahome *et al.*, 2009). Much research has been

devoted to the technologies of applying legumes as green mulch (Schroder, 2005). The maximum net farm income and cost benefit ratio was reported in maize inter cropped with cow pea along with nitrogen application (Sahu, 2006; Tarfia *et al.*, 2006; Rehman *et al.*, 2010). The advantage of rapid mineralization of mulched legumes to fix the nitrogen in soil organic compounds (Malecka and Blecharczyk, 2008) even under low soil moisture (Chakravarti *et al.*, 2005; Ossom and Matsenjwa, 2007) strongly recommends green manuring (Duda *et al.*, 2003; Sparling *et al.*, 2003; Sultani *et al.*, 2007). Hence, a study has been undertaken to assess the impact of legume green mulching by utilizing the inter-space of *T. tomentosa* plantation, in enhancing the soil physico-chemical condition of rain-fed tropical tasar fields to augment the leaf yield.

MATERIALS AND METHODS

The present study was conducted during the rainy season (June to September) of three successive years in the tasar food-plant economic plantation of *T. tomentosa* maintained by the Agronomy division of Central Tasar Research and Training Institute (CTR&TI), Ranchi, India to evaluate the potential of various leguminous green mulches in improving the soil physico-chemical characters of tasar field and leaf yield of tasar food-plant under tropical rain-fed conditions. The experiment was laid out in a complete randomized block design (CRBD) with five treatments in four replications. The treatments included four legumes *viz.*, green gram (*Vigna radiatus*), black gram (*Vigna mungo*), sun hemp (*Crotalaria juncea*) and daincha (*Sesbania aculeata*) besides the control *i.e.*, without legume green mulching for comparison. The regular agronomical practices were carried out uniformly for all treatments including control. The seeds of four legume varieties were broadcasted in between the rows of *T. tomentosa* economic plantation during first week of June of the respective year with onset of monsoon rains. The raised legume inter-crops were grown up to 50 days till they reached flowering stage for optimal production of green biomass. The legumes were then cut to ground level, weighed and mulched at 75 cm depth into the trenches of the tasar field made in between the rows of

T. tomentosa plants. The season was very ideal for green mulching with required soil moisture content and continued rainfall in the area till the end of September, every year. The soil samples of tasar field were analyzed before initiation of the experiment and subsequent years there on, during experimentation for its physico-chemical constituent status. The observations were recorded on water holding capacity (WHC), moisture content at 30 cm and 45 cm depth, pH, soil electrical conductivity (SEC), soil bulk density (SBD), soil pore space (SPS), soil organic carbon (SOC) content and levels of nitrogen (N), phosphorus (P) and potassium (K) of soil in addition to the yield of green biomass of different legumes upon their harvest during the month of July and the leaf yield of *T. tomentosa* during commercial crop rearing season (September-December) for three successive years of experimentation and the data obtained were subjected to statistical analysis.

RESULTS AND DISCUSSION

Legume biomass, tasar food-plant leaf productivity and soil parameters

The green biomass production by different legumes, the leaf yield of tasar food-plant, *T. tomentosa*, the soil pH, water holding capacity and average moisture content at 30 and 45 cm depth in control as well as in different legume green mulch treatments are presented in Table 1. Among the four legumes studied, sun hemp has recorded the highest average production of 39.0 quintals of green biomass per hectare, while daincha, green gram and black gram have yielded 26.6, 25.3 and 17.7 quintals, respectively. The leaf yield of tasar food-plant recorded for sun hemp treatment was the highest (24.8 MT per hectare) among all the treatments with an increase of 34.0 % over control. The leaf yield of 23.0, 22.6 and 21.6 MT were recorded for daincha, black gram and green gram treatments with an increase of 24.3, 22.2 and 16.7 % over control. Though, the soil pH got tilted slightly towards acidic side in green mulched treatments compared to control, the change was not-significant. The water holding capacity (56.9 % with an increase of 5.2 % over the control) and soil moisture percentage (68.5 and 37.9 % with an increase of 22.9 and

Table 1: Biomass production and impact of leguminous green mulching on leaf yield of tasar food-plant and soil properties

Treatment (legume green mulches)	Legume biomass (q / ha)	Food-plant leaf yield (MT/ ha)	Soil pH value	Water holding capacity (%)	Soil moisture (%)	
					At 30 cm depth	At 45 cm depth
Control	0.0	18.5 ±0.09	5.9 ±0.01	54.1 ±2.5	55.7 ±2.5	31.5 ±1.7
Green gram	25.3 ±0.13	21.6 ±0.11 +16.7	5.7 ±0.02 -3.4	56.1 ±1.9 +3.7	65.6 ±2.2 +17.8	37.2 ±1.5 +18.1
Black gram	17.7 ±0.23	22.6 ±0.12 +22.2	5.6 ±0.01 -5.1	55.2 ±3.0 +2.0	63.2 ±3.5 +13.5	36.1 ±2.0 +14.6
Sun hemp	39.0 ±0.31	24.8 ±0.10 +34.0	5.5 ±0.01 -6.8	56.9 ±3.0 +5.2	68.5 ±2.0 +22.9	37.9 ±2.1 +20.3
Daincha	26.6 ±0.17	23.0 ±0.21 +24.3	5.5 ±0.01 -6.8	56.4 ±2.9 +4.2	66.1 ±2.2 +18.7	37.5 ±2.3 +19.0
CD at 5 %	3.0	1.4	Non Significant	0.6	4.8	2.4

Values are mean ± SE and + or - are the % change over control.

20.3 % at 30 and 45 cm depth, respectively over the control) were recorded maximum in respect of sun hemp mulch among the four legume treatments. The WHC recorded for daincha, green gram and black gram treatments were 56.4, 56.1 and 55.2 % with an increase of 4.2, 3.7 and 2.0 %, respectively over control. The soil moisture too has shown same trend of enhancement by daincha, green gram and black gram treatments with an increase of 18.7, 19.0; 17.8, 18.1 and 13.5, 14.6 %, respectively over control.

Impact of leguminous green mulching on physico-chemical condition of the soil

The physico-chemical condition of the soil of tasar field in terms of SEC, SBD, SPS, SOC and soil nutrient status with reference to N, P and K in the control and legume green mulch treatments are presented in Table 2. The SEC increased in all the biomulch treatments with the highest of 42.8 % for sun hemp followed by daincha and black gram treatments with 9.5 and 4.8 % increase over control, while it remained unchanged for green gram mulch. The SBD was found reduced for the green mulch treatments over control with the highest reduction of 14.5 % for sun hemp followed by 6.1, 3.8 and 1.5 % reduction for daincha, green gram and black gram, respectively. The SPS recorded decrease for all the green mulch treatments with the highest of 5.6 % in sun

hemp followed by 2.4, 2.1 and 0.56 % in black gram, green gram and daincha treatments, respectively when compared with control. The SOC recorded an increased level for all the biomulch treatments over control with the highest of 27.1 % in sun hemp followed by daincha, black gram and green gram (25.0, 22.9 and 20.8 %, respectively). The soil N and K contents had their levels high after green mulch treatments with the highest for sun hemp green mulch, while the soil P was reduced though in-significantly, in all the legume green mulches except for sun hemp, which kept it un-changed. The highest soil N and K contents were recorded for sun hemp mulch with 109.0 and 254 kg/ha, amounting to an increase of 28.2 and 9.5 %, respectively over control followed by black gram, daincha and green gram, while the change in the levels of P was marginal and non-significant with either decreased or static as against the control.

To achieve higher biological activity, growth and crop yields in plants, the nutrients are to be supplemented to the soil through organic matter / composts / manures for optimal physical and functional properties (Carter, 2002; Schroder, 2005). The incorporation of legume crops as green mulch are recommended even under rain-fed conditions to sustain soil fertility reserves for subsequent agriculture crops, as they grow faster and decompose

Table 2: Impact of leguminous green mulching on the physical and chemical properties and the nutrient status of soil

Treatment- (legume green mulches)	Soil electrical conductivity (mhos/cm)	Soil bulk density (g/ cm ³)	Soil pore space (%)	Soil organic carbon (%)	Soil nutrient status		
					N (kg/ha)	P (kg/ha)	K (kg/ha)
Control	0.21 ±0.009	1.31 ±0.009	53.4 ±2.09	0.48 ±0.005	85 ±1.81	10.5 ±0.12	232 ±4.32
Green gram	0.21 ±0.007	1.26 ±0.01	52.3 ±0.25	0.58 ±0.007	94 ±2.02	10.2 ±0.09	240 ±6.19
	0	-3.8	-2.1	+20.8	+10.6	-2.8	+3.4
Black gram	0.22 ±0.008	1.29 ±0.01	52.1 ±1.81	0.59 ±0.004	96 ±2.94	10.4 ±0.11	244 ±5.88
	+4.8	-1.5	-2.4	+22.9	+12.9	-0.95	+5.2
Sun hemp	0.30 ±0.01	1.12 ±0.008	50.4 ±0.15	0.61 ±0.006	109 ±3.11	10.5 ±0.07	254 ±4.62
	+42.8	-14.5	-5.6	+27.1	+28.2	0	+9.5
Daincha	0.23 ±0.008	1.23 ±0.008	53.1 ±2.01	0.60 ±0.004	95 ±2.10	10.3 ±0.08	242 ±6.01
	+9.5	-6.1	-0.56	+25.0	+11.8	-1.9	+4.3
CD at 5 %	0.03	0.02	0.8	0.03	2.4	Non Significant	6.2

Values are mean ± SE and + or – are the % change over control.

better into the soil (Fischler *et al.*, 1999; Chakravarti *et al.*, 2005; Iqbal *et al.*, 2005; Sultani *et al.*, 2007). The tropical tasar culture being a seasonal practice with tentative crop returns, the agronomical procedures followed are to be appropriate, time bound and cost effective. The green biomass production by sun hemp (39.0 q/ha), which stands significantly higher than that of daincha (26.6 q/ha), green gram (25.3 q/ha) and black gram (17.7 q/ha), suggests its better suitability for rain-fed tropical tasar fields, as the soil fertility has direct correlation with the quantity of green biomass mulched to the soil.

