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Tel: +91 80 26282191, 26680162, 26681663

Fax: +91 80 26681663

E-mail: sericologia@gmail.com

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E-mail: ramyareprographic@gmail.com

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DEVELOPMENT OF ROBUST BIVOLTINE BREEDS/HYBRIDS OF THE SILKWORM, *BOMBYX MORI* L. FOR TROPICS - A REVIEW

N. Suresh Kumar*, A. K. Saha and S. Nirmal Kumar

Central Sericultural Research and Training Institute, Berhampore -742101, India.

*E-mail: nairsuresh_in@yahoo.com

ABSTRACT

One of the important stresses noticed for bivoltine silkworm rearing in tropics is the high temperature environment. It is a well established fact that under tropical condition, unlike polyvoltines, bivoltine silkworms are more vulnerable to various stresses viz., hot climatic conditions, poor leaf quality and improper management during summer which are not conducive for bivoltine rearing. Hence, in a tropical country like India, it is very essential to develop bivoltine breeds/hybrids which can withstand the high temperature stress conditions. Many silkworm breeding centres in India have made concerted efforts in this line to evolve temperature tolerant bivoltine breeds/hybrids resulting in the development of compatible bivoltine hybrids suitable for rearing throughout the year. In this review, an attempt has been made to provide a consolidated account of the literature pertaining to the breeding work carried out in this direction over a period of many years.

Key words: *Bombyx mori*, robust bivoltine breeds/hybrids.

INTRODUCTION

The Indian sericulture industry is beset with many problems, the major one being the inability to produce quality silk of international grade. The bulk of silk produced in India is from multivoltines which is of inferior quality. It is a fact that more than 96 % of the silk produced comes from multi x multi or multi x bi hybrids. On the contrary, the Indian power loom sector is in need of bulk quantity of uniform quality silk suitable to these high-speed machines. At present, silk is imported to meet the skeletal demand of the power loom sector. Thus to save foreign exchange and also to achieve a quantum jump in export of silk fabrics and to create further diversification in silk fabrics to give higher returns to the farmers, the production of quality silk is necessary. The bivoltine cocoons which form basic raw material for raw silk are in general, superior with higher silk content. Besides, they possess longer filament, higher neatness, cleanness, less size deviation, low-boil-off loss ratio,

higher tensile strength and less variation in evenness. Hence, these cocoons form suitable raw material for the production of gradable raw silk as compared to multivoltine x bivoltine cocoons. Therefore, it is highly pertinent to have more productive bivoltine silkworm breeds capable of producing quality silk. Bivoltine production targets can be increased with suitable packages and technical support provided to the farmers. In fact, the new era in production of bivoltine has dawned with a promise of higher profits both for the primary producers and reelers alike. With test verified technology package, the production has to be widened covering larger number of farmers and reelers to produce quality cocoons and raw silk to meet the demand of quality silk.

Considering the importance of the introduction of an exclusive bivoltine hybrid to bring in quantitative and qualitative changes in sericulture, Govt. of India and Karnataka have promoted various projects such as Intensive Sericulture Development Project (ISDP),

Karnataka Sericulture Project (KSP) and National Sericulture Project (NSP). All these projects, though contributed in many ways towards promotion of bivoltine raw silk production in the country on a large scale, farmers did not find bivoltine rearing very remunerative and rewarding due to various reasons. However, the hot climatic conditions of India is not conducive to rear productive bivoltines. Hence, there is an urgent need to develop bivoltine breeds which can yield stable crops under the adverse climatic conditions. Accordingly, efforts should be focussed by the silkworm breeders to develop bivoltine breeds with genetic plasticity to buffer against the adverse climatic conditions. The main constraint of the tropical environment is the high temperature coupled with high and low humidity. It is a well established fact that the bivoltines are highly vulnerable to high temperature coupled with high and low humidity especially in the late instars. The hot climatic conditions of tropics prevailing particularly in summer are contributing to the poor performance of the bivoltine breeds and the most important aspect is that many quantitative characters such as viability and cocoon traits decline sharply when temperature is high.

The silkworm breeds developed for tropical conditions in India have to adapt to both seasonal and local conditions for stable cocoon production under the high temperature associated biotic and abiotic conditions. In India, mulberry leaves are available throughout the year including the summer months. However, during summer, the rearing of bivoltines is very challenging with frequent crop losses. Therefore, the farmers are forced to switch over to multivoltine x bivoltine hybrids which are comparatively more stable under such environmental conditions. Since, the rearing of bivoltines in summer months becomes very difficult, the concept of bivoltine throughout the year to produce quality silk becomes jeopardised. In India, the adverse climatic conditions during summer is not the same throughout; some locations are characterized with high temperature coupled with high humidity and in some, high temperature with low humidity condition prevails besides, poor leaf quality at times. Summer breeds are having significant

importance in increasing cocoon production through rearing bivoltine hybrids round the year in tropical areas. The advantages of summer hybrids are high pupation rate, adaptabilities to high temperature coupled with high and low humidity and inferior food quality during the rearing. Stable cocoon crop under the bad conditions of high temperature with low quality mulberry leaves are difficult, but summer breeds/hybrids should have the potentiality for increasing production under such un-favourable weather conditions.

The problems with bivoltine have been many and different for different agricultural regions of the country. The farmers by and large have reservations about the bivoltine rearings and therefore, the acceptance of bivoltine hybrids on large scale as choice of seed has remained restricted. Added to this, the bivoltine hybrid cocoons have always been beset with problems of marketing at remunerative price due to lack of quality appreciation and thereby till recently, it is felt that besides the risk involved, the rearing of bivoltine is not economically viable.

In a tropical country like India, several factors influence the success of cocoon crops of which biotic and abiotic factors play a vital role. Among the abiotic factors, temperature plays a major role on growth and productivity (Benjamin and Jolly, 1986). India enjoys the patronage of second position for the production of silk in the world next only to China. Sericulture in India is practiced predominantly in tropical environmental regions such as Karnataka, Tamil Nadu, Andhra Pradesh and West Bengal and to a limited extent in temperate environment of Jammu and Kashmir. The existing tropical situation provides scope for exploiting multivoltine x bivoltine hybrid at commercial venture as they are hardy and have tremendous ability to survive and reproduce under varied or fluctuating environmental climatic conditions. But its quality is at low ebb when compared to the existing international standard.

Considering these drawbacks, adoption of bivoltine sericulture became imperative and imminent considering

its potentiality even under Indian tropical conditions. Keeping this in view, breeding experiments were initiated at Central Sericultural Research and Training Institute, Mysore to evolve hardy bivoltine silkworm races suited to tropical conditions for achieving the primary objective of establishing bivoltine hybrids as a concept among sericulturists. Accordingly, many productive and qualitatively superior bivoltine hybrids have been developed by utilizing Japanese commercial hybrids as breeding resource material (Basavaraja *et al.*, 1995). However, the hot climatic conditions prevailing particularly in summer are not conducive to rear these high yielding bivoltine hybrids throughout the year. Therefore, attempts were made to develop promising bivoltine breeds tolerant to high temperature and high humidity conditions of the tropics.

Effect of high temperature

Effect of exposure to high temperature (38°C) in two phases of fifth instar, *i.e.*, spinning period and pupal stages of eight silkworm breeds were analyzed. Exposure to high temperature during the later developmental stages considerably reduced the survival rate, pupation rate, cocoon quality and fecundity of the breeds and resulted in increased pupal mortality and unfertilized eggs. Among the breeds, Hosa Mysore, Kalimpong 'A' and the hybrid HM x KA revealed increased tolerance to high temperature conditions and overall better crop results (Pillai and Krishnaswami, 1987).

Geneticists and breeders of all the sericultural countries have experienced the influence of environment during the process of breeding. The effect of temperature on silkworm was reported earlier by many scientists. Watanabe (1918, 1919, 1924, 1928) and Kogure (1933) reported that the quantitative characters of silkworms such as cocoon weight, cocoon shell weight, pupal weight, silk weight, filament length, filament thickness and survival rate of larvae in a known environment are of utmost importance in sericulture. Many of these characters are not only controlled by genes but also influenced by environmental factors such as nutrition, incubation, temperature, photoperiod *etc.* Ueda and Lizuka (1962) demonstrated that silkworms were more sensitive

to temperature during 4th and 5th stages. Shibukawa (1965) made an observation that lines selected at high temperature and humidity perform better than the lines selected under normal temperature and humidity.

Rapusan and Gabriel (1976) reported that environmental factors especially temperature and humidity play a very important role in the life cycle of silkworm determining the cocoon characters and its existence in a particular zone. Takeuchi *et al.* (1964) and Ohi and Yamashita (1977) reported that silkworm larvae become damaged by rearing at temperature higher than 30°C. Huang *et al.* (1979) and He and Oshiki (1984) used survival rate of silkworms as a main characteristic for evaluating thermotolerance. Alimurong (1984) reported that Chinese strain (Tung34 x Su12) performed better than the Japanese strain (Doei x Kohaku) in terms of fecundity, cocoon and silk production under high temperature.

Pillai and Krishnaswami (1987) indicated the effect of exposure of silkworm larvae to high temperature during 5th instar and attributed the resultant low survival rate due to the low feeding activity of the silkworm resulting in the physiological imbalance and poor health of the larvae. Shekarappa and Gururaj (1989) were of the opinion that silkworm being poikilothermic, will be directly affected by temperature and humidity with reference to its biological activities.

Falconer (1990) in his review on the environmental effects on insects concluded that the performance of an insect was improved by selection in the environment in which it is subsequently exploited. The performance of a race or a strain is a function of both the hereditary potential of its population and the extent to which it is exposed. The environment is dynamic and different environments bring about profound changes in the physical and biotic factors governing the expression of commercial characters in silkworm (Kobayashi *et al.*, 1986). It was also observed that though no positive selection response was noticed on survival rate when reared at high temperature followed by directional selection, progenitive lines performed remarkably superior in subsequent generations at room

temperature conditions.

Suresh Kumar and Yamamoto (1995) and Suresh Kumar *et al.* (2001) while studying the effect of high temperature on F1 hybrids between polyvoltine and bivoltine indicated that the hybrids are more tolerant than pure races and there was maternal effect regarding temperature tolerance as evidenced from the better performance of those hybrids where the female parents used were more tolerant as pure races. Hsieh *et al.* (1995) made the studies on the thermotolerance of silkworm and concluded that high temperature ($36 \pm 1^\circ\text{C}$) affected the survival rate more than other characters and the polyvoltines are more tolerant to high temperature than bivoltine strains during 4th and 5th instars and pupal stage.

Tazima and Ohnuma (1995) while attempting to synthesize high temperature resistant silkworm races confirmed the genetical heritability nature of thermo tolerance by selection based on pupation rate of silkworm reared under high temperature conditions in 5th instar. The breeding experiments aimed at evolution of hardy bivoltine races for tropics by Maribashetty *et al.* (1998) indicated that, genetic diversity, productivity and viability are complexly related, being influenced by the intrinsic and extrinsic factors.

Breeding of robust bivoltine breeds/hybrids

A new hardy bivoltine breed was developed by Rajanna and Sreerama Reddy (1992). A few superior breeds of *Bombyx mori* L. suitable for tropical conditions were developed (Kalpana, 1992). Breeding experiments were conducted to evolve new hardy bivoltine breeds of silkworm, *B. mori* L. by utilizing two existing bivoltine races, NB4D2 and NB7 and a multivoltine race, Pure Mysore. By inbreeding the hybrids of the above pure races combined with recurrent backcrossing and selection for productivity and viability at each and every generation, two hardy bivoltine breeds, one spinning white oval cocoons and the other white dumbbell cocoons, were isolated. These breeds, herein referred to as MG511 with Chinese racial features and MG512 with Japanese racial features, were bred through over 35 generations and

revealed significant improvements with regard to viability compared to the existing bivoltines. The overall performance of the evolved breeds with regard to viability and productivity as well as fibre technological characters emphasize their superiority over the existing bivoltine races in the field (Raju and Krishnamurthy, 1993).

A robust bivoltine line MU720 of silkworm, *Bombyx mori* L. for tropics was developed by Maribashetty and Sreerama Reddy (1995). A few bivoltine silkworm races with better survival and high shell content for tropics were developed (Shekarappa *et al.*, 1999). Naseema Begum *et al.* (2000 b) also could identify bivoltine silkworm hybrids suitable for tropical conditions.

To evolve silkworm hybrids with higher survival and better cocoon characters, evaluation of seven hybrids in the laboratory (short-listed out of 143 hybrids) resulted in the identification of two promising hybrids, A3 x 935 E (HSP1) and A3 x 916B (HSP2). The hybrids were evaluated at three different Regional Sericultural Research Stations of Central Silk Board during 1997-1998 and also tested with the farmers along with two control hybrids, KA x NB4D2 and CSR18 x CSR19. Evaluation of the hybrids indicated that these hybrids can be reared in all the seasons, especially during summer. These hybrids show shorter larval duration (22 days 17 h against 23 days in control KA x NB4D2) and better cocoon characters as compared to the cross breed, PM x NB4D2 (Naseema Begum *et al.*, 2000 c).

Silkworm hybrids developed from inbred lines or from different breeds are commercially exploited for production of silk. With the objective of selection of compatible silkworm hybrids to suit the fluctuating climatic conditions of tropics, studies were taken up for optimum expression of productivity and survival. Four bivoltine breeds evolved under high temperature and high humidity ($31 \pm 1^\circ\text{C}$ and RH 85 ± 5 per cent) stress condition viz., A HT, B HT (ovals) and F HT, G HT (dumbbells) showed survival of 85-90 per cent and shell percentage of 20-21. These evolved breeds were crossed with productive breeds having shell percentage of 23-24

and evaluated for hybrid vigour on nine economically important traits viz., total larval duration, survival, and yield/10,000 larvae by weight, cocoon weight, shell weight, shell percentage, filament length, raw silk recovery and reelability contributing to silk yield (Naseema Begum *et al.*, 2000 a).

A number of CSR breeds and hybrids were evolved at CSRTI, Mysore, under the guidance of Japan International Co-operation Agency (JICA) experts in recent years. The superiority of these hybrids with regard to quantitative and qualitative traits is now well established. The commercial exploitation of hybrid vigour in silkworms has already been introduced since the beginning of the century in most of the developed countries. The high yielding and robust CSR bivoltine hybrids along with their parents were chosen as materials in the study for the estimation of heterosis and heterobeltiosis both at $25 \pm 1^\circ\text{C}$ and $36 \pm 1^\circ\text{C}$ temperature in three trials. The results obtained were found to be significant when tested by employing t-test (Suresh Kumar *et al.*, 2000).