The optimal plant growth occurs under neutral pH and the non-significant change in the soil pH after the application of legume green mulching indicates its suitability for tasar fields. The enhanced WHC and soil moisture content at 30 and 45 cm soil depths further supports the application value of legume mulch for tasar fields. This might be the reason for enhanced leaf yield up to 24.8 MT/ha in tasar food-plant on green mulching with sun hemp. The legume biomulching not only enhances bacterial, fungal and actinomycetes colonies but also favours soil properties on water holding capacity and moisture retention as the SOM and SOC influences the humus content in the soil and thereby the agricultural output (Fischler *et al.*, 1999; Iqbal *et al.*, 2005). The other factors that led to enhanced leaf yield might have been the synchronized changes that occurred in soil

physico-chemical and biological properties on legume green mulching.

The improved SEC with legume biomulching in all the treatments, 42.8 % being the highest for sun hemp mulch, is also an indicator of enhanced physical and biological condition. The SBD, the ratio of mass of dry solids to bulk volume of the soil, changes for a given soil with its structural condition, mineral content and the degree of compaction. The bulk density of quartz records very high (2.65 g/cm³) and the soil with high clay and organic content records the least (1 g/cm³) (Assouline, 2006). Though, the SBD got reduced upon legume green mulching in all the treatments and the least being with sun hemp mulching (1.12g/ cm³), with significant decrease (14.5 %) over the control, is nearer to the levels of clay and distant to that of quartz. Similarly, the increase in SPS would be important for better percolation and water storage space. The reduced SPS on mulching of legume green biomass as organic matter stops the crops suffer neither from shortage nor excess of water (Bulluck *et al.*, 2002). The reduction in SPS on biomulching in general and better with sun hemp mulch (5.6 %) over the control is a precision towards soil properties of tasar field to support the leaf productivity of tasar food-plant even under tropical rain-fed conditions.

Understanding and management of soil organic matter (SOM) in tropical soils is a major challenge of

soil science and a must for sustainable agriculture. The soils contain carbon (C) in both organic and inorganic forms and most soils hold C as soil organic carbon (SOC), which otherwise refers to C in the soil as SOM. The SOC is often reported as the most important sign of soil quality and agricultural sustainability, as it is the central indicator of soil health, worth and dependant of soil management (Farquharson *et al.*, 2003) and the organic C of sandy soil is less than 1 %, while, it is almost 100 % in wetland soils (Sparling *et al.*, 2003; Ossom and Matsenjwa, 2007). The higher soil C indicates the larger population of microbial biomass and respiration of soil, besides large quantities of mineral nitrogen (N) in the top layers (Fischler *et al.*, 1999; Shashidhar *et al.*, 2009).

Further, the application of legume green manure will add important nutrients such as N, sulphur (S) and P to the soil which helps to build SOM making the soil pore size healthier with increased water holding and cation exchange capacity (CEC) for effective utilization of inorganic fertilizers (Alvarez and Alvarez, 2000; Suryanarayana *et al.*, 2005; Liu *et al.*, 2006).

The incorporation of sun hemp green biomass has improved the SOC over the control, but the improvement was marginal when compared with other legumes viz., daincha, green gram and black gram. This suggests the value and suitability of any legume green mulching to tropical tasar fields under rain-fed conditions. Further, the additional benefit of using a legume mulching is to fix atmospheric N and make it available as biological source of N (Schroder, 2005; Sahu, 2006) essential for plant growth and leaf yield. When legume biomass reaches the soil, its halt is not longer but the mineralization increases depending upon temperature, moisture content, microbial load of the soil and C/N ratio of the mulched organic matter. Hence, the mulching of legumes was done during July month to allow the biomass to decompose into soil under ideal soil moisture and microbial levels with continued rains in the area till September month of the year.

The healthiness of the soil depends on its pH, texture, extractable nutrients, N-P-K status and supplying potential of base cations viz., Ca, Mg & K (Alvarez and

Alvarez, 2000; Pervaiz *et al.*, 2009) and the green manuring with legumes are preferred for their ability to fix atmospheric nitrogen (Duda *et al.*, 2003; Sultani *et al.*, 2007). Though, the application of organic manure play a role of soil fertility conservation, the uncertain crop returns in rain-fed tropical tasar culture cannot break even the commercial crop economics. The green mulching can conserve the moisture, build up organic matter and improve the properties of terrestrial soil and activity of microbes supporting the mineralization rate and release of N, P and K in greater proportion (Carter, 2002; Feichtinger *et al.*, 2004). The application of sun hemp with its highest produced biomass as green mulch has increased tasar field water holding capacity and soil moisture content with complimentary changes in SEC, SBD, SPS, organic C and available N and K. The enhanced water holding and physico-chemical condition of the soil with improved levels of N and K on legume green mulching indicates the value of legumes for tropical rain-fed tasar fields. The highest green biomass production, upgraded physico-chemical condition of soil with enhancement in the leaf yield of *T. tomentosa* by sun hemp infers its high application value as green mulch among the evaluated legumes, for tropical tasar fields under rain-fed conditions.

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Research Paper

EFFECT OF APPLICATION OF DIFFERENT SOURCES AND LEVELS OF LIME IN SOIL ON THE LEAF YIELD OF RAIN-FED MULBERRY IN THE ACID RED SOILS OF EASTERN GHAT HIGHLAND ZONE OF ODISHA, INDIA

K. M. Purohit¹, R. N. Datta², B. D. Dash³, R. Sahu, B. B. Bindroo² and N. K. Das²

Regional Sericultural Research Station, Central Silk Board, Koraput-764 020, Odisha, India.

¹Research Extension Centre, Central Silk Board, Deogarh-768 108, Odisha, India.

²Central Sericultural Research and Training Institute, Berhampore-742 101, West Bengal, India.

³Basic Seed Multiplication & Training Centre, Nabarangpur, Odisha, India.

E-mail: kmpurohit25@gmail.com

ABSTRACT

A field experiment was undertaken for four years (2003-07) in the Farm of Regional Sericultural Research Station, Koraput by using three different sources of lime viz., Calcitic Lime Stone Powder (91 % CaCO_3), Paper Mill Sludge (71 % CaCO_3) and Basic Slag (55 % CaCO_3) at two levels each (0.125 LR and 0.062 LR) to find out their effect on leaf yield of rain-fed mulberry. The plantation was raised in June, 2003 using S₁₆₃₅ mulberry genotype with a spacing of 90 x 90 cm, the gross plot size being 6.7 x 6.7 m. The experiment was laid out in a Randomized Block Design in three replications and six treatment combinations compared against a no lime control. Liming materials were applied in two equal split doses in June and September. Farm Yard Manure at 10 MT/ha/yr and N: P₂O₅:K₂O at 150:50:50 kg/ha/yr with N in two equal split doses were applied in July and September after 15 days of application of lime. Application of 0.125 LR lime was found to neutralize the acidic soil to the desired level which went down to acidic level again by March every year. Average annual leaf yield over three years (2004-05 to 2006-07) indicated that application of 0.125 LR (i.e., 1670 kg/ha/yr of CaCO_3 equivalent) lime in the form of Calcitic lime stone powder recorded the highest leaf yield of 12356.66 kg/ha/yr followed by Basic Slag (11876.42 kg/ha/yr) and Paper Mill Sludge (11656.82 kg/ha/yr) registering 43.68, 38.09 and 35.54 % increase in yield over no lime control (8600.22 kg/ha/yr). However, economics calculated on the basis of cost of cocoon production, prices of dfls, sale price of cocoons prevalent during the period of investigation revealed that the net income with Basic Slag, Paper Mill Sludge and Calcitic Lime Stone Powder were \$ 637.335, \$ 621.572 and \$ 554.465, respectively vis-à-vis no lime control (\$ 389.658) from one hectare of rain-fed mulberry with benefit-cost ratio of 2.41:1, 2.42:1 and 1.97:1. Hence, it is recommended to use any of these three liming materials in order of preference @ 0.125 LR (1670 kg/ha/yr of CaCO_3 equivalent) every year by the farmers depending on their availability in the particular locality having acidic soils.

Key words: Acid red soil, leaf yield, lime, mulberry, rain fed conditions.

INTRODUCTION

Odisha has 4.5 million hectares of acid soils (Sahu and Senapati, 1997) which fall under three important soil groups i.e., red, lateritic, and mixed red and yellow. The red soils share the major portion of acid soil and the entire eastern ghat highland zone of Odisha are highly

to moderately acidic. Soils of Koraput district are mostly red and acidic with sandy loam to sandy clay loam texture with poor fertility status. They are highly eroded, rich in iron and aluminium content. Acidity and iron toxicity are problems in most of the blocks of Koraput district in Odisha (Anonymous, 2001). It is reported

that soils reaction (pH) affects the availability of different plant nutrients in various ways (Subbaswamy *et al.*, 1994). Satisfactory crop yield is not obtained unless the acidic soils are properly amended with lime (Sahu and Senapati, 1997). The same holds good in the case of mulberry also for which the desirable pH range is 6.3-7.5 (Subbaswamy *et al.*, 1994; Dandin *et al.*, 2000). By using lime sludge from paper mills, basic slag from steel industry and commercial powdered lime stone, Panda and Das (1971) recorded increase in pH as also the yield of dry matter in maize. Rao and Mittra (1991) in response to liming found an increase in yield of both pigeon pea and groundnut. Singh *et al.* (1990), Patiram (1991a,b) and Singh *et al.* (1995) observed higher seed and straw yield of soybean on using lime + FarmYard Manure + full dose of NPK. Although the beneficial effect of lime application in soil on various crops has been reported, the same on mulberry is not available. Studies were, therefore, conducted to test the efficacy of different sources of lime and to find out the optimum level of lime application for amendment of the acidity of soil and thereby to boost mulberry leaf production per unit area.