Screening of fifteen bivoltine silkworm breeds of *Bombyx mori* L. at a temperature of $31 \pm 1^\circ\text{C}$ and relative humidity of 85 ± 5 per cent resulted in the identification of eight thermo-tolerant breeds. The survival and cocoon shell percentage of the tolerant breeds ranged from 72.7 to 78.7 per cent and 20.0 to 20.1, respectively. The tolerant breeds comprised of four oval breeds and four dumb-bell breeds. Eight foundation crosses prepared by crossing the oval and dumb-bell parents among themselves were screened at a temperature of $31 \pm 1^\circ\text{C}$ and relative humidity of 85 ± 5 per cent. The performance of the foundation crosses on 11 economic characters were analyzed by employing Multiple Trait Evaluation Index method. Four foundation crosses which scored average index value of > 50 were selected as parents and breeding initiated for the evolution of thermo-tolerant bivoltine silkworm breeds (Naseema Begum *et al.*, 2001).

The newly evolved bivoltine hybrids of silkworm (*Bombyx mori* L.) were evaluated with control hybrid KA

x NB4D2 during three seasons of a year for their seasonal performance in respect of 10 quantitative traits. The results showed significant genotype x environment interaction with respect to four quantitative characters viz., fecundity, yield/10,000 larvae, filament length and raw silk (percentage). Environmental effects were significant for nine out of ten characters evaluated. A 105 x J2 and B x NB4D2 were considered as highly adaptable hybrids to local conditions with high mean for maximum of characters studied and found suitable to be reared in all seasons (Sudhakara Rao *et al.*, 2001).

In order to introduce bivoltine races in a tropical country like India, it is necessary to have stability in cocoon crop under high temperature environments. Unlike any temperate country like Japan, the rearing conditions/environment, climatic conditions, quality of mulberry leaf and incidence of diseases are unpredictable in India. Geneticists and breeders of all the sericultural countries have experienced the influence of environment during the process of breeding. In order to select efficiently the breeds with high temperature tolerance, it is very important to analyze clearly the heritability nature of high temperature tolerance. In this direction, a study was undertaken to determine the effect of high temperature through treatments of (A): $35 \pm 1^\circ\text{C}$ and 85 ± 5 per cent RH for 24 hours continuously, (B): $35 \pm 1^\circ\text{C}$ and 85 ± 5 per cent RH for 48 hours continuously and (C): the control ($25 \pm 1^\circ\text{C}$ and 65 ± 5 per cent RH in the normal rearing condition) from 3rd to 5th instar on the pure races such as Moria, N137 and C146 as well as their F1 hybrids which are more tolerant than the pure races. It was also observed that the overall performance declined in those batches where 48 h treatment was given. The most interesting observation noticed in this study was that there was maternal effect regarding temperature tolerance as evident from the better performance of those hybrids where the female parent used was more tolerant as pure race (Suresh Kumar *et al.*, 2001).

Of late, molecular marker facilitated investigations using isozyme/DNA markers are being widely explored in the breeding of crop plants and live stock for the

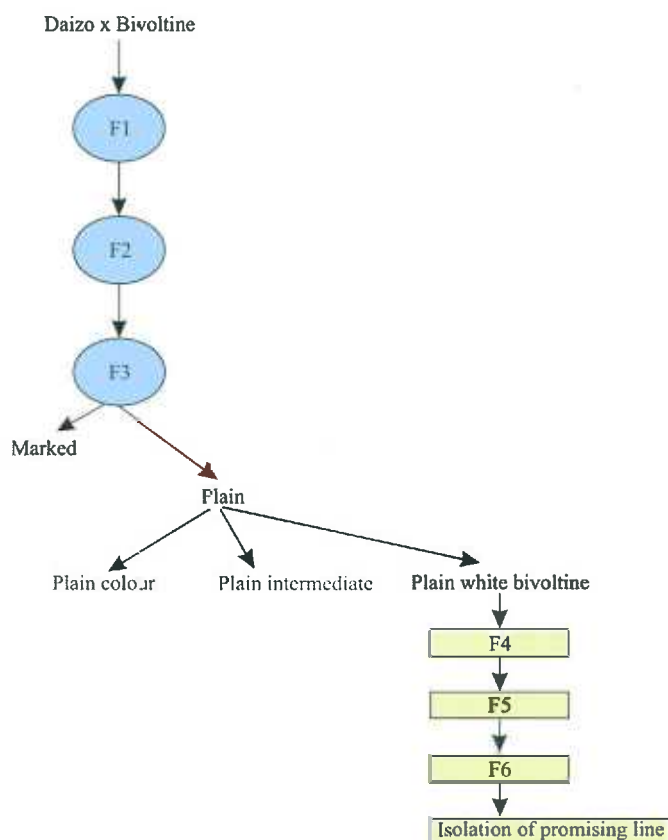
improvement of desirable traits. In India, limited success of conventional breeding and selection strategies adopted so far in silkworm breeding, has warranted testing of the new strategies for maximising yield realisation. In this direction, work carried out earlier on a number of biochemical parameters has shown the prospects of using digestive amylase as a marker in silkworm breeding due to its close association with survival, better digestibility and isozyme polymorphism. A test breeding plan was adopted using the indigenous low yielding polyvoltine breeds namely, Pure Mysore and Nistari having '4 band' and '5 band' cathodic amylase isozyme types, respectively as donor parents (DP) and the productive bivoltine breeds *viz.*, CSR2 and CSR5 with 'null' type of isozyme as recurrent parent (RP). The isozymes from Nistari and Pure Mysore were introgressed into CSR2 and CSR5 and Gen3 and Gen2, respectively were developed (Ashwath *et al.*, 2001).

Development of new hybrids to suit different agro-climatic conditions is of utmost importance for increasing raw silk production. Keeping in view the tropical conditions and need for increasing production of quality silk, breeding studies have addressed different target groups. The first approach wherein NP2 x KSO-1/KSO-1 x NP2 (Rajatha Sampathu) bivoltine hybrids were identified with hardiness as the primary objective are currently popularized in four southern districts of Karnataka *viz.*, Bangalore (Rural), Bangalore (Urban), Kolar and Tumkur districts yielding higher returns to both farmers and reelers *vis-a-vis* the existing cross-breed. In the second approach, NTCM x CTM/CTM x NTCM, KSO-1 x NP4, KSO-1 x NP5 and KSO-3 x NP2 bivoltine hybrids were identified which are hardy and with improved productive characters (21 per cent shell) targeting farmers with better conditions (Krishna Rao *et al.*, 2001).

In India, majority of the farmers have moderate input abilities and invariably raise multivoltine x bivoltine hybrids. Quality cocoon production utilizing bivoltine hybrids has been possible during favourable seasons from June to February and in specific geographic locations

with assured irrigation. Nearly 40 % of the mulberry is under rainfed conditions, which can sustain only low yielding silkworm hybrids. Accordingly, KSSRDI developed "Rajatha Sampathu (NP2 x KSO1) bivoltine hybrid for rearing during different seasons with special emphasis for summer season (Krishna Rao *et al.*, 2003).

Conventional hybridization and selection method (recurrent stringent selection) was adopted for a breeding programme involving multivoltine Daizo (for robustness) and productive bivoltine races (for productivity traits and silk quality) as donor parents. Screening of isolated line and hybrid combinations were done under stress conditions (high temperature, pathogen *etc.*) to adjudicate their suitability. The breeding plan is depicted below.



Rajatha Sampathu (NP2 x KSO1) is a bivoltine hybrid with improved robustness, developed primarily for use by average cross-breed farmers with existing conditions of Karnataka. The distinct advantages that the hybrid

possesses are shorter larval duration by 2 days, minimum leaf wastage, better conversion/water retention efficiency, uniform ripening process, easiness in identification of ripe larvae, better cocoon weight, cocoon shell weight, cocoon shell percentage, less renditta, better reelability, tenacity, raw silk percentage, neatness, cleanliness and less denier variation. The raw silk quality is better and is suitable for power looms. This hybrid can be reared easily during summer when raising of bivoltine is generally not recommended. Nearly 12 lakh hybrid layings were reared by nearly 7,400 farmers in Karnataka to get an average yield of 42.0 kg/100 dfls. The cocoons fetched an average of ₹25 to 30 higher than cross-breed rate per kilogram, thus, bringing higher returns to the farmers.

Earlier breeding experiments undertaken at CSRTI, Mysore, India for a decade had resulted in the development of many productive and qualitatively superior bivoltine hybrids. However, the hot climatic conditions of tropics prevailing particularly in summer are not conducive to rear these high yielding bivoltine hybrids. This has necessitated breeding of compatible bivoltine hybrids for year round rearing. Accordingly, the Japanese hybrid, B201 x BCS18 which was found to be tolerant to high temperature was used as breeding resource material. Following the method of hybridization and selection, rearing of silkworms was taken up in SERICATRON (Environmental Chamber with precise and automatic control facilities for uniform maintenance of temperature and humidity) at high temperature of $36 \pm 1^\circ\text{C}$ and $85 \pm 5\%$ RH in fifth instar and the control batches at $25 \pm 1^\circ\text{C}$ and $65 \pm 5\%$ RH. Directional selection was resorted to the batches reared at $36 \pm 1^\circ\text{C}$ till the productivity characters started showing signs of deterioration. Therefore, from F6 onwards, the experiment was modified in such a way as to conduct normal rearing for every alternate generation to regain the lost vitality due to continuous exposure to high temperature and high humidity stress. At F2, oval and dumbbell cocoons were separated out and designated as CSR18 and CSR19, respectively. The detailed breeding plan adopted for CSR18 and CSR19 is depicted in Figure 1.

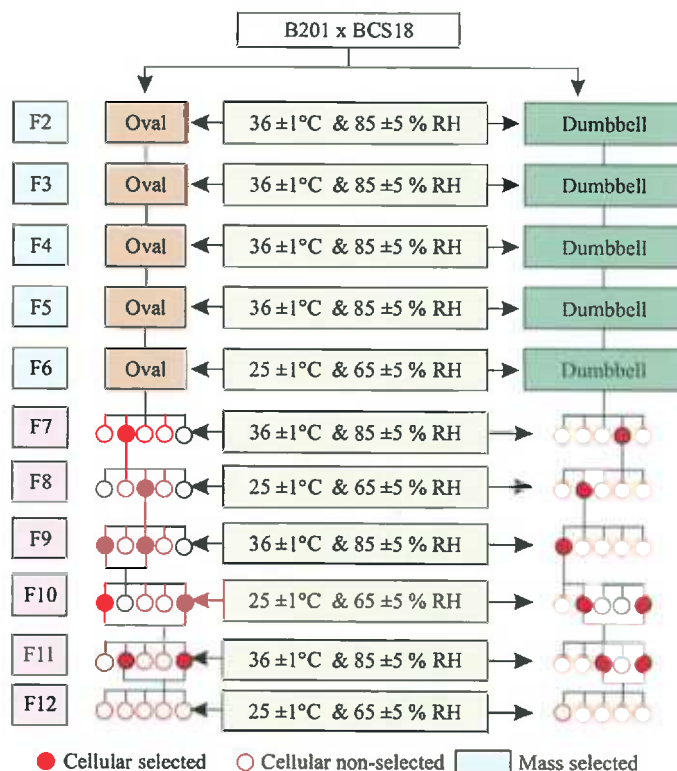


Figure 1: Breeding plan for CSR18 x CSR19

By utilizing these lines at F12, the hybrid CSR18 x CSR19 was prepared and studied for thermo-tolerance by subjecting to stress condition at high temperature of $36 \pm 1^\circ\text{C}$ and $85 \pm 5\%$ per cent RH in fifth instar and the control batches at $25 \pm 1^\circ\text{C}$ $65 \pm 5\%$ per cent RH. The better performance of CSR18 x CSR19 (survival > 88 per cent) at $36 \pm 1^\circ\text{C}$ (Figure 2) clearly indicates its general superiority with regard to high temperature tolerance over the productive hybrids. It can also perform well in varied agro-climatic conditions of the tropics with optimum qualitative and quantitative characteristics (Suresh Kumar *et al.*, 2002). Accordingly, in 1998, after the Race Authorization Test, Central Silk Board, India has authorized the hybrid, CSR18 x CSR19 for commercial exploitation (Suresh Kumar *et al.*, 2002).

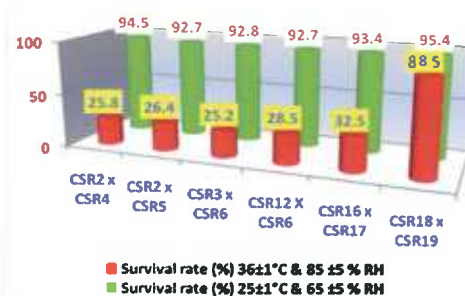


Figure 2: Comparative survival rate of CSR18 x CSR19

Ten hybrids of the silkworm, *Bombyx mori* L. exposed to three different combinations of temperature and relative humidity *i.e.*, $25 \pm 1^\circ\text{C}$ and RH 75 ± 5 per cent; $31 \pm 1^\circ\text{C}$ and RH 85 ± 5 per cent and $36 \pm 1^\circ\text{C}$ and RH 85 ± 5 per cent were analyzed for 8 economic traits *i.e.*, 5th instar period, yield/10,000 larvae by number (cocoon survival), cocoon weight, shell weight, shell percentage, average filament length, raw silk percentage and reelability percentage. The performance of the hybrids at $25 \pm 1^\circ\text{C}$ and at $31 \pm 1^\circ\text{C}$ was at par. The effect of temperature was significant for all the traits except for the shell percentage ($P < 0.05$). The interaction effect (temperature x hybrid) was significant for survival ($P < 0.05$). At $36 \pm 1^\circ\text{C}$ temperature treatment, all the hybrids showed slightly better cocoon survival as compared to the control hybrid, KA x NB4D2. The better performance of these ten hybrids at $36 \pm 1^\circ\text{C}$ may be due to the maternal effect of thermo-tolerance where the female parent used was more tolerant. But the deleterious effect of high temperature and high humidity was more pronounced in KA x NB4D2, as evident from the low survival of cocoons (2944 at $36 \pm 1^\circ\text{C}$). However, two hybrids *i.e.*, AHT x FHT (8996) and BHT x GHT (9155) recorded higher cocoon survival number when compared to the other hybrids at $36 \pm 1^\circ\text{C}$ and RH 85 ± 5 per cent (Naseema Begum *et al.*, 2002).

Four thermo tolerant lines of silkworm, *Bombyx mori* L. *viz.*, A HT, B HT (Chinese type) and F HT and G HT (Japanese type) were evolved by utilizing the breeding resource material (identified from initial screening at a temperature of $31 \pm 1^\circ\text{C}$ and relative humidity, 85 ± 5 per cent) through conventional breeding. These tolerant lines were crossed with productive breeds and forty four hybrids were evaluated on eight economic traits by the Multiple Trait Evaluation Index method. Ten hybrids were short listed based on the average evaluation index values. The identified ten hybrids recorded higher index values (> 50) for most of the traits studied. Single hybrid G x CSR12 indicated average index value higher than 50 for six traits *viz.*, pupation number (58), cocoon weight (67), shell weight (65), average filament length (74), raw silk percentage (69) and reelability percentage (51) except for shell percentage (41). The standard deviation of the

cocoons in the above hybrid was 8.41 for cocoon length and width measurement. However, two selected hybrids *viz.*, A x CSR5 and G x CSR13 recorded average index value larger than 50 for all the traits *viz.*, pupation number (57, 60) cocoon weight (50, 54), shell weight (56, 57), shell percentage (59, 53), average filament length (55, 60), raw silk percentage (63, 67) and reelability percentage (53, 53). The standard deviation of the cocoons with reference to length: width ratio in the two selected hybrids *viz.*, A x CSR5 and G x CSR13 were 8.41 and 8.06, respectively for the cocoon length and width measurement (Naseema Begum *et al.*, 2003)

Stability analysis was carried out to select suitable parents of bivoltine silkworm breeds tolerant to high temperature and humidity condition for initiating new breeding programme. Fifty seven bivoltine silkworm breeds were evaluated at high temperature ($36 \pm 1^\circ\text{C}$) and high humidity (85 ± 5 per cent RH) as well as at room temperature conditions. Based on the pupation rate (> 60 per cent) at high temperature and high humidity conditions, 17 breeds were short-listed. Those were further reared in SERICATRON at three different temperature and humidity conditions. The data were analyzed by employing Eberhart and Russel's Model (1966) of Stability Analysis. The breeds which scored regression coefficient (b-value) less than or nearer to 1 with pupation rate > 60 per cent at high temperature and high humidity conditions were selected. Based on the performance, 11 breeds namely, 5HT, 6HT, 7HT, 8HT, 9HT, 10HT, NK32, A24, CSR18, CSR19 and Daizo were selected as breeding resource material tolerant to three different temperature and humidity conditions (Palit *et al.*, 2003).

Heterosis, general and specific combining abilities in 5 newly evolved thermo-tolerant breeds *viz.*, SR1, SR2, SR3 SR4 and SR5 of silkworm *Bombyx mori* L. were evaluated under different temperature and humidity conditions by using 3 widely adapted testers *i.e.*, NB4D2, CSR4 and CSR5. Data were collected for seven quantitative traits *viz.*, pupation rate, cocoon yield, cocoon weight, cocoon shell weight, cocoon shell percentage, filament length and

raw silk (percentage) under room temperature (T0). The performance at high temperature ($36 \pm 1^\circ\text{C}$) and high humidity (90 ± 5 per cent (T1) and high temperature ($36 \pm 1^\circ\text{C}$) and low humidity (50 ± 5 percent) (T2) were only taken into consideration for selecting the best lines/hybrids. Among the lines, SR3 and SR4 exhibited positive GCA effects for pupation rate, cocoon yield, cocoon weight and cocoon shell weight traits, followed by SR5 for pupation rate, cocoon yield and cocoon weight under T1 and T2 conditions. Among testers, CSR4 exhibited positive GCA effects for four quantitative traits viz., pupation rate, cocoon yield, cocoon weight and cocoon shell weight under both the adverse temperature conditions and reported as a good general combiner. The hybrids, SR3 x CSR4 and SR4 x NB4D2 exhibited significant positive SCA effects for majority of the characters under both the adverse (T1 and T2) conditions of rearing. The better parent value of heterosis (heterobeltiosis) was exhibited by the hybrids SR3 x CSR4, SR1 x CSR5 and SR4 x NB4D2. Hybrids viz., SR3 x CSR4 and SR4 x NB4D2 were selected based on the SCA results for recommending to field trials for commercial exploitation in tropical climate (Sudhakara Rao *et al.*, 2003).

It was reported that the survival rate which is considered as the main yardstick to measure the effect of high temperature, was more in those hybrids where the robust breeds, CSR18, CSR19 and the hybrid CSR18 x CSR19 were used as male components with PM. This clearly indicates that during hostile environmental conditions, especially during summer months, it is advisable to use the robust bivoltine breeds/hybrids as male components rather than using productive bivoltine breeds/hybrids. However, the productive bivoltine races such as CSR2, CSR4 *etc.*, could be exploited only during favorable months (Suresh Kumar *et al.*, 2003).

One of the main aims of the breeders is to recommend to farmers the silkworm breeds that are stable under different environmental conditions and thus minimize the risk of falling below a certain yield level. Silkworm breeds exhibiting less variation when reared over a series

of environments are considered stable. However, the hot climatic conditions of tropics prevailing particularly in summer are not conducive to rear high yielding (productive) bivoltine hybrids. The low adaptability of these hybrids to the fluctuating environmental conditions of the tropical climate make them unsuitable for commercial exploitation throughout the year. Even though, they are known for their productive merit, absence of genetic plasticity to buffer against the tropical environmental stresses acts as a constraint to tap full economic potential of these hybrids. Therefore, there is an urgent need for suitable robust bivoltine hybrids which can yield consistently good cocoon crop under the macro and micro environmental conditions and inferior management prevailing in the tropical conditions. Among the many factors that are attributed to poor performance of the bivoltine strains under tropical conditions, the most important one is that many quantitative characters such as viability and cocoon traits decline sharply when temperature rises above 28°C (Shibukawa, 1965). Kato *et al.* (1989) in a series of experiments observed that, high temperature tolerance is a heritable character and it may be possible to breed silkworm races relatively tolerant to high temperature. Keeping in view of the above research findings, in a tropical country like India, it is essential to develop bivoltine breeds / hybrids which can withstand the high temperature stress conditions. This has necessitated the development of compatible hybrids for rearing throughout the year by utilizing Japanese thermo-tolerant hybrids as breeding resource material (Suresh Kumar *et al.*, 2004).

An investigation was undertaken to assess the effect of high temperature and high humidity on various quantitative and qualitative characters of temperature tolerant and temperature sensitive breeds and their hybrids to generate additional knowledge on the genetic basis of temperature tolerance so that it can be effectively utilized for future breeding programmes. The results of the study clearly indicated that the productive bivoltine pure breeds are highly sensitive to high temperature and high humidity conditions. It was also observed that the pupation rates of those hybrids are more (93.1 to 97.4 %) where the female

parents used are more tolerant to high temperature and high humidity conditions. It was also evident that even bivoltine hybrids will exhibit reciprocal effect when the parents involved are temperature tolerant and sensitive breeds. The expression of hybrid vigour was different in hybrids at the two temperature treatments proving that the level of heterosis present in the hybrids can be influenced by the environment (Suresh Kumar *et al.*, 2005).

Dandin *et al.* (2006) in their attempt to develop bivoltine breeds/hybrids which can withstand the high temperature stress conditions recommended a few hybrids *viz.*, CSR18 x CSR19, CSR46 x CSR47 and CSR50 x CSR51.

A breeding experiment was conducted to improve the viability characters of two bivoltine races of silkworm *Bombyx mori*, namely NB4D2 and Kalimpong - A by utilizing genetically distinct disease resistant polyvoltine race, namely NPND stock (non pigmented but non diapause). By inbreeding the hybrids utilising the bivoltine female parents with males of NPND followed by backcrossing and appropriate selection procedures, two improved lines were extracted at 12th generation. At every generation, rigid selection was applied to select non diapause eggs, white colour cocoons having uniform built and shape and progenies exhibiting the highest effective rate of rearing resembling the male parents. The improved line derived from hybridization experiments utilizing NB4D2 as one of the parents was denoted as NB4D2-I and the improved line extracted from the cross where Kalimpong-A is used as one of the parents was denoted as KA-I. The two improved lines were subjected to seasonal evaluation by rearing them in three different seasons of the year along with the parental races. Both the improved lines exhibited the maximum level of effective rate of rearing (ERR) of 94 per cent and above compared to the two bivoltine parents. The study emphasized the importance of utilization of multivoltine races in improving the viability traits of bivoltine races (Murthy and Subramanya, 2006).

With an objective of evolving a robust bivoltine

silkworm hybrid of *Bombyx mori* L. suitable for tropical climate, a breeding programme was initiated at Central Sericultural Research and Training Institute, Mysore by utilizing indigenous polyvoltine and productive bivoltine breeds. The breeding was carried out under high temperature ($36 \pm 1^\circ\text{C}$) and low humidity (50 ± 5 per cent) conditions in the environmental chamber. By F12, three oval and three dumbbell breeds with higher survival and productive merits were isolated. These breeds were utilized in the hybrid evaluation along with other popular breeds. Based on combining ability results, the hybrid SR1 x SR4 was selected and evaluated in different seasons. The results indicated that the hybrid has higher viability and productive merits and is suitable for rearing throughout the year. The hybrid SR1 x SR4 recorded a survival of 92.0 per cent, cocoon shell weight of 0.417 g, cocoon shell percentage of 23.0 and filament length of 1042 meters under hot and dry conditions of environmental chamber revealing its superiority over the control *i.e.*, thermo-tolerant hybrid, CSR18 x CSR19 (Sudhakara Rao *et al.*, 2006, 2007).

The compatible hybrid CSR18 x CSR19, for rearing throughout the year was developed in India by utilizing Japanese thermo-tolerant hybrids as breeding resource material. Though the introduction of CSR18 x CSR19 in the field during summer months had considerable impact, the productivity level and returns realized did not match to that of other productive CSR hybrids. Therefore, the acceptance level of this hybrid with the farmers was not up to the expected level because of the low productivity traits. This has necessitated the development of a temperature tolerant hybrid with better productivity traits than CSR18 x CSR19. Considering the gravity of the situation and also to cope up with the challenge, though it was a difficult task to break the negative correlation associated with survival and productivity traits, attempts in this line had resulted in the development of CSR46 x CSR47, a temperature tolerant bivoltine hybrid with better productivity traits than CSR18 x CSR19. The breeding plan for the development of CSR46 is depicted in Figure 3 (Suresh Kumar *et al.*, 2006).

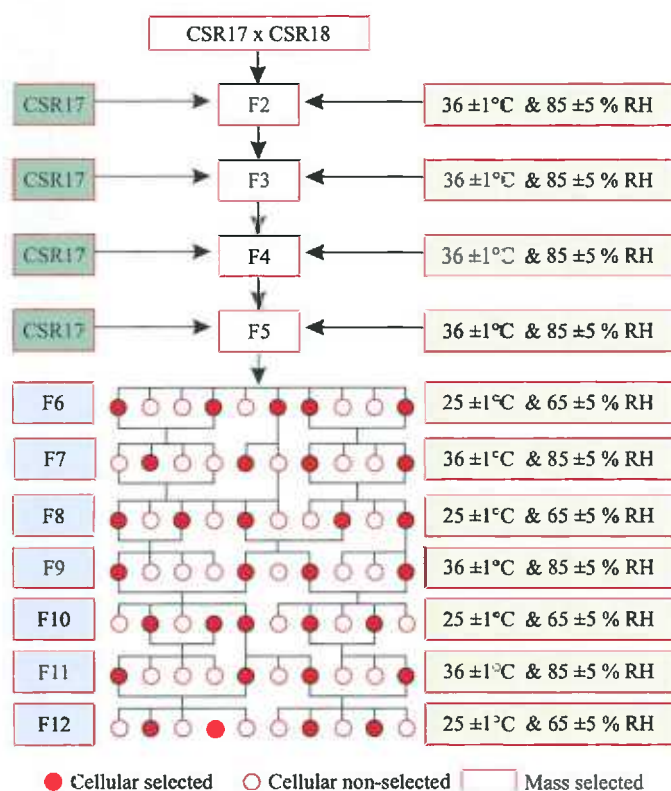


Figure 3: Breeding plan of CSR46

The success of silkworm rearing with presently available conventional bivoltine is unpredictable during some seasons in the tropical regions due to highly fluctuating adverse climatic conditions. Thus, in order to popularize bivoltine breeds in tropical parts of India, it is very much essential to have a bivoltine breed(s), which can offer stable cocoon crop under variable environments. With this objective, a breeding programme was undertaken to improve the survival trait in bivoltine silkworm by introducing multivoltine genes into bivoltine through back crossing. Resultant bivoltine lines showed significantly higher survival compared to the receptor bivoltine parent and control bivoltine breed. Esterase isozyme analysis revealed similar banding pattern in the developed bivoltine and in the donor multivoltine, which assures the introgression of multivoltine character into evolved bivoltine (Moorthy *et al.*, 2007).

Screening of twenty bivoltine silkworm breeds of *Bombyx mori* L. at targeted temperature of 32 ± 1°C and relative humidity of 50 ± 5 per cent conditions resulted in

the identification of eight thermo-tolerant (four each of oval and peanut) breeds. The survival percentage of the tolerant breeds ranged from 92.3 (APS31) to 89.0 per cent (APS19) among oval and from 93.0 (APS24) to 90.1 per cent (APS6) among peanut breeds. The short-listed breeds were crossed in the pattern of oval x oval and peanut x peanut foundation crosses. The resultant 12 oval and peanut foundation crosses were screened once again at the above targeted environmental conditions. The performance of the foundation crosses was analyzed by employing Multiple Trait Evaluation Index method and Subordinate Index methods. Accordingly, five oval x oval crosses viz., APS11 x APS31; APS11 x APS19; APS19 x APS11; APS31 x APS19 and APS7 x APS31 and five peanut x peanut crosses viz., APS12 x APS6; APS18 x APS24; APS6 x APS18; APS6 x APS24 and APS6 x APS12 which scored higher average index values were selected as breeding resource parents to initiate breeding for the evolution of thermo-tolerant bivoltine silkworm breeds (Lakshmi and Chandrashekaraiah, 2007).