MATERIALS AND METHODS

A field experiment was undertaken at the Regional Sericultural Research Station (RSRS) Farm at Koraput (Odisha) for four years (2003-07) in the acid red soil (with pH 5.4 -5.5) using S₁₆₃₅ mulberry genotype with a spacing of 90 x 90 cm. The experiment was laid out in a Randomized Block Design (RBD) having three replications and seven treatments including a no lime control. Paper mill sludge (71 % CaCO₃) from J. K. Paper mill, Rayagada, basic slag (55 % CaCO₃) from Visakhapatnam steel plant and calcitic lime stone powder (91 % CaCO₃) were used. The treatments comprised T1=No lime control, T2=0.125 LR Calcitic lime stone powder, T3=0.062 LR Calcitic lime stone powder, T4=0.125 LR paper mill sludge, T5=0.062 LR paper mill sludge, T6=0.125 LR basic slag and T7=0.062 LR basic slag [1 Lime Requirement (LR) =13.4 MT CaCO₃/ha]. The gross plot size was 6.7 x 6.7 m. Liming materials were applied in two equal split doses in June and September. Farm Yard Manure (FYM) at 10 MT/ha/yr

in a single dose and NPK at 150:50:50 kg/ha/yr with N in two equal split doses were applied in July and September, the approximate composition of FYM being N=0.3-0.5 %, P=0.2-0.4 % and K=0.3-0.6 %. The plantation was raised in June, 2003 and was left for establishment until June, 2004. One bottom pruning in June and a half height pruning in December were performed every year. The treatments were imposed in 2004-05 and 2006-07 and in 2005-06, the residual effect was studied. Data were recorded for three years from 2004-05 onwards. Analysis of variance of pooled data of seven treatments over four seasons, each in three years was done to find out significance of effect of these three factors and their interactions on leaf yield. The overall mean leaf yield for each treatment as well as that for individual seasons were compared with corresponding value of critical difference to find out season specific as well as overall treatment impact and to decide upon the best treatment.

RESULTS AND DISCUSSION

Analysis of variance data (Table 1) indicated highly significant differences ($P<0.01$) for the effect of year, season, treatment and their all possible interactions on leaf yield. Season-wise and overall mean yield of leaf for each treatment along with their respective values of critical difference is furnished in Table 2. The treatment T2 (0.125 LR calcitic lime stone powder) was found to record significantly higher leaf yield than all other treatments followed by T6 (0.125 LR basic slag) and T4 (0.125 LR paper mill sludge). On comparing the treatments in individual seasons, the same conclusion can be drawn in the case of September crop as well. In November, leaf yield of T2 and T6; and in March and June, that of T2, T4 and T6 were found significantly higher than other treatments.

Average annual leaf yield over three years (2004-05 to 2006-07) indicated that application of 0.125 LR (*i.e.*, 1670 kg/ha/yr of CaCO₃ equivalent) lime in two split doses in the form of calcitic lime stone powder recorded the significantly highest leaf yield of 12356.66 kg/ha/yr followed by basic slag (11876.42 kg/ha/yr) and paper mill sludge (11656.82 kg/ha/yr)

Effect of application of lime in soil on mulberry leaf yield

Table 1: Pooled Analysis of Variance for Leaf yield (kg/ha)

Source	DF	SS	MS	F	CD at 5 %	CD at 1 %
Replication	2	34596	-	-	-	-
Year (Y)	2	9749823	4874912	645.76**	26.47	34.93
Season (S)	3	353955125	117985042	15629.06**	30.56	40.34
Treatment (T)	6	20153436	3358906	444.94**	40.43	53.36
YxS	6	17229602	2871600	380.39**	52.94	69.87
YxT	12	3808108	317342	42.04**	70.03	92.43
SxT	18	7539183	418843	55.48**	80.87	106.73
YxSxT	36	2699479	74986	9.93**	140.06	184.86
Error	166	1253147	7549	-	-	-
Total	251	416422500	-	-	-	-

Table 2: Mean leaf yield (kg/ha) for treatments

Treatment	Sept	Nov	March	June	Mean	Annual yield
T1 (Control)	3141.79	2708.93	1061.20	1688.30	2150.05	8600.22
T2 (0.125 LR CLSP)	4859.02	3948.68	1535.35	2013.61	3089.17	12356.66
T3 (0.062 LR CLSP)	4417.54	3505.99	1363.85	1921.54	2802.23	11208.92
T4 (0.125 LR PMS)	4530.64	3708.69	1457.97	1959.52	2914.20	11656.82
T5 (0.062 LR PMS)	4163.09	3459.71	1266.22	1908.38	2699.35	10797.40
T6 (0.125 LR BS)	4536.61	3925.16	1466.09	1948.56	2969.11	11876.42
T7 (0.062 LR BS)	4192.76	3471.12	1245.92	1807.60	2679.35	10717.40
Mean	4263.06	3532.61	1342.37	1892.50	-	-

Critical Difference

Source	Treatment	Season	TxS
CD at 5%	40.43	30.56	80.87
CD at 1%	53.36	40.34	106.73

CLSP = Calcitic lime stone powder; PMS = Paper mill sludge; BS = Basic slag

registering 43.68, 38.09 and 5.54 % increase in yield, respectively over no lime control (8600.22 kg/ha/yr) (Table 2). Increase in leaf yield of mulberry may be attributed to more uptake of nutrients with the use of organic manures and lime and consequent increase in soil pH to the desired level. It is reported that the

Table 3: Changes in soil pH value

Treatment	2004-05		2005-06 (Residual)		2006-07	
	Sept.'04	Mar.'05	Sept.'05	Mar.'06	Sept.'06	Mar.'07
T1 (Control)	5.5	5.4	5.5	5.4	5.4	5.3
T2 (0.125 LRCLSP)	7.3	5.6	5.8	5.6	7.2	5.5
T3 (0.062 LR CLSP)	6.2	5.5	5.8	5.6	6.1	5.5
T4 (0.125 LR PMS)	7.1	5.6	5.9	5.5	7.0	5.4
T5 (0.062 LR PMS)	6.1	5.5	5.7	5.5	6.0	5.4
T6 (0.125 LR BS)	6.9	5.5	5.6	5.5	6.8	5.5
T7 (0.062 LR BS)	5.9	5.4	5.6	5.5	6.0	5.4

maximum availability of all the major plant nutrients is in pH range of 6.5 – 7.5 (Subbaswamy *et al.*, 1994). This corroborates the findings of Panda and Das (1971) in the case of maize, Rao and Mittra (1991) on pigeon pea and groundnut, Patiram (1991a,b) and Singh *et al.* (1995) on soybean.

As regards the changes in pH at 90 days of liming, it increased up to the desired level with 0.125 LR lime application in both the years, 2004-05 and 2006-07 but came down to the acidic level in March. During 2005-06, lime was not applied to study the residual effect. Though active pH (*i.e.*, determined through pH meter water extract) showed diminished value during residual year when no liming materials were applied, there was increase in leaf yield *vis-à-vis* control. This may be due to clay-crystal bound exchangeable calcium effect from clay-colloids. The clay-colloids still saturated with calcium might have provided calcium as secondary nutrients to the roots of plants, though not reflected in pH value. From the above results (Table 3), it may be inferred that 0.125 LR (*i.e.*, 1670 kg/ha/yr of CaCO₃ equivalent) is to be applied every year since pH of the soil comes down to acidic level by March.

Economics calculated on the basis of cost of lime, transportation, FYM, fertilizers, disease free layings (dfls), rearing and sale price of cocoons prevalent during the period of investigation revealed that the net income with basic slag, paper mill sludge and calcitic lime stone powder were \$ 637.335, \$ 621.572 and \$ 554 465, respectively *vis-à-vis* control (\$ 389.658) from one hectare rain fed mulberry with benefit-cost ratio of 2.41:1, 2.42:1 and 1.97:1 (Table 4). The additional income due to application of basic slag, paper mill sludge and calcitic lime stone powder were \$ 247.677, \$ 231.914 and \$ 164.807. Hence, it is recommended to use any of these three liming materials at 0.125 LR (1670 kg/ha/yr of CaCO₃ equivalent) every year by the sericultural farmers of eastern ghat highland zone of Odisha having acidic soils, depending on their availability in the particular locality.

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Table 4: Economics of liming with three different materials for one hectare of rainfed mulberry

Treatment	Leaf yield (kg/ha/yr)	Disease free layings brushed (No.)	Cocoon yield (kg)	Cost of liming materials/ Transportation (\$)	Cost of FYM+ Fertilizers (\$)	Rearing & Miscellaneous cost (\$)	Total cost of production of cocoons (\$)	Gross income (\$)	Net income (column 9-8) (\$)	Additional income (\$)
1	2	3	4	5	6	7	8	9	10	11
Control	8600	482 m x bi 313 bi x bi	192.8 187.8	-	115.467	271.731	387.198	776.856	389.658	-
0.125 LR CLSP	12356	686 m x bi 456 bi x bi	274.4 273.6	146.150	115.467	306.834	568.451	1122.916	554.465	164.807
0.125 LR PMS	11656	648 m x bi 430 bi x bi	259.2 258.0	50.114	115.467	272.346	437.927	1059.499	621.572	231.914
0.125 LR BS	11876	647 m x bi 449 bi x bi	258.8 269.4	68.337	115.467	268.975	452.779	1090.114	637.335	247.677

LR= Lime Requirement; CLSP= Calcitic lime stone powder; PMS=Paper mill sludge; BS = Basic slag; m x bi = multivoltine x bivoltine; bi x bi = bivoltine x bivoltine. Paper mill sludge and basic slag were available free of cost, but the transportation cost was paid.