Breeding strategies directed towards the development of hardy bivoltine races to improve the quality and unit production of silk, warrant the selection of suitable parental material and their effective utilization. In this direction, forty seven bivoltine breeds maintained as germplasm at Andhra Pradesh State Sericulture Research Institute, Hindupur, India were reared under summer [high temperature (30 - 36°C) and low humidity (50 - 55 per cent)] conditions. Nine quantitative and qualitative traits of the breeds were considered for evaluation based on the Joint Scoring index method. Based on the evaluation, twenty bivoltine breeds comprising of ten oval breeds which scored lower values viz., APS5 (2.5764), APS7 (3.3050), APS19 (3.6508), APS11 (4.0610), APS9 (4.1034), APS31 (4.2272), APS27 (4.2939), APS45 (4.2956), APS39 (4.5588) and APS17 (4.7332) (oval) and ten peanut breeds viz., APS4 (3.1863), APS8 (3.2886), APS32 (3.4138), APS24 (3.5794), APS12 (3.8078), APS16 (3.9715), APS18 (4.1263), APS62 (4.2164), APS6 (4.2656) and APS10 (4.3777) were adjudicated as potential breeding resource material for initiation of breeding programme for the development of bivoltine

silkworm hybrids suitable for tropical conditions (Lakshmi and Chandrashekaraiah, 2008).

In West Bengal, the rearing of high yielding bivoltine silkworm varieties is challenging owing to the prevalence of high temperature and high humidity. Multivoltine breeds though better in survival, yet poor in economic traits, are unable to fetch better returns. As such, a scheme was framed to evolve temperature tolerant bivoltine lines with moderate technological traits suitable for plains of West Bengal. Therefore, six genetically divergent bivoltine silkworm breeds *viz.*, P5, JD6, YS3, SF-19, NB18 and KPG-B were reared alternatively under thermal stress followed by normal rearing for 18 generations. They were then screened under high temperature and high humidity conditions. Three new temperature tolerant lines *viz.*, BHR1, BHR2 and BHR3 with moderate economic traits could be evolved out of the study (Rao *et al.*, 2008).

Evaluation of the working germplasm maintained at Central Sericultural Research and Training Institute, Mysore, India was carried out at high temperature ($40 \pm 1^\circ\text{C}$) and high and low humidity conditions (85 ± 5 and 50 ± 5 per cent RH) to select breeding resource materials for high temperature tolerance. Breeds recording pupation rate of around 60 per cent at high temperature conditions, with least b-values, the highest index scores and the highest evaluation indices were selected as breeding resource materials. Accordingly, the breeds, CSR18, CSR19, CSR46, CSR47, CSR50 and CSR51 were selected as breeding resource materials for initiating the breeding programme for the development of breeds with high temperature tolerance (Harjeet Singh and Suresh Kumar, 2008).

The bivoltine rearing in harsh tropical climate of our country is not yielding fruitful results as the bivoltines are gifted with high productivity and less tolerance to high temperature and high humidity. In order to have continuous supply of quality bivoltine cocoons to produce quality raw silk, the silkworm breeds which can withstand high temperature and high humidity are the need of the

hour. Hence, in a study, by utilizing temperature tolerant breeds, six breeding lines were made and at every generation, the 5th instar larvae were exposed to high temperature and high humidity and the survived ones were back crossed with the breeds moderately tolerant to diseases to improve the quantitative traits. From F6 generation onwards, alternate rearing under normal and high temperature conditions were conducted. At the end of F12 generation, it was possible to isolate three oval breeds *viz.*, HH1, HH3 and HH6 with improvement in quantitative traits (Harjeet Singh and Suresh Kumar, 2009).

In India, the traditional breeding methods employed during the last few decades have resulted in the development of a number of productive silkworm breeds which have contributed significantly in increasing the silk production. Although, efforts of several years of breeding and selection work for many economic traits and concomitant improvement in rearing has enhanced the silk productivity, the full genetic potential of the hybrids for various yield attributes has not yet been realized in the field. As a result, there is a wide gap between the yield potential recorded in the laboratory, and the yield realized in the field (Dandin *et al.*, 2003). Efforts made in this direction during the '90s have led to the evolution of highly productive CSR bivoltine breeds which have the potential to produce international grade silk (Basavaraja *et al.*, 1995; Datta *et al.*, 1997, 2000, 2001; Mal Reddy *et al.*, 2003, 2004). However, these new breeds are being popularized on a limited scale with progressive farmers who can provide the high input and managerial skills. Even though they are known for their productive merit, absence of genetic plasticity to buffer against the tropical environmental stresses acts as a constraint to tap the full economic potential of these hybrids. The bivoltine breeds continue to suffer badly in adverse conditions of high temperature, humidity, germ-load, poor leaf quality and low management prevalent with the small and marginal farmers and hence they can rear only cross breeds which cannot produce high quality raw silk. Tropical sericulture beset with wide fluctuating environmental conditions and poor leaf quality, urgently needs the development of broad

based silkworm breeds with genetic plasticity to buffer these adverse situations. Keeping this in view, attempts were made to develop bivoltine silkworm double hybrids relatively tolerant to diseases and high temperature environment (Suresh Kumar *et al.*, 2011).

Previous studies have clearly underscored the utility of digestive amylase as an ideal marker in silkworm breeding which imparts better digestibility and higher survival leading to improvement in robustness of bivoltine breeds. Against this background, six polyvoltine breeds, viz., Pure Mysore, CNichi, Daizo (with 4 band type of amylase), Nistari, Sarupat and Moria (with 5 band type of amylase) carrying high activity digestive amylase genes were used as donor parents (Dp) and two productive bivoltine breeds, namely CSR2 and CSR4 with 'null' type of amylase were selected as recurrent parents (Rp). Backcross breeding was employed up to BC₆ by selecting the progeny with Dp type of amylase activity at each generation. Six oval near isogenic lines (NILs) of CSR2 and five dumb-bell NILs of CSR4 were evolved with high activity amylase genes, which showed significantly higher survival than their respective Rps. Using the evolved lines, 36 single hybrids (oval x dumb-bell) and 25 double hybrid combinations were raised and evaluated by multiple trait index values. Among the hybrids, the highest EI values were recorded in Gen1 x 4C (54.1) followed by GEN1 x CSR4 (53.0), as against the control hybrid CSR2 x CSR4 (46.9). Among the double hybrids, G3 x G8 was found to be superior in terms of EI value (56.6), followed by G4 x G9 (56.3) and G2 x G8 (54.5), when compared with the control, FC1 x FC2 (47.3). Based on the results, the single hybrid, GEN1 x 4C and the double hybrid G3 x G8 were short-listed and subjected for in-house testing at the institute as well as on station trials at Regional Sericultural Research Station (RSRS) units, which showed the superiority of the short-listed hybrids in terms of higher yield and better cocoon traits than the control hybrids (Ashwath *et al.*, 2011).

With an object of evolving superior robust bivoltine races for summer season, breeding experiments were taken up at Karnataka State Sericulture Research and

Development Institute and five robust, oval cocoon spinning bivoltine races (BRO2, BRO3, KSO-1, KSO-2 and KSO-3) and five robust, dumbbell cocoon spinning races (BRD12, BRD13, BRD15, NP2, NP4) were developed which performed better during high temperature and low humidity conditions of summer season. After preliminary studies, field evaluation of new pure races and hybrids was taken up from 2006 to 2009 in association with Department of Sericulture, Government of Karnataka. The new bivoltine hybrid combinations *i.e.*, BRO2 x NP4, and NP4 x BRO2 were reared by 69 medium farmers in Bangalore (U), Ramanagaram, Kolar and Mandya districts of Karnataka. Compared to control, the average cocoon yield, rate, returns, yield/unit area *etc.*, were superior in the new hybrids during summer season. The study stressed commercial exploitation of the new bivoltine hybrids during summer season to improve bivoltine cocoon and raw silk production (Krishna Rao *et al.*, 2011).

Silkworm breeders across the country contributed significantly to the development of many bivoltine breeds not only with improved economic merit but also suitable for variable climatic conditions so as to make tropical sericulture a sustainable avocation. However, there is a considerable dearth for season and region specific breeds. Silkworm breeding attempts made at Andhra Pradesh State Sericulture Research and Training Institute (APSSRDI), Hindupur, India contributed to the development of a thermo-tolerant bivoltine hybrid, HTO5 x HTP5. Fifty hybrid combinations involving 10 parents (5 each of oval and peanut) were evaluated in a complete diallel pattern and identified the combination, HTO5 x HTP5 as the most promising (Lakshmi *et al.*, 2011 a, 2011 b).

Though a number of thermo-tolerant bivoltine silkworm hybrids have been evolved by conventional methods in the institute, limited success has been achieved in their popularity in the field. There is a need to develop robust and productive bivoltine breeds which can be reared during the high temperature conditions of summer by small and marginal farmers. Previous work in the

laboratory have clearly shown the prospects of using molecular markers like digestive amylase in breeding for developing robust breeds, by introgressing high activity amylase genes from the polyvoltines into the genome of productive bivoltine breeds. In this line, a study was taken up with the objective to assess the thermo tolerance of the breeds and hybrids developed by amylase selection and identify thermo-tolerant hybrids for field evaluation. The parental breeding lines developed using amylase selection, single hybrids, foundation crosses and double hybrids were subjected to high temperature ($36 \pm 1^\circ\text{C}$) and high humidity (85 ± 5 per cent) conditions from 3rd day of 5th instar for 6 hours daily till spinning and normal temperature and humidity ($24 \pm 1^\circ\text{C}$ and 65 ± 5 per cent RH) during cocooning. Among the single hybrids, 2C x 4S and 2C x 4C recorded the highest pupation of 59.3 per cent, when compared to 35.4 per cent in the control, CSR2 x CSR4. Among the oval foundation crosses, GEN1 x 2C showed the highest pupation rate of 54 per cent followed by 45.7 per cent in GEN1 x 2M, when compared to 37.9 per cent in the control, FC2. In the case of dumbbell FCS, high pupation rate of 58.3 and 54.7 per cent was observed in 4P x 4D and 4P x CSR4, respectively as against 40.1 per cent in control, FC1. Using the short-listed oval and dumb-bell FCS, 25 double hybrids were raised and exposed to heat stress wherein the highest pupation rate was observed in G11 x G23 (60.3 per cent) followed by G11 x G19 (58.3 per cent). Based on the results, G11 x G19 was short-listed for large scale in-house testing at the institute as well as for on station trials at RSRS farms. The results indicate the prospects of identifying robust hybrids suitable for rearing under high temperature conditions of tropical climate (Mahalingappa *et al.*, 2011).

Unlike other traditional sericultural states of India, Eastern India especially in West Bengal, rearing of bivoltine parent during seed crop for preparing multi x bi eggs is very difficult owing to unpredictable, fluctuating and harsh climatic condition that prevails in most of the seed crop seasons. As a result, bivoltine seed cocoons are to be procured from other parts of the country. To overcome this, after a series of experiments, a suitable bivoltine foundation cross (FC), namely SK6 x SK7 was

identified after being tested under field trials. Multi x bi hybrid combinations prepared with this FC namely, Nistari x (SK6 x SK7) and M6DP(C) x (SK6 x SK7) were evaluated at farmers level in different commercial seasons at West Bengal for two years and have shown encouraging performance. Thus with SK6 x SK7 (FC), bivoltine seed crop stabilization - the bottleneck for the development of sericulture industry in Eastern and North Eastern India particularly in West Bengal could be overcome as bivoltine seed cocoons could be raised itself, thus avoiding transportation of seed cocoons from far flung places which saves money and energy (Moorthy *et al.*, 2011).

Cocoon crop stability with sustainably good performance is a pre-requisite to introduce bivoltine races in a tropical country like India under high temperature and humidity stress. Considering the poor performance of productive bivoltine hybrids during summer season, emphasis was laid on to evolve bivoltine silkworm breeds suitable to tropical conditions for achieving the primary objective of establishing bivoltine sericulture with quality raw silk among sericulturists. Therefore, it becomes imperative or essential to develop bivoltine breeds/hybrids which can withstand high temperature and humidity stress. In India, it is not conducive to rear highly productive bivoltine hybrids, especially in summer. Therefore, attempts are being made to develop bivoltine silkworm hybrids tolerant to high temperature situations of the tropics. Attempts made earlier in this line had resulted in the development of robust bivoltine hybrids viz., CSR18 x CSR19, CSR46 x CSR47 and CSR50 x CSR51. However, these hybrids could not make much impact in Indian sericulture industry except for certain region/seasons. Keeping this in view, efforts were undertaken to develop productive and stable bivoltine double hybrids tolerant to high temperature and high humidity conditions of the tropics (Suresh Kumar *et al.*, 2011). A few attempts were carried out to evaluate and identify suitable bivoltine breeds under West Bengal conditions of India (Suresh Kumar *et al.*, 2012, 2013).

The challenging task faced by breeders is to develop silkworm breeds which can produce eggs under prevailing

conditions of temperature and humidity. The reproductive potential of a few single and double hybrids was evaluated under high temperature and high humidity as well as high temperature and low humidity conditions of the tropics. The moth emergence percentage, laying recovery percentage, egg recovery/kg cocoon, number of eggs/gram and percentage of unfertilized eggs were calculated and compared among single and double hybrids (Suresh Kumar *et al.*, 2012).

Efforts in the line of silkworm breeding and development of new races are continuous in nature as India always aim at vertical growth in superior quality bivoltine silk production. Hence, it should be the priority of silkworm breeders / biotechnologists to initiate need specific, relevant breeding programmes in native environments to develop races / hybrids with genetic plasticity to buffer against the prevailing environmental stresses of tropics.

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Revue

DEVELOPPEMENT DE LIGNEES/HYBRIDES BIVOLTINS ROBUSTES DU VER A SOIE *BOMBYX MORI* L. POUR LES TROPIQUES - REVUE

N. Suresh Kumar*, A. K. Saha and S. Nirmal Kumar

Central Sericultural Research and Training Institute, Berhampore -742101, India.

*E-mail: nairsuresh_in@yahoo.com

RÉSUMÉ

L'un des stressés importants lors de l'élevage des vers à soie bivoltins sous les tropiques est la haute température environnementale. Il est bien établi que sous des conditions tropicales, contrairement aux polyvoltins, les vers à soie bivoltins sont plus vulnérables aux fortes températures, à la faible qualité de la feuille et à une conduite impropre pendant l'été qui n'est pas approprié pour l'élevage de bivoltins. Aussi, dans un pays tropical comme l'Inde, il est essentiel de développer des lignées/hybrides bivoltins qui puissent supporter les hautes températures. Beaucoup de centres en Inde ont fait des efforts concertés dans ce domaine afin d'obtenir des lignées/hybrides bivoltins tolérants à la température élevée ce qui a permis de développer d'hybrides bivoltins utilisables toute l'année. Dans cette revue, nous tentons de fournir un aperçu conséquent de la littérature relative au travail de breeding réalisé dans cette direction pendant de nombreuses années.

Mots-clés: *Bombyx mori*, lignées/hybrides bivoltins robustes.



ANTIOXIDANT AND ANTI-TYROSINASE ACTIVITY OF FIBROIN EXTRACT FROM FIBRE AND SILK GLAND OF TASAR SILKWORM, *ANTHERAEA MYLITTA* D.

K. Jena*, A. K. Sinha, J. P. Pandey, Chakrapani, P. Kundu and A. Sahay

Central Tasar Research and Training Institute, Central Silk Board, Piska Nagri F O , Ranchi 835303, Jharkhand, India.

*E-mail: jenakb2010@gmail.com

ABSTRACT

In this study, we report the *in vitro* antioxidant and anti-tyrosinase activity of tasar silk fibroin. *In vitro* antioxidant activity of fibroin extract was evaluated by 2, 2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay, superoxide radical scavenging assay, hydrogen peroxide scavenging, nitric oxide scavenging and inhibition of lipid peroxidation. The anti-tyrosinase activity of fibroin extract was determined by using mushroom tyrosinase as a suitable model system. The existence of fibroin in the extract was confirmed through Fourier transform infrared spectroscopy (FTIR), which showed sharp peaks at wavelengths, 1674.21~1670.70, 1546.91~1539.20 and 1253.71 in FTIR spectrum pattern. The results suggested that tasar silk fibroin possesses antioxidant and anti-tyrosinase activities deserving an application in the field of cosmeceuticals, which could lead to significant economic and social benefits.

Key words: Antioxidant, anti-tyrosinase, fibroin, free radicals, tasar silkworm.

INTRODUCTION

Silk sericin and fibroin are natural macromolecular proteins derived from the cocoons of silkworm and are synthesized in the silkworm's posterior and middle silk gland, respectively. Sericin envelops the fibroin fiber with successive adhesive layers and ensures the cohesion of the cocoon by gluing the silk threads together. To date, fibroin has been found to possess various biological functions such as antioxidant and anti-tyrosinase activities (Luccini, 2012).

In India, the total production of tasar cocoon was 2619 MT in 2013-14 (CSB, 2014), which means approximately 786 MT of tasar silk waste (silk waste contributes approximately 30 % of total cocoon production as reported elsewhere) was generated during the period in different tasar silk producing states viz., Jharkhand, Chhattisgarh, Odisha, Madhya Pradesh, Andhra Pradesh and West Bengal. Generally, silk wastes are produced

during cooking, cocoon deflossing, reeling and spinning. As per the market, reeled yarn silk prices are in the range of ₹3000-3200/kg and the waste silk fibres are sold at ₹125-134/kg (Source: Raw Material Bank, Chaibasa, Jharkhand). Silk waste is used as coarse yarn and spun silk, which are used in rubber industry to achieve the physicochemical properties (Iizuka, 1996). There is also scope to utilize the waste silk by extracting fibroin from silk polymer, which helps to make sericulture a viable agro industry. The goals of this study were to characterize the fibroin isolated from waste fibre and silk gland of tasar silkworm, *A. mylitta*. The antioxidative activity of fibroin was demonstrated earlier in mulberry silk (Luccini, 2012). However, the ability of tasar silk fibroin to scavenge free radicals in chemo - biological systems has not been comprehensively investigated. Hence, this study primarily aims to elucidate the antioxidant and anti-tyrosinase potential of tasar silk fibroin, employing a wide range of well established *in vitro* systems to gain mechanistic insights

MATERIALS AND METHODS

The fibroin threads were rinsed with water and kept for oven dry. Fibres and silk glands were solubilised with 9.3M LiBr solution and dialysed for 3 days in water. The solutions were lyophilized and stored at 4°C for further biochemical analysis.

Biochemical assays

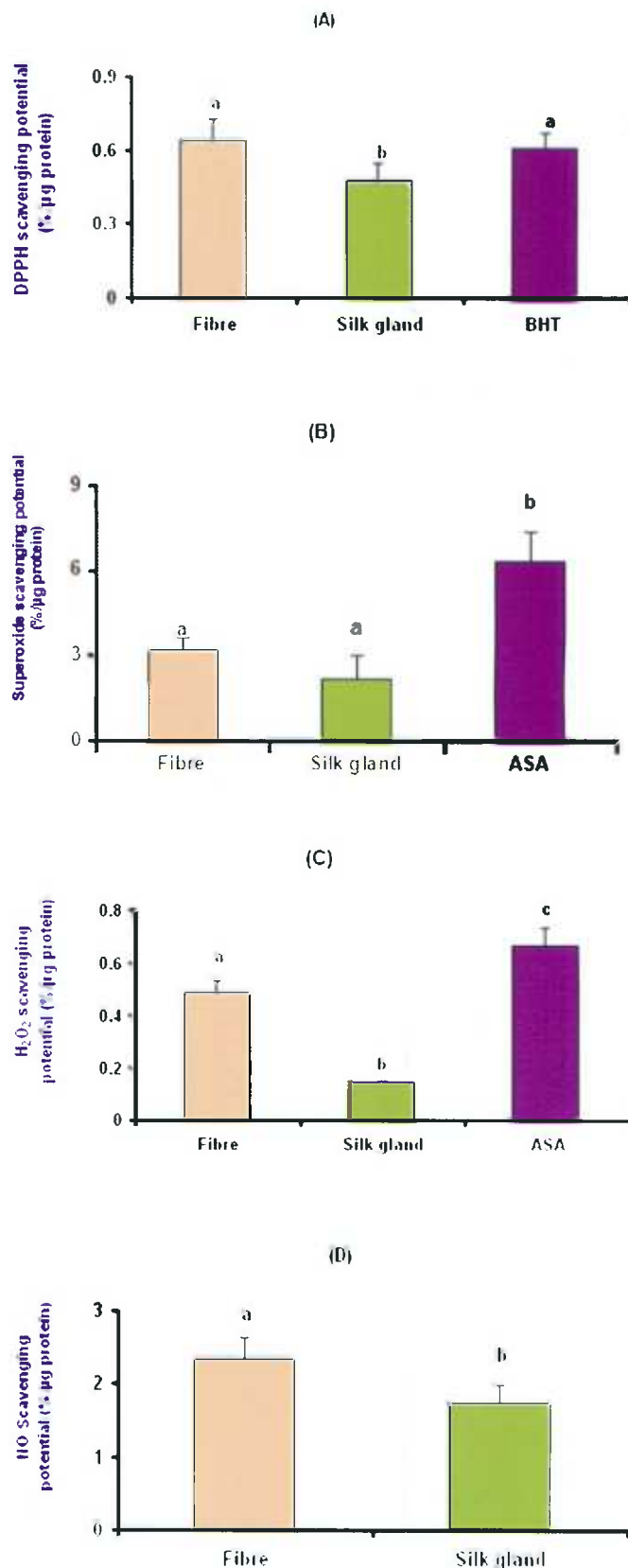
The protein estimation was done as per the method described by Bradford (1976). Free radical scavenging potential was measured by 2, 2-diphenyl-1-picryl-hydrazil (DPPH) by the method of Blois (1958). The superoxide scavenging ability of fibroin was assessed by the method of Nishikimi *et al.* (1972). The H_2O_2 scavenging power of extracts was estimated using the method of Ruch *et al.* (1989). Nitric oxide scavenging potential was estimated as per Sreejayan and Rao (1997). Anti-tyrosinase activity was also estimated (Aramwit *et al.*, 2010). Lipid peroxidation was induced by $FeSO_4$ system in sheep liver homogenate, and estimated as thiobarbituric acid reactive substances (TBARS) by the method of Ohkawa *et al.* (1979). Infrared spectra of cocoon and silk gland were measured by FTIR Spectroscopy. All the spectra were taken in the spectral range of $4000\sim 450\text{ cm}^{-1}$ (Outsource: Central Instrumentation Facility Laboratory, BIT Mesra, Ranchi)

Statistical analysis

All experiments were conducted with three replicates and results were expressed as mean $\pm$ standard deviation (SD). Differences among the means of samples were analyzed by ANOVA. Differences were considered statistically significant at a level of $P < 0.05$.

RESULTS AND DISCUSSION

The antioxidant activity of fibroin was analysed through DPPH radical assay, which primarily evaluates proton radical-scavenging ability. DPPH is one of the compounds that possesses a proton free radical with a



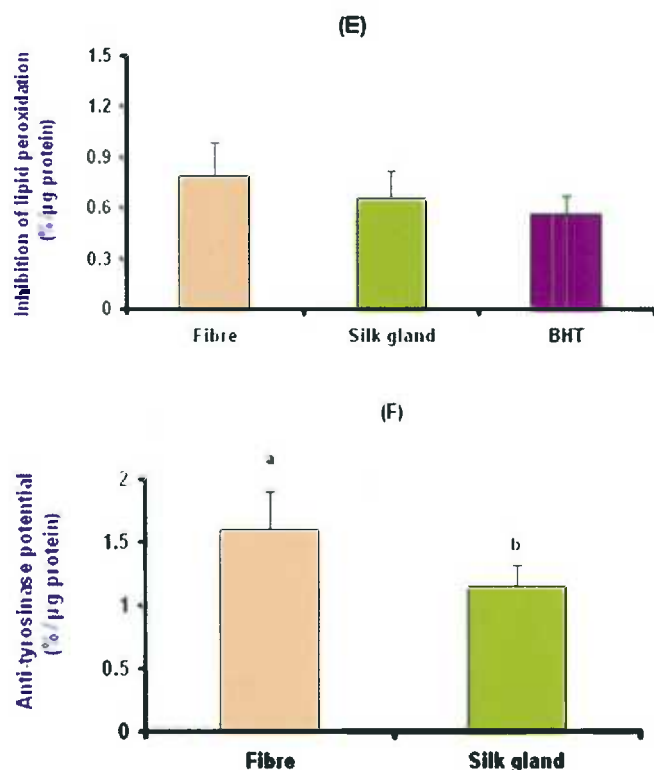


Figure 1: (A) DPPH scavenging, (B) Superoxide scavenging, (C) Hydrogen peroxide scavenging, (D) Nitric oxide scavenging, (E) Lipid peroxidation inhibition and (F) Anti-tyrosinase potential of fibre and silk gland of *A. mylitta*. Values are mean of triplicate determination $\pm$ SD (n=3). Superscripts of different letters are significantly different from each other at $P < 0.05$. (BHT-Butylated hydroxyl toluene; ASA-Ascorbic acid)

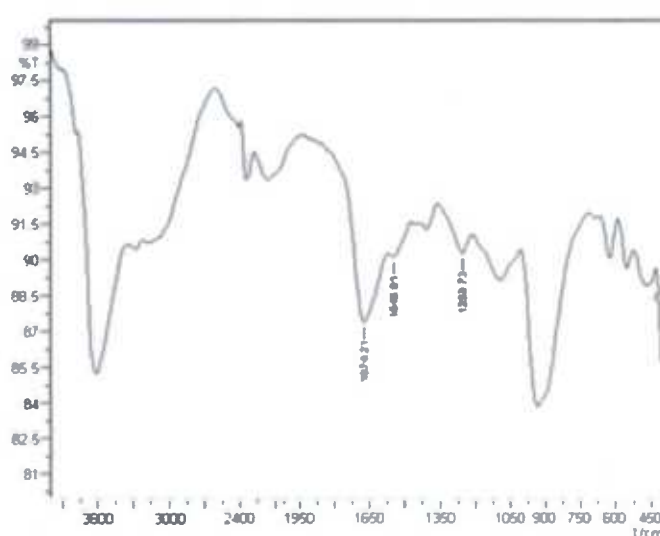


Figure 2 (A): FTIR spectra of fibre

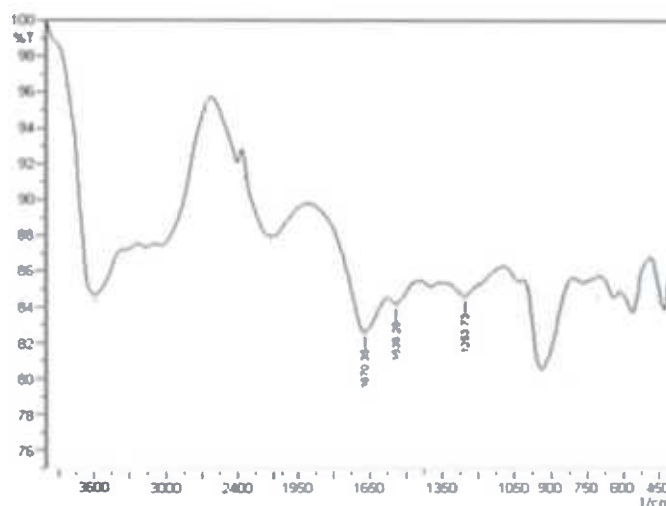


Figure 2 (B): FTIR spectra of silk gland

characteristic absorption at 517 nm, which decreases significantly on exposure to proton radical scavengers (Yamaguchi *et al.*, 1998). Further, it is well accepted that the DPPH free radical-scavenging by antioxidants is due to their hydrogen-donating ability (Chen and Ho, 1995). In the present study, fibre showed DPPH scavenging potential, which may be attributed to its hydrogen-donating ability (Figure 1 A).

Although superoxide is a relatively weak oxidant, it decomposes to form stronger reactive oxidative species, such as singlet oxygen and hydroxyl radicals, which initiate lipid peroxidation (Dahl and Richardson, 1978). In the present study, fibroin effectively scavenged superoxide radical (Figure 1 B). Further, superoxides are also known to indirectly initiate lipid peroxidation as a result of H_2O_2 formation, creating precursors of hydroxyl radicals (Meyer and Isaksen, 1995). These results clearly suggest that the antioxidant activity of fibroin may also be related to its ability to scavenge superoxides.

Although H_2O_2 is not very reactive, its high penetrability of cellular membrane leads to hydroxyl formation when it reacts with Fe^{2+} or the superoxide anion radical in the cell (Halliwell and Gutteridge, 2001). As shown in Figure 1 C, fibroin demonstrated H_2O_2 scavenging activity potential. Compared with fibroin, ascorbic acid was more effective for scavenging H_2O_2 .