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Research Paper

ROLE OF BACTERIA (*STREPTOCOCCUS FAECALIS* & *STAPHYLOCOCCUS AUREUS*), VIRUSES AND THEIR COMBINED INFECTION IN CAUSATION OF FLACHERIE UNDER DIFFERENT ENVIRONMENTAL CONDITIONS

T. Selvakumar¹ and R. K. Datta

Central Sericultural Research and Training Institute, Mysore - 570 008, India.

¹Silkworm Seed Production Centre, National Silkworm Seed Organization, Central Silk Board,

K. R. Nagar - 571 602, India.

E-mail: tselvakumar_csb@rediffmail.com

ABSTRACT

Flacherie is a complicated disease in silkworm caused either by different types of bacteria or viruses or due to their mixed infection. These pathogens prevail in the infected silkworm and rearing environment during all the seasons. In the present study, bacteria viz., *Streptococcus faecalis* and *Staphylococcus aureus*, viruses viz., *Bombyx mori* Infectious Flacherie Virus (BmIFV), *Bombyx mori* Densonucleosis Virus I (BmDNV1) and *Bombyx mori* Nuclear Polyhedrosis Virus (BmNPV) isolated from infected silkworms were tested for their pathogenicity individually and in combination in silkworm under different environmental conditions such as optimum temperature and humidity (T1), constant high temperature and low humidity (T2) and fluctuating temperature and humidity (T3) conditions maintained for 12 h daily. It was observed that the combined infection of bacteria (*S. faecalis* and *S. aureus*) and viruses (BmIFV and BmDNV1) cause high level of mortality under fluctuating temperature and humidity conditions (T3: 33.67 – 79.33 %) than high temperature and low humidity (T2: 5.33 – 26.67 %) and optimum temperature and humidity (T1: 0.67 – 4.00 %) conditions and also significantly higher than single infection of bacteria (T3: 27.67-35.67 %; T2: 5.67-6.67 %; T1: 0.33 %) or viruses (0.00 %). But in the case of combined infection of *S. faecalis* / *S. aureus* with BmNPV, there was no remarkable increase in the larval mortality when compared to individual infection by BmNPV alone. The total mortality caused by the individual infection of BmNPV was 10.33 – 55.67 % under different concentrations and along with *S. faecalis* / *S. aureus*, it caused the same trend of mortality (9.00 – 56.33 %). Hence, the mortality recorded under the combined infection of *S. faecalis* / *S. aureus* with BmNPV was prominently due to BmNPV alone under all the environmental conditions tested with no synergism observed in this case.

Key words: Environmental conditions, flacherie, combined infection, *S. aureus*, *S. faecalis*, viruses.

INTRODUCTION

Flacherie disease, characterized by flaccid condition, is generally called as digestive disorders and septicemia in silkworm. There are several studies attributing flacherie disease in silkworm to bacterial infection. The *Streptococcus* sp. (Nakasuji *et al.*, 1970), *Micrococcus* sp. (Nakasuji and Kodama, 1970), *Staphylococcus* sp. (Nakasuji and Kodama, 1970), *Bacillus thuringiensis* (Angus, 1967; Selvakumar *et al.*, 1999) and *Serratia marcescens* (Sam Devadas, 1991)

have been reported to cause flacherie disease in silkworm. The flacherie caused by viruses viz., *Bombyx mori* Infectious Flacherie Virus (BmIFV) (Shimizu, 1975), *Bombyx mori* Densonucleosis Virus (BmDNV) (Abe *et al.*, 1990; Iwashita *et al.*, 1994) and mixed infection of viruses viz., BmIFV and BmDNV (Abe and Watanabe, 1987) have also been reported in silkworm. There are a few reports on the possible synergistic association of bacteria and viruses in causing flacherie under laboratory conditions (Matsumoto *et al.*, 1985; Sivaprasad *et al.*, 2000; Selvakumar *et al.*, 2009).

Under different physiological stress conditions, the multiplication rate of microbes causing flacherie increases thereby enhancing the development of the disease. There are reports on influence of temperature on the development of flacherie (Inoue, 1972). Adverse environmental conditions such as high temperature and humidity (Miyajima, 1978), polluted air (Kanke *et al.*, 1987) and starvation (Samson *et al.*, 1981) are considered important predisposing factors for incidence of flacherie and cocoon crop loss. Temperature higher or lower than 25°C acts as a stress factor and increases the susceptibility of silkworm to viral infections (Steinhaus, 1958). Venugopala Pillai and Krishnaswamy (1980) could relate the increased susceptibility of silkworm larvae to viral infections to extremes of temperature and relative humidity.

In the present study, the observations on the role of environmental factors on flacherie disease development by the individual and combined infection of pathogenic bacteria and viruses, isolated from flacherie infected silkworms are presented and the results discussed.

MATERIALS AND METHODS

Influence of environmental factors on infection of individual pathogen

The silkworm larvae were reared till the beginning of second instar following the standard method. To study the influence of environmental factors on individual pathogen's infection, the bacteria such as *Streptococcus faecalis*, *Staphylococcus aureus*, viruses such as BmIFV, BmDNV1 and *Bombyx mori* Nuclear Polyhedrosis Virus (BmNPV) which were isolated from flacherie diseased silkworm were utilized as the inoculum. Different groups of 100 larvae each were inoculated *per os* individually with specific inoculum of specific pathogens. Concentration that caused the lowest mortality (1×10^7 cells/ml) was selected with respect to *S. faecalis* & *S. aureus* while for the viruses (BmIFV & BmDNV1) the infective concentrations (dilutions of inoculum) that caused IC_{10} (10^{-9} & 10^{-7}), IC_{30} (10^{-8} & 10^{-6}) & IC_{50} (10^{-7} & 10^{-5}), respectively were selected (Selvakumar, 2003). In the case of BmNPV, LC_{10}

(1×10^3), LC_{30} (1×10^4), & LC_{50} (1×10^5) doses were selected.

Influence of environmental factors on combined infection of pathogens

Under combined infection, different groups of silkworm larvae were inoculated with specific bacteria (*S. faecalis* / *S. aureus*) / virus (BmIFV / BmDNV1 / BmNPV) on 1st day of second instar and after 24 h, second time inoculation with specific bacteria / virus was done. However, the concentration of pathogen in the inoculum was determined based on the level of pathogenicity caused by the individual pathogen. The concentration that caused the lowest mortality (1×10^7 cells/ml) was selected with respect to *S. faecalis* and *S. aureus*, while for the viruses (BmIFV & BmDNV1) the infective concentrations that caused IC_{10} , IC_{30} and IC_{50} were selected. LC_{10} , LC_{30} and LC_{50} doses were selected in the case of BmNPV. The inoculum and their concentrations utilized are furnished in Table 1.

Treatments

Each silkworm group inoculated with specific concentration of specific bacteria, virus or both was subjected to the experimental treatments immediately after inoculation. To study the effect of treatment on the combined infection, first inoculation with specific concentration of bacteria or virus was followed by second inoculation with virus or bacteria after 24 h. The treatment involved the rearing of silkworm for 15 days PI (post inoculation) under different environmental conditions as treatments *viz.* T1, T2 and T3 (T1: $25 \pm 1^\circ\text{C}$ and $75 \pm 5\%$ RH (optimum temperature & humidity); T2: $28 \pm 1^\circ\text{C}$ and $60 \pm 5\%$ RH (high temperature & low humidity); T3: 25 & $28 \pm 1^\circ\text{C}$ and 75 & $60 \pm 5\%$ (fluctuating temperature and humidity for 12 h / day)). The required environmental conditions were maintained using thermostatic controlled heater and humidistat controlled humidifier. It was also recorded by electronic Thermo Hygrograph (Nihonkeiryoki Kogyo Co., Ltd., Japan).

Each treatment had three replications of 100 larvae each. Normal control group without any inoculation of

Table 1: Pathogens and their inoculum concentrations (cells/ml or dosages)

Pathogen		Concentration		
<i>S. faecalis</i>		1×10^7 cells/ml		
<i>S. aureus</i>		1×10^7 cells/ml		
BmIFV		IC ₁₀ ;	IC ₃₀ ;	IC ₅₀ dosages
BmDNV1		IC ₁₀ ;	IC ₃₀ ;	IC ₅₀ dosages
BmNPV		LC ₁₀ ;	LC ₃₀ ;	LC ₅₀ dosages
1st day	2nd day			
<i>S. faecalis</i>	BmIFV	1×10^7 & IC ₁₀ ;	1×10^7 & IC ₃₀ ;	1×10^7 & IC ₅₀
BmIFV	<i>S. faecalis</i>	IC ₁₀ & 1×10^7 ;	IC ₃₀ & 1×10^7 ;	IC ₅₀ & 1×10^7
<i>S. faecalis</i>	BmDNV1	1×10^7 & IC ₁₀ ;	1×10^7 & IC ₃₀ ;	1×10^7 & IC ₅₀
BmDNV1	<i>S. faecalis</i>	IC ₁₀ & 1×10^7 ;	IC ₃₀ & 1×10^7 ;	IC ₅₀ & 1×10^7
<i>S. faecalis</i>	BmNPV	1×10^7 & LC ₁₀ ;	1×10^7 & LC ₃₀ ;	1×10^7 & LC ₅₀
BmNPV	<i>S. faecalis</i>	LC ₁₀ & 1×10^7 ;	LC ₃₀ & 1×10^7 ;	LC ₅₀ & 1×10^7
<i>S. aureus</i>	BmIFV	1×10^7 & IC ₁₀ ;	1×10^7 & IC ₃₀ ;	1×10^7 & IC ₅₀
BmIFV	<i>S. aureus</i>	IC ₁₀ & 1×10^7 ;	IC ₃₀ & 1×10^7 ;	IC ₅₀ & 1×10^7
<i>S. aureus</i>	BmDNV1	1×10^7 & IC ₁₀ ;	1×10^7 & IC ₃₀ ;	1×10^7 & IC ₅₀
BmDNV1	<i>S. aureus</i>	IC ₁₀ & 1×10^7 ;	IC ₃₀ & 1×10^7 ;	IC ₅₀ & 1×10^7
<i>S. aureus</i>	BmNPV	1×10^7 & LC ₁₀ ;	1×10^7 & LC ₃₀ ;	1×10^7 & LC ₅₀
BmNPV	<i>S. aureus</i>	LC ₁₀ & 1×10^7 ;	LC ₃₀ & 1×10^7 ;	LC ₅₀ & 1×10^7

pathogens was maintained separately. The larvae under each treatment and control group were observed for a period of 15 days for disease development and the mortality due to respective pathogens (*S. faecalis*, *S. aureus* and BmNPV) was recorded after ascertaining through Koch's postulates. In the case of BmIFV and BmDNV1, the midgut homogenate of respective dead silkworm larvae were subjected to textile dye-based dipstick immunoassay for detection of BmIFV (Nataraju and Datta, 1999) and agar gel immunodiffusion test for detection of BmDNV1 (Nataraju *et al.*, 1996). The data were compiled, analyzed (Scheffler, 1980) and discussed.