The principle of the procedure is that sodium nitroprusside in aqueous solution at physiological pH spontaneously generates nitric oxide, which interacts with oxygen to form nitrite ions that can be detected by using Griess reagent. Isolated fibroin sample showed NO scavenging potential (Figure 1 D). In addition to reactive oxygen species (ROS), reactive nitrogen species (RNS) such as nitric oxide is also a factor involved in inflammation, cancer, and other pathological conditions (Nabavi *et al.*, 2008). Fibroin extracts may have the property to counteract the effect of NO formation and, in turn, may be of considerable interest in preventing the ill effects of excessive NO generation in the human body. Furthermore, the scavenging activity may also help to arrest the chain of reactions initiated by excess generation of NO, that are detrimental to human health.

In biological systems, lipid peroxidation (oxidative degradation of polyunsaturated fatty acid in the cell membranes) generates a number of degradation products, such as malondialdehyde (MDA), and is found to be an important cause of cell membrane destruction and cell damage (Yoshikawa *et al.*, 1997). MDA, one of the major products of lipid peroxidation, has extensively been studied and measured as an index of lipid peroxidation and as a marker of oxidative stress (Janero, 1990). In the present study, we measured the potential of fibroin to inhibit lipid peroxidation in goat liver homogenate, induced by the FeSO₄ system. It was observed that the standard (ASA) as having higher inhibition potential than fibroin samples (Figure 1 E).

Tyrosinases are copper-containing enzymes that catalyse the ortho-hydroxylation of monophenols to catechols and their subsequent oxidation to ortho-quinones (Schurink *et al.*, 2007). Further, it has been reported that tyrosinase plays a role in cancer and neurodegenerative diseases such as Parkinson's disease (Cavalieri *et al.*, 2002). Now a days, different tyrosinase inhibitors, such as kojic acid, polyphenols (flavonols, flavones, flavanones, flavanols, isoflavonoids, chalcones, stilbens and coumarins), benzaldehyde and benzoate derivatives (gallic acid), long-chain lipids and steroids,

other natural (anthraquinones) or synthetic inhibitors, are under investigation (Shimogaki *et al.*, 2000). The results reported here confirm that tasar fibroin exhibits anti-tyrosinase properties (Figure 1 F). The anti-tyrosinase activity of silk fibroin has already been established in *Bombyx mori* (Lucconi, 2012).

The results of the FTIR spectra gave us the specific absorbance wavelengths of the specific bonds which appeared in the silk fibroin particles. Typical peaks of silk fibroin are 1621, 1515 and 1231 cm⁻¹, characteristic for amide I (C=O stretching), amide II (NH deformation and C-N stretching) and amide III (C-N stretching and N-H deformation) (Zaharia *et al.*, 2012). FTIR spectra of silk fibroin particles show slightly shifted peaks as shown in Figure 2 A & B: 1674.21 (fiber) and 1670.70 cm⁻¹ (silk gland) for amide I, 1546.91 (fiber) and 1539.20 cm⁻¹ (silk gland) for amide II and 1253.73 (fiber) and 1253.73 cm⁻¹ (silk gland) for amide III. This shifting of the amides (I & II) may be the characteristic of β -sheet structure of regenerated silk fibroin particles.

In conclusion, the results obtained in the present study, clearly demonstrate that the fibroin contains a number of antioxidant compounds, which can effectively scavenge various ROS/RNS under *in vitro* conditions. The broad range of activity of the extract suggests that multiple mechanisms are responsible for the antioxidant activity of fibroin. Although we have not isolated the compounds responsible for the antioxidant activity, we speculate that it may be related to the protein in the extract. Further, fibroin extracts are having anti-tyrosinase potential. The multiple properties of fibroin demonstrated the potential application value of the tasar silk waste. However, the *in vivo* safety of fibroin needs to be thoroughly investigated in experimental mammalian models prior to its possible application as an antioxidant ingredient, either in pharmaceutical or in cosmetics.

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Article scientifique

**ACTIVITE ANTIOXYDANTE ET ANTI-TYROSINASE D'EXTRAITS
DE FIBROINE DE FIBRE ET DE GLANDE SERICIGENE DU VER A
SOIE TASAR, *ANTHERAEA MYLITTA* D.**

K. Jena*, A. K. Sinha, J. P. Pandey, Chakrapani, P. Kundu and A. Sahay

Central Tasar Research and Training Institute, Central Silk Board, Piska Nagri P.O.,
Ranchi 835303, Jharkhand, India.

*E-mail: jenakb2010@gmail.com

RÉSUMÉ

Dans cette étude, nous montrons l'activité antioxydante et anti-tyrosinase *in vitro* de la fibroïne tasar. L'activité antioxydante est évaluée par le test d'enlèvement du radical 2,2-diphényl-1-picrylhydrazyl (DPPH), le test d'enlèvement du radical superoxyde, l'enlèvement du peroxyde d'hydrogène, l'enlèvement de l'oxyde nitrique et l'inhibition de la peroxydation des lipides. L'activité anti-tyrosinase des extraits de fibroïne a été déterminée en utilisant une tyrosinase fongique comme un système modèle adéquat. La présence de fibroïne dans les extraits est confirmée par la spectroscopie infrarouge de la transformée de Fourier (FTIR) qui montre des pics pointus aux longueurs d'ondes 1674,21~1670,70 ; 1546,91 ~1539,20 et 1253,71 dans le spectre FTIR. Les résultats suggèrent que la fibroïne tasar possède des activités antioxydante et anti-tyrosinase qui trouvent leur place en cosmétique ce qui pourrait entraîner des bénéfices économiques et sociaux significatifs.

Mots-clés: Antioxydant, anti-tyrosinase, fibroïne, radicaux libres, ver à soie tasar.



ONCE IN THREE DAYS FEEDING DURING YOUNG AGE SILKWORM REARING - A PATH BREAKING TECHNOLOGY

C. Shivakumar^{1*}, M. V. Chandrakala¹ and G. Satish²

¹Karnataka State Sericulture Research and Development Institute
Thalaghattapura, Bengaluru 560062, India.

²Department of Sericulture, Govt. of Karnataka, Bengaluru 560001, India.

*E-mail: dr.shivakmr@gmail.com

ABSTRACT

Young age silkworm (chawki) is commercially grown in large numbers by 'Chawki Rearing Centers' (CRC) and supplied to cocoon producers. Success in silkworm crop is largely influenced by quality of chawki rearing. Chawki rearing demands stringent maintenance of leaf quality, pathogen free environment, optimum temperature and relative humidity in addition to constant attention and skillful handling. Under tropical conditions, quality of harvested leaf deteriorates due to loss of moisture during feeding intervals. Hence, larvae are repeatedly fed with fresh leaf 3 to 4 times per day during chawki rearing, demanding high input cost in terms of leaf and labour. Ever increasing input cost, expenditure on wages and decreasing labour resource have become the main factors of concern, challenging the growth and sustenance of sericulture industry. In this context, Karnataka State Sericulture Research and Development Institute, Bengaluru, India has developed a novel method of chawki rearing called "One Feed per Instar Technique" (OFIT) which cuts down the quantum of leaf requirement and labour dependency leading to significant reduction in cost of cocoon production. The technique is based on the principle of systemic maintenance of mulberry leaf on the rearing bed enabling leaf to remain fresh and succulent throughout the instar. Prolonged keeping quality of leaf on the rearing bed suffices feeding of chawki larvae only once in an instar. Further, the innovation enables supplementation of nutrients systemically through mulberry shoot-lets to silkworm to enhance nutritional status of the feed.

Key words: Chawki, OFIT, one feed, silkworm rearing.

INTRODUCTION

Quality of mulberry leaf plays a vital role in the success of young age silkworm (chawki) rearing and cocoon yield. Maintenance of leaf quality on the rearing bed is an issue of concern and has been a challenge under the tropical climate for several decades (Datta, 1992). Attempts have been made earlier to maintain the freshness of leaf in the rearing bed for prolonged periods through 'single feeding technology', and use of 'isolation chamber' during chawki rearing (Sekharappa *et al.*, 1991, 1995), but these techniques did not gain popularity in adoption at the field level. Several methods are being

practiced for conservation of leaf quality and maintenance of leaf moisture (Srinawat *et al.*, 1987) in the rearing bed viz., using wet foam pads and paraffin paper during young age silkworm rearing (Datta, 1992; ESCAP 1993; Krishnaswami, 1979) and different feeding methods viz., chopped leaf, whole leaf and mulberry twigs (Vidya *et al.*, 1987). Silkworms are frequently fed under tropics to combat with the deterioration of leaf quality due to loss of moisture in the rearing bed. Further, frequency of feeding has an influence on the growth of chawki, rearing bed hygiene, input cost and cocoon yield. Of late, decreasing labour resource and increase in input cost are the main concern for the growth and sustenance of the sericulture

industry. The present scenario demands for optimizing input cost and labour force for enhancing the productivity. In this context, Karnataka State Sericulture Research and Development Institute, Bengaluru, India has developed a novel method for chawki rearing called "One Feed per Instar Technique" (OFIT) to bring down dependency on the labour and other input costs. The new technology enables the maintenance of mulberry leaf freshness and succulence for more than 3 days in the silkworm rearing bed, bringing down the requirement of number of feeds per instar. Further, the system can be utilized as a medium for supplementing nutrients to silkworm. OFIT has several other inbuilt potential benefits viz., maintenance of micro-environment, automatic distribution of larvae, maintenance of rearing bed hygiene and replenishing leaf moisture. Apart from sericulture industry, the concept has potentials of application in other disciplines of research. This article presents a brief account on the innovation and its advantages to the industry.

MATERIALS AND METHODS

Disease free layings (DFLs) of the popular silkworm hybrid viz., PM x CSR2 in three replications (5 DFLs / replication) were reared up to the end of 2nd moult as the following treatments: (1) Systemic nutri-media supplementation (2) Systemic carrier control - distilled water and (3) Normal control - Standard rearing practice. Materials essential for conducting silkworm rearing are Nutri-media boxes (Figure 1), OFIT rearing stand (Figure 2), rearing appliances and consumables. Moisture retention efficiency of cut leaf, whole leaf, shootlet (non-systemic) and shootlet maintained systemically under distilled water (cc) and nutrient media (experimental) were determined. Parameters studied are brushing percentage, chawki loss, larval duration, larval biomass, survival rate and cocoon yield, cocoon weight, shell weight and cocoon shell percentage. Further, the performance was evaluated at field level.

Technique of OFIT rearing

The first feed (during brushing) was given with cut



Figure 1: OFIT media box



Figure 2: OFIT chawki rearing stand



Figure 3: OFIT chawki rearing



Figure 4: Auto-circulation of media



Figure 5: Offering of shoot-lets



Figure 6: Larvae settled for 1st moult

mulberry leaf to hatched silkworm larvae and after 2 hours of brushing, mulberry shoot-lets with 4-6 top leaves of 30-35 days plant growth were offered. Mulberry shoot - lets were harvested in the cooler hours i.e., before 8 a.m. in the morning with the cut ends immediately being placed in a bucket containing media/water (2 inches depth of media/water). Shoot - lets were covered by wet cloth to avoid loss of moisture while being transported to rearing room. Temperature of 28 °C and RH of 85 % was maintained in the rearing room. Media boxes were stacked

Table 1: OFIT – Standards for chawki rearing (100 DFLs)

Sl. No.	Particulars	Activity / Standard
1	Garden	Irrigate 4-5 days prior to brushing, 32-35 days plant growth period
2	Mulberry variety	V-1, M-5
3	Shoot-let harvest	Use secateurs/sickle to cut shoot-lets & immerse cut ends of shoot-let in the bucket containing 2-3" depth of media/water. Harvest shoot-lets of 4-6 leaves for 1 st instar & 6-8 leaves for 2 nd instar
4	Leaf : Stump ratio	70 : 30
5	Rearing room temperature & RH	27-28°C & 80-85 %
6	Feeding frequency	Once in 1 st instar & once in 2 nd instar
7	Quantum of feed	1.6-1.7 kg for 1 st instar, 6.5-7 kg for 2 nd instar (70 shoot-lets for 1 st instar & 170 shoot-lets for 2 nd instar)
8	Care during moult	Remove the shoot-lets from media 8 h prior to moult, dust lime powder @ 3-4 g/sft
9	Rearing bed spacing	16 sft – 1 st instar & 32 sft – 2 nd instar
10	Lime & bed disinfectant	3-4 g /sft during 1 st & 2 nd instar
11	Media box – 2'x 5"x 22 mm	16 boxes – end of 2 nd instar
12	Rearing stand (7' H x 2.5' W x 8' L)	300 DFLs @ 9" interval shelves
13	Media / Water	750 ml/box
14	Late age rearing	Rearing as per standard practice after 2 nd instar

on rearing stand (Figure 3) and pipes were connected for auto-circulation of the media (Figure 4). Shoot-lets were offered juxtaposed with cut ends immersed in media (Figure 5). Shoot-lets having 4-6 leaves were offered at the rate of 70 no. / 100 DFLs during 1st instar and those with 6-8 leaves @ 170 no. / 100 DFLs during 2nd instar at the beginning of instar which would suffice for the whole instar. The standard package of practices are presented in Table 1.

Care during moult: As the larvae approached moulting, shoot-lets were withdrawn from the media/water 8 h prior to application of lime powder. Rearing bed was spread and allowed for aeration at relative humidity of 60-65 %. Lime powder at the rate of 2-3 g / sft was dusted when more than 90 % larvae settled for moult (Figure 6). Bed disinfectant at the rate of 4-5 g / sft was applied 30 minutes before resuming the feed to the 2nd instar. Uniform distribution of larvae in the bed was ensured before resuming feed.