RESULTS

Influence of environmental factors on infection of individual pathogen

Bacteria (*S. faecalis* & *S. aureus*)

The fluctuating temperature and humidity conditions (T3) had a remarkable impact on the growth of individual pathogens viz., *S. faecalis* and *S. aureus* as evidenced by the mortality of larvae (34.33~35.67 % and 25.00~27.67 %, respectively). There was not much adverse impact due to conditions of optimum temperature

and humidity (T1: 0.33 - 0.67 % & 0.33 - 0.67 %) and constant high temperature of 28 °C and low humidity (T2: 6.33 - 8.33 % & 5.67 - 8.00 %). However, the negative influence of high temperature and low humidity (T2) was higher than optimum (T1) environmental conditions (Tables 2 & 3).

Viruses (BmIFV, BmDNV1 & BmNPV)

The viruses, BmIFV and BmDNV1 did not cause mortality at IC₁₀, IC₃₀ & IC₅₀ concentrations though infections were observed and confirmed. In the case of BmNPV, under LC₁₀, LC₃₀ & LC₅₀ concentrations, it caused the mortality of 15.67 ~ 16.67 %, 35.00 ~ 36.33 % and 55.00 ~ 55.67 %, respectively at the fluctuating temperature & humidity (T3) conditions (Tables 2 & 3). Under optimum temperature and humidity conditions (T1), it was 10.33 %, 28.67 ~ 30.00 % and 49.67 %, respectively. Under high temperature and low humidity conditions (T2), the mortality rate was 10.33 ~ 11.67%, 30.33 – 33.00 % and 50.33 – 50.67 %, respectively (Tables 2 & 3).

However, the % mortality was high under T3 conditions compared to T1 and T2. It was observed

Table 2: Per cent mortality due to *S. faecalis*, BmIFV, BmDNV1 and BmNPV and by their mixed infections in silkworm *B. mori* under differential environmental conditions

Treatment		% mortality under different environmental conditions		
		25 °C with 75 ± 5 % RH (T1)	28 °C with 60 ± 5 % RH (T2)	25 & 28 °C with 75 & 60 ± 5 % RH (T3)
1st day <i>S. faecalis</i> & 2nd day BmIFV		<i>S. faecalis</i> and BmIFV		
	$1 \times 10^7 + IC_{10}$	01.33 (07.42)	08.33 (17.25)	48.00 (44.14)
	$1 \times 10^7 + IC_{30}$	03.33 (11.20)	16.33 (24.21)	58.67 (50.29)
	$1 \times 10^7 + IC_{50}$	03.67 (11.76)	19.00 (26.20)	77.00 (61.70)
1st day BmIFV & 2nd day <i>S. faecalis</i>				
	$IC_{10} + 1 \times 10^7$	01.33 (07.29)	05.67 (14.30)	43.67 (41.65)
	$IC_{30} + 1 \times 10^7$	02.67 (10.15)	10.33 (19.19)	50.33 (45.48)
	$IC_{50} + 1 \times 10^7$	02.67 (10.22)	16.33 (24.21)	72.33 (58.59)
<i>S. faecalis</i>	1×10^7	00.33 (05.05)	06.33 (15.10)	34.33 (36.17)
BmIFV	IC_{10}	00.00 (04.06)	00.00 (04.06)	00.00 (04.06)
	IC_{30}	00.00 (04.06)	00.00 (04.06)	00.00 (04.06)
	IC_{50}	00.00 (04.06)	00.00 (04.06)	00.00 (04.06)
1st day <i>S. faecalis</i> & 2nd day BmDNV1		<i>S. faecalis</i> and BmDNV1		
	$1 \times 10^7 + IC_{10}$	01.33 (07.52)	09.67 (18.56)	49.33 (44.90)
	$1 \times 10^7 + IC_{30}$	03.33 (11.15)	19.33 (26.44)	58.67 (50.29)
	$1 \times 10^7 + IC_{50}$	04.00 (12.20)	26.67 (31.41)	79.33 (63.36)
1st day BmDNV1 & 2nd day <i>S. faecalis</i>				
	$IC_{10} + 1 \times 10^7$	01.67 (07.98)	08.33 (17.21)	45.33 (42.61)
	$IC_{30} + 1 \times 10^7$	03.67 (11.64)	15.33 (23.43)	55.33 (48.35)
	$IC_{50} + 1 \times 10^7$	03.67 (11.76)	21.67 (28.07)	76.67 (61.47)
<i>S. faecalis</i>	1×10^7	00.33 (05.05)	06.67 (15.50)	35.67 (36.76)
BmDNV1	IC_{10}	00.00 (04.06)	00.00 (04.06)	00.00 (04.06)
	IC_{30}	00.00 (04.06)	00.00 (04.06)	00.00 (04.06)
	IC_{50}	00.00 (04.06)	00.00 (04.06)	00.00 (04.06)
1st day <i>S. faecalis</i> & 2nd day BmNPV		<i>S. faecalis</i> and BmNPV		
	$1 \times 10^7 + LC_{10}$	13.00 (21.38)	15.67 (23.65)	17.67 (25.22)
	$1 \times 10^7 + LC_{30}$	31.33 (34.33)	33.00 (35.36)	36.33 (37.37)
	$1 \times 10^7 + LC_{50}$	50.00 (45.29)	51.67 (46.24)	56.33 (48.93)
1st day BmNPV & 2nd day <i>S. faecalis</i>				
	$LC_{10} + 1 \times 10^7$	09.00 (17.91)	16.00 (23.92)	18.00 (25.43)
	$LC_{30} + 1 \times 10^7$	28.67 (32.67)	31.33 (34.31)	34.33 (36.14)
	$LC_{50} + 1 \times 10^7$	48.33 (44.33)	51.67 (46.25)	53.67 (47.40)
<i>S. faecalis</i>	1×10^7	00.67 (05.74)	08.33 (17.21)	35.00 (36.56)
BmNPV	LC_{10}	10.33 (19.16)	11.67 (20.28)	16.67 (24.44)
	LC_{30}	30.00 (33.51)	33.00 (35.35)	36.33 (37.35)
	LC_{50}	49.67 (45.10)	50.67 (45.67)	55.67 (48.55)
F Test			S.E.	C.D. (5 %)
Pathogens (with different viruses)		**	0.180	0.498
Between environment		**	0.180	0.498
Between treatment		**	0.328	0.909
Pathogen × Environment		**	0.311	0.863
Pathogen × Treatment		**	0.568	1.575
Environment × Treatment		**	0.568	1.575
Pathogen × Environment × Treatment		**	0.984	2.728

Values in the parentheses indicate angular transformed values ($X + 0.5$); **: Significant at 1% .

Table 3: Per cent mortality due to *S. aureus*, BmIFV, BmDNV1 and BmNPV and by their mixed infections in silkworm *B. mori* under differential environmental conditions

Treatment	% mortality under different environmental conditions		
	25 °C with 75 ± 5 % RH (T1)	28 °C with 60 ± 5 % RH (T2)	25 & 28 °C with 75 & 60 ± 5 % RH (T3)
1st day <i>S. aureus</i> & 2nd day BmIFV		<i>S. aureus</i> and BmIFV	
1 × 10 ⁷ + IC ₁₀	00.67 (05.74)	07.33 (16.21)	41.67 (40.49)
1 × 10 ⁷ + IC ₃₀	02.67 (10.15)	14.00 (22.33)	49.67 (45.10)
1 × 10 ⁷ + IC ₅₀	03.67 (11.76)	18.67 (25.94)	66.00 (54.64)
1st day BmIFV & 2nd day <i>S. aureus</i>			
IC ₁₀ + 1 × 10 ⁷	00.67 (05.74)	05.33 (13.90)	33.67 (35.76)
IC ₃₀ + 1 × 10 ⁷	01.67 (07.98)	11.00 (19.75)	46.33 (43.18)
IC ₅₀ + 1 × 10 ⁷	02.67 (10.15)	12.33 (20.97)	60.33 (51.26)
<i>S. aureus</i>			
1 × 10 ⁷	00.67 (05.74)	05.67 (14.28)	27.00 (31.61)
BmIFV			
IC ₁₀	00.00 (04.06)	00.00 (04.06)	00.00 (04.06)
IC ₃₀	00.00 (04.06)	00.00 (04.06)	00.00 (04.06)
IC ₅₀	00.00 (04.06)	00.00 (04.06)	00.00 (04.06)
1st day <i>S. aureus</i> & 2nd day BmDNV1		<i>S. aureus</i> and BmDNV1	
1 × 10 ⁷ + IC ₁₀	01.00 (06.73)	09.67 (18.54)	45.00 (42.42)
1 × 10 ⁷ + IC ₃₀	03.67 (11.76)	17.33 (24.97)	52.33 (46.63)
1 × 10 ⁷ + IC ₅₀	03.67 (11.76)	23.33 (29.21)	66.67 (55.04)
1st day BmDNV1 & 2nd day <i>S. aureus</i>			
IC ₁₀ + 1 × 10 ⁷	01.33 (07.42)	07.67 (16.56)	40.00 (39.48)
IC ₃₀ + 1 × 10 ⁷	03.00 (10.71)	13.67 (22.09)	43.67 (41.65)
IC ₅₀ + 1 × 10 ⁷	03.33 (11.20)	17.33 (24.97)	66.00 (54.64)
<i>S. aureus</i>			
1 × 10 ⁷	00.33 (05.05)	05.67 (14.30)	27.67 (32.05)
BmDNV1			
IC ₁₀	00.00 (04.06)	00.00 (04.06)	00.00 (04.06)
IC ₃₀	00.00 (04.06)	00.00 (04.06)	00.00 (04.06)
IC ₅₀	00.00 (04.06)	00.00 (04.06)	00.00 (04.06)
1st day <i>S. aureus</i> & 2nd day BmNPV		<i>S. aureus</i> and BmNPV	
1 × 10 ⁷ + LC ₁₀	11.67 (20.39)	12.67 (21.25)	15.33 (23.41)
1 × 10 ⁷ + LC ₃₀	28.67 (32.67)	30.67 (33.93)	36.00 (37.16)
1 × 10 ⁷ + LC ₅₀	47.67 (43.95)	49.67 (45.10)	55.67 (48.54)
1st day BmNPV & 2nd day <i>S. aureus</i>			
LC ₁₀ + 1 × 10 ⁷	09.33 (17.96)	09.67 (18.54)	13.33 (21.70)
LC ₃₀ + 1 × 10 ⁷	28.67 (32.68)	30.67 (33.93)	34.67 (36.36)
LC ₅₀ + 1 × 10 ⁷	49.67 (45.10)	50.00 (45.29)	53.67 (47.39)
<i>S. aureus</i>			
1 × 10 ⁷	00.67 (05.74)	08.00 (16.88)	25.00 (30.31)
BmNPV			
LC ₁₀	10.33 (19.14)	10.33 (19.16)	15.67 (23.69)
LC ₃₀	28.67 (32.67)	30.33 (33.72)	35.00 (36.56)
LC ₅₀	49.67 (45.10)	50.33 (45.48)	55.00 (48.16)
F Test		S.E.	C.D. (5 %)
Pathogens (with different viruses)		** 0.192	0.532
Between environment		** 0.192	0.532
Between treatment		** 0.350	0.971
Pathogen × Environment		** 0.332	0.922
Pathogen × Treatment		** 0.607	1.682
Environment × Treatment		** 0.607	1.682
Pathogen × Environment × Treatment		** 1.051	2.914

Values in the parentheses indicate angular transformed values (X + 0.5); ** : Significant at 1%.

that the fluctuating temperature and humidity (T3) and high temperature (28°C) and low humidity of 60 ± 5 % conditions have more influence on the disease development.

Influence of environmental factors on combined infection of pathogens

Combined infection of *S. faecalis* with BmIFV / BmDNV1 / BmNPV

The different environmental conditions viz., T1, T2 and T3 influenced the combined infection of *S. faecalis* with BmIFV / BmDNV1 and *vice versa* resulting in higher level of mortality [1.33 - 4.00 % (T1), 5.67 - 26.67 % (T2) and 43.67 - 79.33 % (T3)] compared to individual infection by *S. faecalis* [0.33 - 0.67% (T1), 6.33 - 8.33 % (T2) and 34.33 - 35.67 % (T3)] or BmIFV / BmDNV1 (0.00 %).

The combined infection of *S. faecalis* with BmNPV, caused comparatively lower mortality than with BmIFV / BmDNV1. The results clearly showed that the different environmental conditions viz., T1, T2 and T3 do not influence the combined infection of *S. faecalis* along with BmNPV and *vice versa* resulting in same level of mortality under all the tested environments [9.00 - 50.00 % (T1), 15.67 - 51.67 % (T2) and 17.67 - 56.33 % (T3)] under different concentrations as like in individual infection of BmNPV [10.33 - 49.67 % (T1), 11.67 - 50.67 % (T2) and 16.67 - 55.67 % (T3)] (Table 1). But the per cent mortality was slightly high under fluctuating environment (T3) compared to high temperature (28°C) & low humidity of 60 ± 5 % (T2) and optimum temperature & humidity (T1) conditions (Table 2).

Combined infection of *S. aureus* with BmIFV / BmDNV1 / BmNPV

The different environmental conditions viz., T1, T2 and T3 influenced the combined infection of *S. aureus* with BmIFV / BmDNV1 and *vice versa* resulting in higher level of mortality under fluctuating temperature and humidity conditions (T3: 33.67 - 66.67 %) compared to T2 (5.33 - 23.33%) and T1 (0.67 - 3.67 %) environments and also individual infection by *S. aureus* [0.33 -

0.67 % (T1), 5.67 % (T2) and 27.00 - 27.67 % (T3)] or BmIFV / BmDNV1 (0.00 %) under all the environmental conditions (Table 3).

The combined infection of *S. aureus* and BmNPV caused comparatively lower mortality than with BmIFV / BmDNV1. The mortality ranges were 9.33 - 49.67 % under T1, 9.67 - 50.00 % under T2 and 13.33 - 55.67 % under T3 environmental conditions at different concentrations. Since the mortality rate was as like as in individual infection of BmNPV under different environmental conditions [10.33 - 49.67 % (T1), 10.33 - 50.33 % (T2) and 15.67 - 55.00% (T3)] (Table 2), it is believed as not much influenced by the combined infection. The per cent mortality was high for LC₅₀ and under fluctuating environment (T3) compared to LC₃₀ & LC₁₀ and high temperature with low humidity (T2) and optimum temperature & humidity (T1) conditions (Table 3).

DISCUSSION

The silkworm pathogens viz., *S. faecalis*, *S. aureus*, BmIFV, BmDNV1 and BmNPV cause diseases individually and in combination under all the environmental conditions. The results indicate that the infectivity of *S. faecalis*, *S. aureus* and BmNPV varies with environmental factors. The infectivity of individual pathogen viz., *S. faecalis*, *S. aureus*, BmIFV and BmDNV1 (0.00-35.67 %) as well as combined infection (*S. faecalis* / *S. aureus* with BmIFV / BmDNV1) was comparatively higher at fluctuating temperature and humidity (T3: 33.67 - 77.00 %) than high temperature & low humidity (T2: 5.33 - 26.67 %) and optimum temperature & humidity (T1: 0.67 - 4.00 %) conditions. Selvakumar *et al.* (1995) and Sivaprasad *et al.* (2000) stated low level pathogenicity of *S. faecalis* and *S. aureus* under optimum temperature and humidity conditions and increased pathogenicity under fluctuating temperature and humidity conditions. The mortality was also comparatively higher at constant high temperature and low humidity (T2) than at optimum temperature and humidity (T1) conditions. The impact of environmental factors viz., temperature and humidity (T1, T2 and T3) on the individual infection of BmIFV and BmDNV1

though observed, was not as significant as the other pathogens.

In the case of combined infection under the fluctuating temperature and humidity (T3) conditions, the mortality caused is almost twice (33.67 – 79.33 %) as that of individual infection (0.00–35.67 %) by bacteria under similar conditions due to their synergistic association. The viruses, BmIFV and BmDNV1 at their infective concentrations did not cause mortality during the observation period of 15 days post inoculation. Govindan *et al.* (1990) reported simultaneous *per os* infection in fourth instar larvae of silkworm with kenchu virus (BmDNV2) and *S. aureus* which resulted in high mortality as well as deterioration in the quantitative traits of cocoon as compared to the infection with kenchu virus or bacterium alone. Sivaprasad *et al.* (2000) reported that *Streptococcus* and *Staphylococcus* sp. caused the mortality of 44.67 and 9.83 %, respectively and along with BmIFV, the mortality was increased and ranged from 50.00 - 84.67 % and 44.66 - 65.66 %, respectively. Selvakumar *et al.* (2009) had also reported that *Streptococcus* sp. along with BmDNV1 also cause high mortality than that due to individual pathogens.

Among the combined infections, the influence of fluctuating temperature and humidity (T3) was comparatively high with the combination involving *S. faecalis* / *S. aureus* and BmIFV. Among the bacteria, it was high with *S. faecalis* compared to *S. aureus*. The influence of fluctuating temperature and humidity (T3) was less in combination involving *S. aureus* and BmDNV1. It may be possible as reported by the other workers that high temperature may weaken the larvae resulting in their high susceptibility (Venugopala Pillai and Krishnaswamy, 1980). Vijaya Kumari *et al.* (2001) reported that minimum incidence of flacherie (0.00 - 3.31 %) was observed under the optimum temperature of 25 °C & humidity of 70 ± 5 % whereas high incidences of 19.70 & 31.80 % were reported under high temperature of 30 °C & 80 ± 5 % RH and 35 °C & 50 ± 5 % RH, respectively.

But the case of combined infection of *S. faecalis* / *S. aureus* with BmNPV proved different. The combined

infection of these pathogens did not show any remarkable increase in the larval mortality when compared to individual infection by BmNPV. The total mortality caused by the individual infection of BmNPV was 10.33 – 55.67 % under different concentrations and along with *S. faecalis* / *S. aureus* it was 9.00 – 56.33 % indicating that the total mortality was not due to the combination and synergistic association of these pathogens. But from very few flacherie diseased silkworm larvae, BmNPV was also isolated along with other pathogens. There are no reports about the combined infection of *S. faecalis* / *S. aureus* with BmNPV and *vice versa* in silkworm. The mortality caused by the combined infection of *S. faecalis* / *S. aureus* with BmNPV was similar to the individual infection of BmNPV under all the environmental conditions tested. Chishti and Schaf (1990) reported that silkworm reared under controlled environmental conditions developed low level of mortality (0.5 - 3.0 %) due to nuclear polyhedrosis, compared to rearing under un-controlled temperature and humidity which result in high level of mortality (25.00 - 32.00 %). They also reported that the higher incidence of grasserie during summer might be due to fluctuation in temperature and humidity.