Table 2: Comparative performance of young age silkworm rearing on OFIT

Treatment	Brushing %	Biomass – 4 th day		Biomass – 8 th day		% Chawki loss	Larval duration (h)
		Weight (mg/larva)	% Increase	Weight (mg/larva)	% Increase		
OFIT (Systemic)	97.20	4.013	120.21	35.101	129.81	3.37	177
Carrier control (Systemic)	96.75	3.866	115.72	32.618	120.61	3.09	177
Normal control (Standard rearing practice)	97.86	3.750	100.00	26.957	100.00	3.52	180

RESULTS AND DISCUSSION

Results on the leaf moisture retention efficiency under normal practice *i.e.*, in cut leaf, whole leaf and shoot let feeding (one feed/day technology) compared to the systemic maintenance of shoot-let (OFIT) clearly indicated that moisture per cent under normal practice reduced drastically (Govindan *et al.*, 1991) over the period and attained the least of 10.88 % on 8th day while, for OFIT, the moisture content was maintained even after 8 days with retention of freshness and succulence of leaf over normal control (Figure 7). The unique feature of OFIT is the prolonged maintenance of moisture content due to continuous imbibition of water and nutrients. The results on growth of young larvae (Table 2) point towards accumulation of higher biomass (body weight) at the end of 7th day (II instar) on systemic nutrient media than control (Figure 8) which can be attributed to continuous and uninterrupted consumption of quality leaf throughout larval duration. Further, there was a reduction in the larval duration (10-12 %) compared to normal rearing which could be due to reaching the nutritional trigger of moulting earlier than the control batch (Figure 9). Further, because of the freshness of leaf, larvae effectively consumed the feed throughout the feeding period resulting in less feed refusal *i.e.*, 5 % against 45-50% in the existing rearing practice. Hence, there is a leaf saving up to 45-50 % with labour saving of 50 %. Labour and time saving feature of the new technology is well pronounced in feed harvest and activities related to feeding and rearing. The cocoon characters of larvae reared on OFIT during chawki stage were superior (Table 3) over normal rearing (branch feeding), indicating the perpetuating effect of higher biomass and congenial micro-environment during young age. Increase of 10.5 % of cocoon weight (Figure 10) in the formulated media may be attributed to enhanced nutritional status of feed during chawki under OFIT system. Increase of 6.6 % in cocoon weight and similar trends in shell weight (Figure 11) and cocoon shell percentage (Figure 12) in carrier control batches are attributed to continuous access of fresh feed throughout the feeding period during chawki. Larval duration (chawki to spinning) was reduced by 6 % in both media

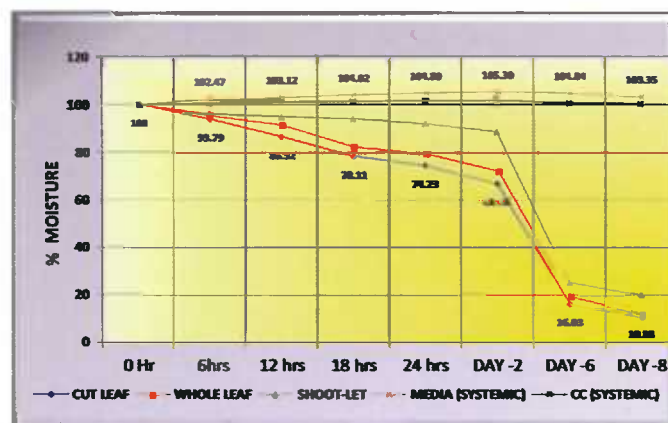


Figure 7: Leaf moisture content at different time intervals among systemic and normal practices

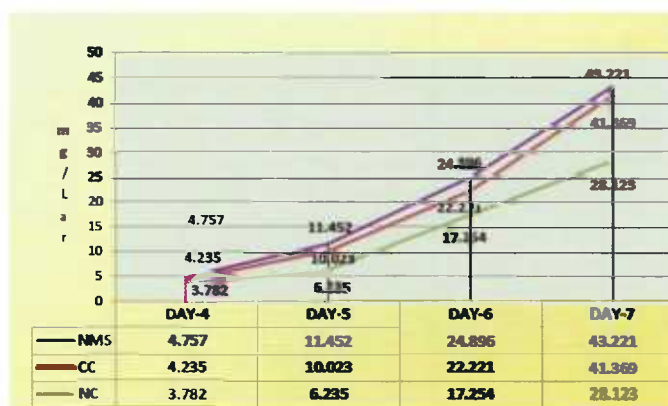


Figure 8: Accumulation of biomass during the progress of chawki rearing. NMS-Nutri media systemic; CC-Carrier control systemic; NC-Normal control.

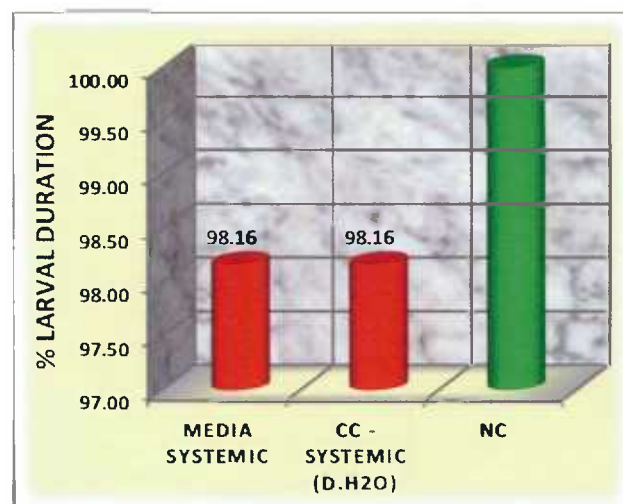


Figure 9: Larval duration up to 2nd moult – OFIT & Standard practice

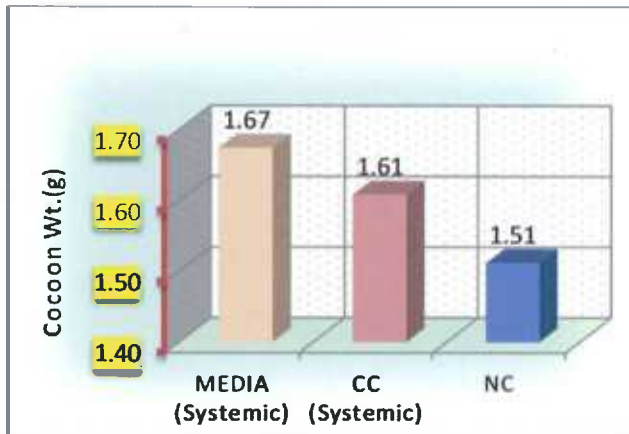


Figure 10: Effect of OFIT during chawki on cocoon weight

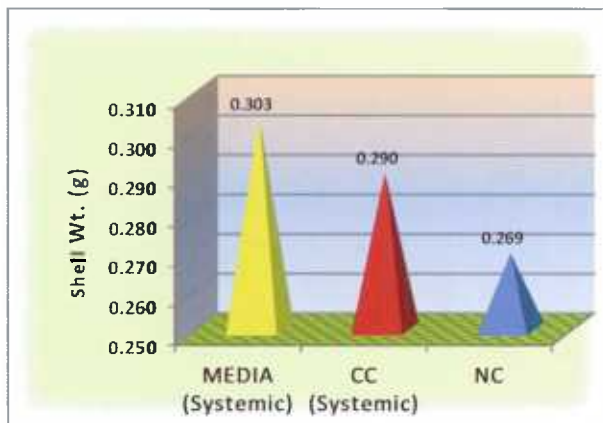


Figure 11: Effect of OFIT during chawki on shell weight

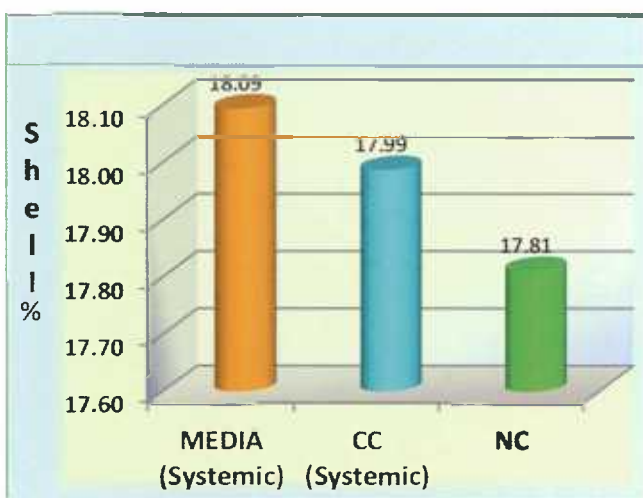


Figure 12: Effect of OFIT on cocoon shell percentage

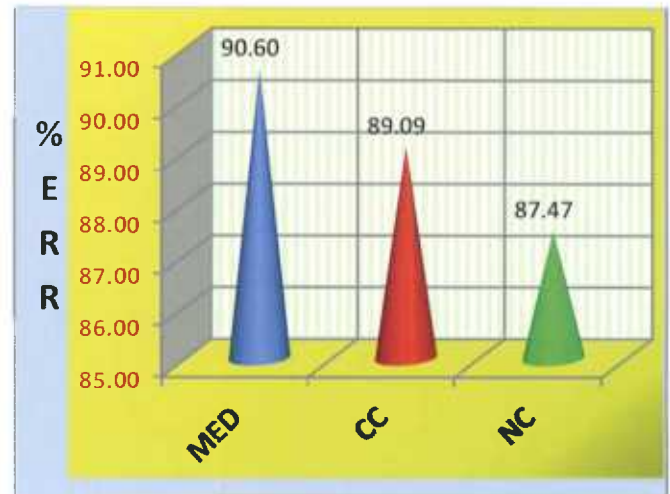


Figure 13: Effect of OFIT on effective rate of rearing

and carrier control batches indicating early moulting response due to nutritional threshold (Bajapeye *et al.*, 1991) during young age. Effective rate of rearing was better in OFIT system (Figure 13) than normal rearing indicating that the OFIT rearing supports the health of the larva by maintenance of rearing bed hygiene. All these responses endorse the beneficial effects of the OFIT over normal (Muniraju *et al.*, 2003) rearing practice in significantly bringing down the input-cost in terms of leaf and labour (Table 4) leading to vertical elevation of economic status of cocoon producers / CRCs and overall prosperity of sericulture industry.

Field performance of OFIT

OFIT chawki rearing was conducted in Commercial Chawki Rearing Center and larvae after 2nd moult were supplied to farmers in different villages of Kanakapura and Haraohalli area of Karnataka, India to study the field performance. 2200 Dfls each of cross breed raised under OFIT and normal rearing practice were supplied to farmers for conducting late age rearing. Performance of OFIT batches indicated enhancement of yield level by 5.8% with improvement in cocoon characters *i.e.*, cocoon weight, shell content and shell percentage over normal rearing practice. Further, the market rate was also higher

Table 3: Effect of OFIT during young age rearing on late age performance

Treatment	Max. larval weight (g)	Cocoon yield		Cocoon weight (g)	Shell weight (g)	Shell %	ERR by No. (%)	Larval duration (h)
		No.	Weight (kg)					
OFIT (Systemic)	4.04	457	0.716	1.59	0.283	17.85	89.60	25:00
Carrier control (Systemic)	3.91	447	0.656	1.49	0.265	17.71	87.27	25:00
Normal control (Standard rearing practice)	3.80	436	0.620	1.44	0.252	17.54	85.20	26:12

Table 4: Advantages of OFIT

Sl. No.	DETAILS	BENEFITS FROM OFIT
1	Labour saving	50 % labour saving compared to existing practice
2	Leaf requirement	50 % leaf saving compared to existing practice
3	Growth and biomass	13-18 % increase over existing practice
4	Productivity	• Increase in cocoon yield and improvement in cocoon quality • Brings down input cost significantly- enhances the productivity
5	Hygiene & contamination of pathogens	• Larval handling is the least: 4 times under OFIT as against 17 times in existing practice • 2 feeds are given under OFIT while, 17 feeds are offered in the existing practice • No bed cleaning is required during chawki under OFIT
6	Leaf quality	Leaf quality is ensured throughout the feeding period as against depletion of leaf quality by the end of each feeding interval in the existing practice
7	Work/attendance requirement	3 days under OFIT practice as against 7 days under existing practice
8	Micro-environment	OFIT system supports easy and effective maintenance of micro-environment during chawki
9	Adoption of technology	• Boon to CRCs, small & medium scale farmers • Advantageous for water/nutrient stressed garden • Provides free time to farmer during rearing • Optimizes input costs
10	Prospects	• The concept can be a potential tool in many research areas besides sericulture

generating an average additional income of ₹2435 per 100 DFLs. These responses from field clearly indicate the impact of improved growth performance of 'OFIT-

chawki' on better performance in late age parameters realising higher returns to the farmers (Table 5).

Table 5: Field performance of OFIT

Sl. No.	Particulars	Rearing Technique	
		OFIT	Existing Practice
1	Silkworm race	PM x CSR2	
2	Number of villages	8	8
3	Number of farmers	7	7
4	Number of crops	12	12
5	Total number of DFLs reared	2200	2200
6	Total cocoon yield (kg)	1960.2	1852.4
7	Average cocoon yield/100 DFLs	89.1	84.2
8	Average cocoon weight (g)	1.912	1.713
9	Average shell weight (g)	0.316	0.306
10	Average shell %	18.89	17.81
11	Average cocoon rate at market (₹)	341.2	332.06
12	Total cocoon sale proceeds (₹)	668663	615108
13	Excess income from OFIT (₹)	53555	---
14	Profit from adoption of OFIT for 100 DFLs (₹) (Excluding benefits and savings during chawki)	2435	--

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Article scientifique

UN NOURRISSAGE TOUS LES TROIS JOURS PENDANT L'ELEVAGE DES JEUNES VERS A SOIE – UN SAUT TECHNOLOGIQUE

C. Shivakumar¹, M. V. Chandrakala¹ and G. Satish²

¹Karnataka State Sericulture Research and Development Institute

Thalaghattapura, Bengaluru 560062, India.

²Department of Sericulture, Govt. of Karnataka, Bengaluru 560001, India.

*E-mail: dr.shivakmr@gmail.com

R É S U M É

Les jeunes vers à soie sont élevés en masse dans les “Chawki Rearing Centers” puis délivrés aux producteurs de cocons. Le succès de la récolte dépend largement de la qualité de l'élevage chawki. Cet élevage demande un maintien strict de la qualité de la feuille, d'un environnement sans pathogènes, d'une température et d'une humidité optimales ainsi que d'une attention constante dans les manipulations. Dans les conditions tropicales, la qualité des feuilles se détériore en raison de la perte d'humidité entre deux repas. Aussi, les larves sont nourries de manière répétée avec des feuilles fraîches 3 à 4 fois par jour, ce qui entraîne un coût élevé en terme de feuilles et de main d'œuvre. L'accroissement des coûts, l'extension des charges et la décroissance des ressources en main d'œuvre sont devenus les principaux facteurs concernés qui entravent le développement et le maintien de la sériculture. Dans ce contexte, le Karnataka State Sericultural Research and Development Institute à Bangalore, Inde a développé une nouvelle méthode d'élevage des jeunes vers à soie appelée « Un repas par Stade » (OFIT) qui réduit la quantité de feuilles et le travail nécessaires conduisant à une baisse significative du coût de la production de cocons. Cette technique repose sur le principe du maintien systématique des feuilles de mûrier sur la litière d'élevage permettant aux feuilles de rester fraîches et succulentes pendant tout le stade. De plus, cela permet l'ajout systématique de nutriments à travers les tiges de mûrier ce qui permet d'améliorer le statut nutritionnel de l'aliment pour les vers à soie.