It is concluded that the combined infection of bacteria (*S. faecalis* / *S. aureus*) and viruses (BmIFV / BmDNV1) along with fluctuating temperature and humidity conditions play an important role in enhancing the incidence of flacherie disease compared to normal room temperature and humidity conditions. But in the combined infection of *S. faecalis* / *S. aureus* along with BmNPV, these fluctuating temperature and humidity do not increase the mortality as like in other combinations and the mortality rate is as like as in the individual infection of BmNPV. Hence, it is suggested to control the silkworm diseases in commercial silkworm rearing by maintaining the required temperature and humidity during both young age and old age rearing along with elimination of silkworm pathogens before silkworm rearing by proper disinfection. It is also suggested to dust proper bed disinfectants on the silkworm and rearing beds to prevent secondary contamination and spread of silkworm diseases during rearing.

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Research Paper

PRODUCTION OF COMPOST FROM MULBERRY SHOOTS USING LIGNO-CELLULOLYTIC FUNGI AND ITS IMPACT ON GROWTH AND YIELD OF MULBERRY

V. Nishitha Naik, P. M. Pratheesh Kumar, D. D. Sharma, B. R. Dayakar Yadav and S. M. H. Qadri

Central Sericultural Research and Training Institute, Srirampura, Mysore - 570 008, India.

E-mail: nishi_naik2002@yahoo.co.in

ABSTRACT

Huge quantity of mulberry shoot is often left over as waste after silkworm rearing especially with the introduction of shoot rearing practice. These shoots take 10-12 months for decomposition under natural condition as it contains high amount of cellulose, lignin and hemicellulose. Therefore, disposal of this discarded hard shoots within the shortest period of time is essential to overcome amassing of mulberry shoot. In view of this, two species of fungi viz., *Pleurotus florida* and *P. ostreatus* possessing ligno-cellulolytic enzyme activity were assessed for their efficacy to decompose the left over shoots. The study unveiled, significant difference ($P < 0.01$) in decomposition rate of mulberry shoot by *P. florida* compared with control and *P. ostreatus*. The decomposition rate due to *P. florida* was even up to 92.28 % within a span of 150 days. Physical, chemical and biological properties of the compost prepared thereby were as following: pH: 7.2-7.9; EC: < 1.0 ; OC: 1.61-3.06 %; N: 0.30 - 0.60 %; P: 0.15 - 0.40 %, K: 0.30 - 0.50 % and high amounts of micronutrients such as Mn (592 ppm), Cu (72.50 ppm) and Zn (75 ppm). Moreover, the matured compost was rich in beneficial microbes. Soil fertility status was improved after incorporation of this compost in the soil as evidenced by the significant ($P < 0.05$) impact on plant height, number of leaves and leaf yield. The study recommends *P. florida* for hastening of decomposition of mulberry shoot for production of value added compost.

Key words: Decomposition, ligno-cellulolytic activity, mulberry shoots, *Pleurotus florida*.

INTRODUCTION

With the introduction of shoot rearing practice, disposing of hard mulberry shoots left over after rearing has become a major concern. Disposal of this shoots by burning in the field not only results in loss of nutrients and organic matter but also leads to environmental pollution and health hazards. Hence, the better option is to convert it into organic manure so as to recycle and effectively utilize it in the mulberry field.

Recently, amendment with agro-industrial wastes such as sugar cane trash, coir pith, press mud and spent mushroom substrate in the soil has assumed great importance in crop production as these materials form rich source of plant nutrients after decomposition using lignolytic fungi (Padamadevi *et al.*, 2006; Kalita *et al.*,

2008; Dubey *et al.*, 2009). Fungi of *Pleurotus* spp. of Basidiomycetes are having lignolytic/ cellulolytic activity capable of degrading the woody substrate (Rajaratnam *et al.*, 1994; Geetha and Sivaprakasam, 1998; Singh, 1998; Subba Rao, 2000). Present study was conducted in order to explore the ligno-cellulolytic activity of these fungi to decompose hard mulberry shoot to quality compost and thereby to recycle the waste.

MATERIALS AND METHODS

Two fungi viz., *P. florida* and *P. ostreatus* obtained from the culture maintained at Plant Pathology Laboratory of the Institute were multiplied in Jowar in sterilised condition. These fungi were used alone and also in combination with lime, sugarcane molasses and single super phosphate so

as to facilitate weakening of the lignin structure, boost the initial activities of microbes and change the C: P ratio.

The treatments imposed were as following: T1 = *P. florida* (Pf), T2 = *P. ostreatus* (Po), T3 = Single super phosphate (SSP) + Pf, T4 = SSP + Po, T5 = Lime powder (LP) + Pf, T6 = LP + Po, T7 = Sugarcane molasses (SM) + Pf, T8 = SM + Po, T9 = SSP + LP + SM + Pf, T10 = SSP + LP + SM + Po and T0 = Mulberry shoots alone (MS) as control. For conversion of one tonne mulberry shoots into compost, 5 kg each of *P. florida*, lime powder and single super phosphate along with 1 kg sugarcane molasses and 50 kg cowdung slurry are required. Pits of 4 x 4 x 4 ft size made in leveled land in a shaded place were filled with mulberry shoots cut into 2 ft length and the treatment components layer by layer under anaerobic condition. The fresh weight of shoots put into each pit was recorded. Three replications were maintained against each treatment and control.

The pits were covered with gunny cloth and watered regularly to maintain 70 % moisture. The decomposing material was overturned every month till it decomposed completely. The maturity index of the decomposed material was calculated as:

$$\text{Maturity Index (\%)} = \frac{\text{Wt. of fresh shoot} - \text{Wt. of left over shoot}}{\text{Wt. of fresh shoot}} \times 100$$

After decomposition of the mulberry shoots, the composts were analyzed for physico-chemical (Jackson, 1973) and biological properties (Waksman, 1927). Further, the compost was applied to the mulberry garden (Variety V1) @ 2MT/acre and its impact on growth and yield parameters such as plant height, number of leaves and yield were recorded after 60 days.

RESULTS AND DISCUSSION

Significant differences ($P < 0.01$) in decomposition of mulberry shoots in various treatments were observed when compared with control (Table 1). *P. florida* alone and in combination with other components showed higher decomposition (>81.63 %) compared with *P. ostreatus* and its combinations (<72.33 %). The highest rate of decomposition (92.28 %) was recorded for T9 [*P. florida* (Pf) along with single super phosphate, lime powder and sugarcane molasses] within 150 days followed by T7 (*P. florida* and sugarcane molasses: 88.36 %), T5 (*P. florida* and lime powder: 86.58 %) and T3 (*P. florida* and single super phosphate: 85.58 %). However in control, the decomposition rate was the least (53.68 %).

Table 1: Efficacy of various treatments on decomposition of mulberry shoots

Treatment		Decomposition (%)			Mean (%)
		Rainy	Winter	Summer	
T0	MS alone	54.12	53.82	53.12	53.68
T1	MS + Pf	82.50	81.30	81.10	81.63
T2	MS + Po	62.41	61.20	61.08	61.56
T3	MS + SSP + Pf	85.14	86.36	85.26	85.58
T4	MS + SSP + Po	64.91	65.53	65.12	65.18
T5	MS + LP + Pf	87.12	86.50	86.13	86.58
T6	MS + LP + Po	67.32	65.96	66.00	66.42
T7	MS + SM + Pf	87.90	89.37	87.83	88.36
T8	MS + SM + Po	69.15	70.25	69.12	69.50
T9	MS + SSP + LP + SM + Pf	92.00	92.85	91.99	92.28
T10	MS + SSP + LP + SM + Po	71.51	73.36	72.12	72.33
Mean		74.91	75.13	74.44	
CD at 5 %					
Season		0.2			
Treatment		0.4			
S x T		NS			

MS = Mulberry shoots; Pf = *P. florida*; Po = *P. ostreatus*; SSP = Single Super Phosphate; LP = Lime powder; SM = Sugarcane molasses.

As far as the seasonal differences were considered, the decomposition activity was faster during winter (75.13 %) followed by rainy (74.91 %) and summer (74.44 %) seasons. During rainy season, maximum decomposition (92.0 %) was observed in treatment T9 within 150 days. The combinations with *P. ostreatus* have decomposed the mulberry shoot only up to 71.51 %, while *P. florida* and its combinations showed significantly better results (>82.50 %). During winter, maximum decomposition (92.85 %) was observed in the treatment T9 followed by *P. florida* and sugarcane molasses (89.37 %), *P. florida* and lime powder (86.50 %), as well as *P. florida* and single super phosphate (86.36 %). Here also, *P. florida* and its combinations were superior (75.13 %) to its counterparts. As in other seasons, T9 exhibited the maximum decomposition (91.99 %) in summer too followed by *P. florida* and sugarcane molasses (87.83 %), *P. florida* and lime powder (86.13 %) and *P. florida* and single super phosphate (85.26 %). Over all, the decomposition was found less in summer and none of the treatments showed higher decomposition rate in a particular season.

The overall results revealed that *P. florida* (Pf) along with single super phosphate (SSP), lime powder (LP) and sugarcane molasses (SM) (T9) is effective for decomposition of mulberry shoot up to 92.28 % within 150 days. *P. ostreatus* could facilitate decomposition of mulberry shoots only up to 72.33 %. Mulberry shoots left alone (control) decomposed only up to 53.68 %. Further, the compost generated was analyzed for physical, chemical and biological properties. The compost was odour less, dark brown with loose structure. It contained 25 per cent organic matter and 58 % moisture. Similarly, the chemical properties were recorded as pH: 7.2-7.9; Electrical conductivity: <1.0; Organic carbon: 1.61-3.06 %; N: 0.30 - 0.60 %; P: 0.15 - 0.40 % and K: 0.30 - 0.50 % and micronutrients, Magnesium (Mn): 592 ppm, Copper (Cu): 72.50 ppm and Zinc (Zn): 75 ppm. The matured compost contained beneficial fungi spp. viz., *Trichoderma*, *Penicillium*, *Aspergillus*, *Rhizopus* and *Chaetomium* (10^5 - 10^7); bacteria, *Bacillus subtilis* and *Pseudomonas* spp. (10^9 - 10^{10}) and actinomycetes, *Streptomyces* and *Nocardia* spp.

(10^4 - 10^6). No microbes pathogenic to mulberry were detected in the compost.

The fertility status was monitored after incorporation of compost in the soil (Table 2). Percentage of organic carbon increased from 0.97 to 3.01 %. Similarly, nitrogen increased from 0.18 to 0.24 %, phosphorus from 0.15 to 0.20 % and potash from 0.13 to 0.30 %. Regarding the microbial population (cfu/g soil), fungi increased from 0.99 to 150-160 ($\times 10^5$), bacteria from 1.05 to 170-180 ($\times 10^5$) and actinomycetes from 0.32 to 0.50-0.60 ($\times 10^5$).

Table 2: Soil fertility status before and after incorporation of compost

Property	Before	After
pH	7.34	7.51
EC (ds/cm)	0.74	0.47
OC (%)	0.97	3.01
Nitrogen (%)	0.18	0.24
Phosphorous (%)	0.15	0.20
Potash (%)	0.13	0.30
Fungi (cfu/g soil $\times 10^5$)	0.99	150-160
Bacteria (cfu/g soil $\times 10^5$)	1.05	170-180
Actinomycetes (cfu/g soil $\times 10^5$)	0.32	0.50-0.60

Besides, by the application of this compost, there was a significant improvement ($P < 0.05$) in growth and yield of mulberry (Table 3). Plant height was recorded the maximum (208 cm) in treatment T9 followed by T7 (200 cm) and T5 (195 cm). Yield also significantly ($P < 0.01$) increased in all the combinations of *P. florida* compared to control with maximum (364 g) in treatment T9 followed by T7 (360 g) and T5 (282 g). In the case of leaf yield, all the treatments were found to have significantly higher values than the control (170 g). Likewise, the highest number of leaves was observed in T9 (198.6) followed by T7 (189.8) and T5 (175.4). The above results indicate that the plant growth and yield parameters are enhanced due to application of compost irrespective of the treatments. Overall, it is observed that T9 was the most effective treatment in improving all the plant growth and yield parameters.

Large number of microorganisms are characterized with production of ligno-cellulolytic enzymes. Extra

Table 3: Effect of compost on plant growth parameters

Treatment		Plant height (cm)	Leaves (no.)	Leaf yield (g)
T0	MS	156 (±11.93)	110 (±18.90)	170 (±10.36)
T1	MS + Pf	185 (±21.67)	161.8** (±21.72)	261** (±3.53)
T2	MS + Po	167 (±18.18)	122.2 (±26.64)	190* (±18.37)
T3	MS + SSP + Pf	193 (±19.23)	166.0** (±15.25)	265** (±18.66)
T4	MS + SSP + Po	168 (±19.23)	125.4 (±18.98)	226* (±18.90)
T5	MS + LP + Pf	195* (±23.45)	75.4** (±14.19)	282** (±7.58)
T6	MS + LP + Po	185 (±28.72)	136.0* (±12.64)	227** (±9.35)
T7	MS + SM + Pf	200* (±29.70)	189.8** (±21.32)	360** (±6.51)
T8	MS + SM + Po	187 (±36.05)	141.2* (±7.85)	240** (±16.43)
T9	MS + SSP + LP + SM + Pf	208** (±23.45)	198.6** (±12.04)	364** (±10.83)
T10	MS + SSP + LP + SM + Po	193 (±20.73)	150.8** (±18.43)	242** (±19.23)
CD at P<0.01		47.66	36.7	27.67
CD at P<0.05		33.51	25.02	19.43

Figures in parentheses are Standard Deviation; * P<0.05; **P<0.01

MS – Mulberry shoots; Pf – *P. florida*; Po – *P. ostreatus*; SSP – Single Super Phosphate; LP – Lime powder; SM – Sugar molasses.

cellular lignin and manganese peroxidases produced by white rot fungi mediate decomposition process (Kirk and Farrell, 1987; Pal *et al.*, 1995). In the present study two lignocellulolytic fungi viz., *P. florida* and *P. ostreatus* were tested and *P. florida* was observed as effective in decomposing the mulberry shoot within 150 days. Studies by various workers in this line had already reported the cellulose and lignin degrading potential of *Pleurotus* sp. on sawdust and sugarcane bagasse (Geetha and Sivaprakasam, 1998; Singh, 1998) and biological efficiency of *P. citrinopileatus* for degradation of coir waste and paddy straw (Rajarathinam *et al.*, 1994). Periasamy and Natarajan (2004) reported a variation in lignin degradation and lignocellulolytic enzyme activity in relation to different substrates and fungal strains. In

the present study, the mulberry growth and yield parameters improved due to application of compost produced using *P. florida*. Similar results were reported by Padamadevi *et al.* (2006) in the context of improving the performance of economically important crops by compost produced through *Hypsizygus ulmarius* fungi using coir pith as substrate. The organic content, micronutrient content and microbial population were compared with that of farmyard manure. The improvement in growth and yield may be attributed to the presence of more organic content in the compost and enhanced micronutrients supplemented with the higher microbial population. Similar result on growth promoting ability of biocompost obtained from coir pith on seedlings of *Vigna radiata* was reported (Anand *et al.*, 2009).

The fungus, *P. florida* showed decomposing efficiency of hard mulberry shoot within 5 months which otherwise takes 10-12 months for decomposition. The compost obtained was found high in organic content, micro and macronutrients besides higher population of beneficial microbes. Further, application of the compost significantly improved growth and yield parameters of mulberry. Hence, *P. florida* can be used for hastening the decomposition process of mulberry shoot to generate value added compost with high nutrient value.

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Ms. Ishita Roy, assumes the charge of Secretary General, ISC



Ms. Ishita Roy, the Chief Executive Officer of Central Silk Board, Government of India took charge as the Secretary General of International Sericultural Commission on 01.01.2013. Ms. Roy was elected the Secretary General in the XXI Conference of ISC held at Cluj Napoca, Romania on 14th June 2012. Consequent upon her assuming the charge, the Headquarters of the ISC has also started functioning from Bangalore, India. She succeeds Mr. Christian FRESQUET who held the post for a brief period of one year in 2012. Ms. Roy has proposed a detailed Plan of Action for her three year term as the Secretary General. With this, the ISC is expected to play a greater role in supporting the Member Countries for improving productivity and quality of various silk commodities and at the same time initiate coordinated efforts to develop the sericulture industry in the potential areas of Asian, African and Latin American Countries.

XXII Conference of International Sericultural Commission at New Delhi

The XXII Conference of ISC was held at New Delhi on 23rd February 2013. The Conference is the Chief Governing council of ISC represented by up-to five delegates each from 13 member countries. Govt. representatives from non-member countries were also invited as observers. The Conference gave its consent to take forward the Plan of Action proposed by the new Secretary General that included taking up multi-institutional collaborative research programmes, training, Volunteer Expert Service Programme, Scholarship programme, sharing of genetic materials, collaboration with fashion industry etc. The Conference also approved the detailed proposal submitted by the Indian delegation for organizing the XXIII Congress of International Sericultural Commission scheduled to be held at Bangalore, India in December 2014.



New Headquarters for ISC

In line with its commitment made to the International Sericultural Commission and the Governments of the ISC Member Countries, Government of India has provided 3,000 square feet of Office space for setting up the Headquarter Office of ISC in the Office premises of Central Silk Board, Bangalore, India. The brand new office is equipped with all modern facilities and adequate space for preserving the books, indexed scientific articles, archives, and other historical documents brought from its Lyon office. The new



Office was virtually inaugurated on 23rd February 2013 by Ms. Zohra Chatterji, Secretary to Govt. of India, Ministry of Textiles in the presence of Mr. Pinak Ranjan Chakravorty, Secretary (ER), Ministry of External Affairs, Govt. of India in a function organized at Hotel Sheraton, Saket, New Delhi. In her brief address to the audience, which also included the delegates of the XXII Conference of ISC held on the same day and the Ambassadors of many countries, Ms. Chatterjee reiterated the commitment of Government of India to support the activities of ISC in India.

BACSA conference, "BISERICA" 2013 at Padua, Italy

The 5th BACSA International Conference with the theme "Building Value Chains in Sericulture" –



"BISERICA" 2013 was held in Padua, Italy from 7 to 12 April 2013. The Council of Research and Experiments in Agriculture, Apiculture and Sericulture Unit of Bologna, Padua seat, Italy co-hosted the Conference along with the Black, Caspian Seas and Central Asia Silk Association (BACSA). The Secretary General, ISC attended the Conference and addressed the gathering in a meeting held on 9th April 2013. In a brief address to the participants, the Secretary General emphasized the need for close collaboration between the countries from BACSA and ISC in the field of R&D in sericulture and frontier areas of research involving silkworm. The Secretary General also appealed to the Government representatives of BACSA countries to join ISC for taking part in the coordinated programmes of ISC aiming to expand sericulture practices among more countries to meet the increased global demand for silk.





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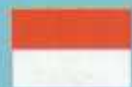
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International Sericultural Commission
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