Mots-clés: Chawki, OFIT, un repas, élevage de vers à soie.



BIOLOGICAL AND HEMATOLOGICAL STUDIES ON FLACHERIE DISEASED LARVAE OF GAMMA IRRADIATED SILKWORM, *BOMBYX MORI* L.

Souad M. Mahmoud¹, Akila M. El-shafei², Abulyazid I.³ and Rehab H. Taha^{*}

¹Agricultural Research Center, Plant Protection Research Institute, Sericulturals Research Department, Giza, Egypt.

²Ain Shams University, Faculty of Science, Cairo, Egypt.

³Atomic Energy Authority, Cairo, Egypt.

^{*}E-mail: rehab_hosny1@hotmail.com

ABSTRACT

Gamma radiation at three different doses (10, 20 and 30 Gy) were applied to silkworm *Bombyx mori* at late embryonic egg stage. Naturally diseased (flacherie affected) and healthy silkworms out of the progeny were investigated for the impact of gamma irradiation on the biological and commercial characters of silkworms. The manifestations if any on the development and progress of flacherie disease was studied. Blood cell deformations in naturally diseased larvae of irradiated and non-irradiated groups were also observed. The results revealed that, gamma radiation at the above experimental doses did not have any impact on the symptoms of flacherie disease. 30 Gy dose proved to be fatal at embryonic stage itself. 10 Gy dose could not bring about any significant changes on parameters studied whereas for 20 Gy dose, all these parameters exhibited a significant decline, compared with control. But there was a positive response towards 10 Gy dose in terms of increased number of different blood cells that boosted immunity enabling the insect to resist microbial infection and a consequent reduction in death rate. Gamma radiation as well as disease induced deformations in all blood cells.

Key words: Biological and commercial characters, blood cells, *Bombyx mori* L., flacherie disease, gamma irradiation.

INTRODUCTION

It's of a great concern that mulberry silkworm, *Bombyx mori* L. is prone to bacterial infection throughout the year. Flacherie disease caused by both bacteria and viruses has been taking a heavy toll on the cocoon crop. Infectious flacherie virus (IFV) that causes flacherie disease, infects the goblet cells of the midgut. These cells secrete digestive fluids, with bacteriostatic and virucidal properties. Degeneration of goblet cells affects these functions and permits rapid proliferation of enteric bacteria. Under the invasion of viruses and bacteria, mortality of silkworm larvae is accelerated (Lian, 1991). The pathogen is difficult to be detected at early stage of

infection, as the discernible morphological symptoms are developed at late stages of infection (Shamim *et al.*, 1996). Since there are no specific preventive measures for the occurrence and spread of disease other than sanitized breeding and rearing methods, the only commercial practice is to discard large stock of worms in the case of infection to avoid the spread of disease (Acharya *et al.*, 2002). Bacterial infection to silkworm larvae cause behavioral and physiological alterations, leading to a new metabolic profile as reported by Taha (2007). Bacteria often suppress the insect immune system in order to maintain a favorable environment thus prolonging their ability to reproduce (Keeling and Fast, 2002). Insects possess an effective innate immune system against foreign

microorganisms. Gamma rays are naturally cosmic rays which lead to changes that may induce positive mutation in any living organism. Gamma rays are known to widen the genetic variability, enabling the breeder to step up selection for the quantitative characters and are extensively used in crop and animal improvement programs (Premila Chanu and Ibotombi, 2011).

The present investigation aims to study the biological and haematological changes in diseased and healthy mulberry silkworm, *Bombyx mori* L. of irradiated and non-irradiated groups. The impact of irradiation as manifested on the qualitative and quantitative characters related to silk yield was assessed.

MATERIALS AND METHODS

Rearing technique

Preserved eggs of European univoltine hybrid silkworm were obtained from The Sericulture Research Department of Plant Protection Research Institute, Agricultural Research Center, Egypt. The standard methodology of silkworm rearing was followed (Krishnaswamy, 1978).

Irradiation was conducted at the Gamma Cell Unit at The Middle Eastern Regional Radioisotope Center for the Arab Countries, Dokki, Egypt. The Co 60 Gamma cell provides 3.91 rad/sec. Experimental egg groups, each weighing 0.5 g were sealed in porous plastic sacks and placed inside the cell to be irradiated with the selected gamma doses (10, 20 and 30 Gy) on the 7th day of incubation at 25 °C (late embryo stage). Treated eggs were prepared as follows: 100 eggs / 4 replicates / group and incubated under optimum conditions. Hatched larvae were reared till the end of the fifth larval instar. Non-irradiated control batch was reared in parallel. The naturally diseased (flacherie) larvae were collected to form separate experimental groups under each category. Incubation period, larval duration, larval mortality percentage, pupation rate, cocoon and cocoon shell weights and cocoon shell percentage for each group was

recorded / estimated.

Haemocyte count

Total and differential haemocyte counts were carried-out in the control and irradiated groups for both healthy and flacherie diseased larvae on the sixth day of the fifth larval stage, according to Sirotina (1949). Morphological descriptions of haemocytes were based on type of cells, nuclei shape, diameter, nuclear - cytoplasmic ratio, vacuoles and other characteristics (Salt, 1970).

Statistical analysis

Data were analyzed statistically by using T-TEST.

RESULTS AND DISCUSSION

The results obtained on biological and commercial characters of healthy control and irradiated groups are tabulated in Table 1. No significant difference was noticed in the incubation period between that of 10 and 20 Gy irradiated groups and control group (8.333, 8.333 and 9.667 days, respectively). 10 and 20 Gy doses stimulated egg hatchability, while 30 Gy dose caused an inhibition in this regard. However, 10 and 20 Gy doses didn't affect the symptoms of flacherie disease.

10 Gy irradiated group revealed no-significant differences with non - irradiated one in larval duration, larval mortality, pupation rate, cocoon weight and cocoon shell percentage for both the sexes. On the contrary, 20 Gy group was significantly different from control in all the above mentioned parameters. Yusifov *et al.* (1991) mentioned that, applying gamma rays at low dose-rate to *B. mori* L. larvae drastically decreases the death rate of larvae. Irradiation increases the number of cells in the glands, resulting in an increase in the formation of liquid silk, consequently increasing the cocoon shell weight (Aruga, 1994). Kamelia and Souad (1995) drew the same conclusion by using low doses and reported that the greatest stimulatory effect for all the biological traits was achieved when the eggs of *B. mori* L. were exposed to low doses of radiation.

It is probable that, the response of both male and female pupae was similar to irradiation. Nirmala *et al.* (1999) in *B. mori* L. recorded that, the stimulatory or inhibitory effects of different doses of ionizing radiation on the growth of larvae and their silk glands reflected on the formation of pupae, cocoons and silk content.

Blood cells

Haemocytic variations as well as the changes in cells themselves depended not only on a microbe but also on whole series of other causes as temperature, age of host, quantity and quality of injected substances, *etc.* (Ratcliffe, 1986). Irradiation generally induced deformations in all haemocytes, the rate being proportional to the dose (El-Maasarawy and Abd El-Salam, 1991).

Information on the count and morphological features of blood cells of healthy and flacherrie diseased larvae belonging to irradiated and control groups are represented in Table 2 and Figure 1. On the basis of morphological cell features and staining properties (using Giemsa stain), five cell types were observed in the larval haemolymph: proleucocyte cells, granular cells, plasmatocyte cells, spherule cells and oenocytoid cells. In the present study, bacterial infection induced deformations in all blood cells.

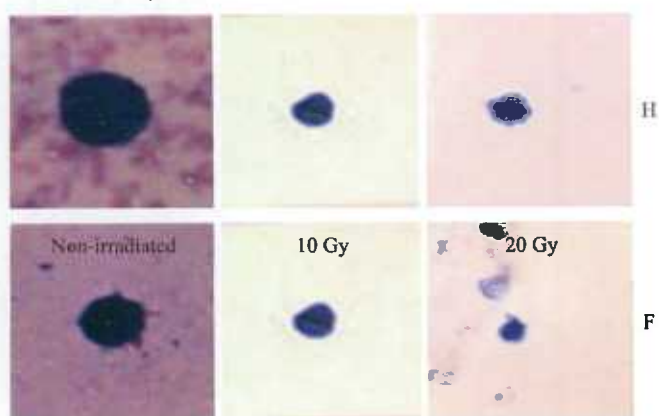
Proleucocytes are mitotically dividing cells proposed to be the stem cell that gives rise to all other cell types (Essaway *et al.*, 1985). In the present study, proleucocytes percentages in non-irradiated flacherrie diseased larvae and in those irradiated with 10 and 20 Gy doses were highly significantly different from that of healthy (control) ones. The only change noticed for proleucocyte cells in flacherrie diseased larvae was percentage increment, while proleucocytes of 10 Gy and 20 Gy irradiated larvae showed shrinkage in size and intense staining compared with that of healthy samples (Figure 1 A).

Functions of granular cells include phagocytosis (Jones, 1962), nodule formation (Ratcliffe and Gagen,

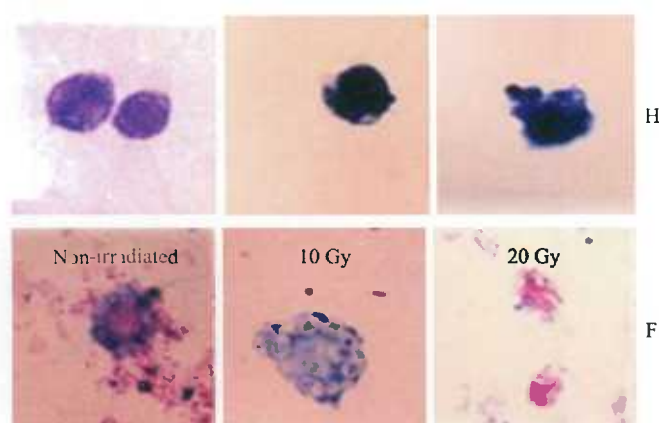
1976) and contain components of phenoloxidase system (Aruga, 1994). In the present study, granular cells constituted the largest portion of the haemocyte populations followed by plasmatocytes and account 51.892 ± 3.98 % of total blood cell count (Table 2, Figure 1 B). Granular cells of non-irradiated flacherrie diseased larvae showed a significant difference from that of healthy (control) ones (36.517 and 51.892 %, respectively). There was a significant difference between irradiated flacherrie diseased larvae and the respective healthy (control) ones in respect of granular cells (in 10 Gy irradiated larvae, it was 41.059 % and 35.990 %, respectively and in 20 Gy, it was 20.862 and 31.230 %, respectively). Granular cells of 10 and 20 Gy treatments of flacherrie diseased larvae showed the same pathological changes as it induced in non-irradiated cells. The quantities of bacterial nodules were lower than that of non-irradiated larvae. Wago (1982) suggested that, the haemolymph of *B. mori* contain two kinds of humoral factors which affect the cellular reactions against foreign materials: one is to promote the attachment of granular cells to these materials and the other is to activate filopodia elongation of granular cells.

Plasmatocytes percentage in non-irradiated group of flacherrie diseased larvae was not significantly different from that of healthy (control) ones (22.557 and 31.968 %, respectively) whereas in 10 Gy and 20 Gy irradiated larvae, plasmatocytes percentage of flacherrie diseased larvae was highly significantly different from that of healthy (control) ones (33.058 and 47.490 %), (15.283 and 48.402 %, respectively). These types of haemocytes are with variable shapes, polymorphic with variable sizes but usually spherical, ovoid or fusiform, often with pseudopod. The plasmatocytes are characterized by homogenous, vacuolized cells with usually faintly stained cytoplasm (basophilic) with pink nucleus on Giemsa staining (Figure 1 C). Plasmatocytes were highly affected by bacterial infection and played an important role in phagocytosis. Under the condition of flacherrie, a pathological vacuolization in the cytoplasm was detected with increasing rate of infection, the cells being surrounded by bacteria to finally form bacterial nodules

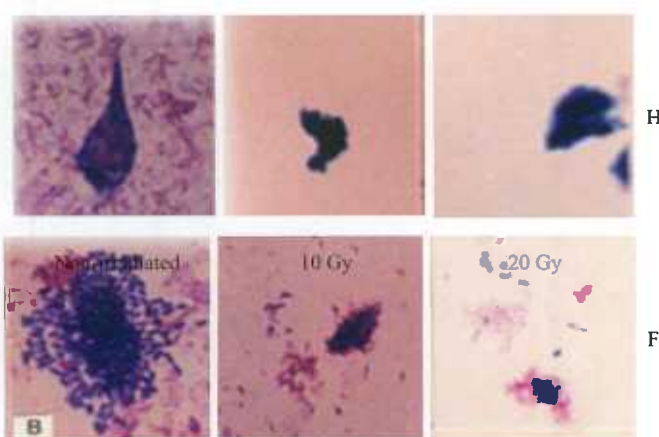
A. Proleucocyte cells



B. Granular cells

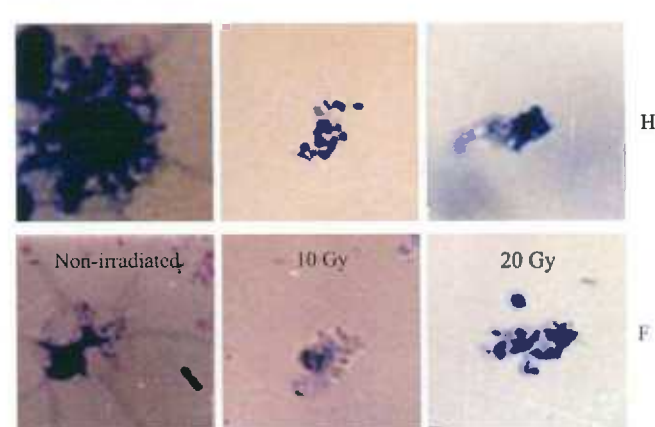


C. Plasmacyte cells



with a rapid fall-off in plasmacytes number. Plasmacytes of healthy 10 Gy irradiated larvae showed morphological deformations as damage to the outer cell surface or cell boundaries, the cells gained dark stain and shrunk in size. Irradiation with 20 Gy caused more deformations in plasmacytes but cells appeared fainter than that of 10 Gy dose treatment. Deformed

D. Spherule cells



E. Oenocytoid cells

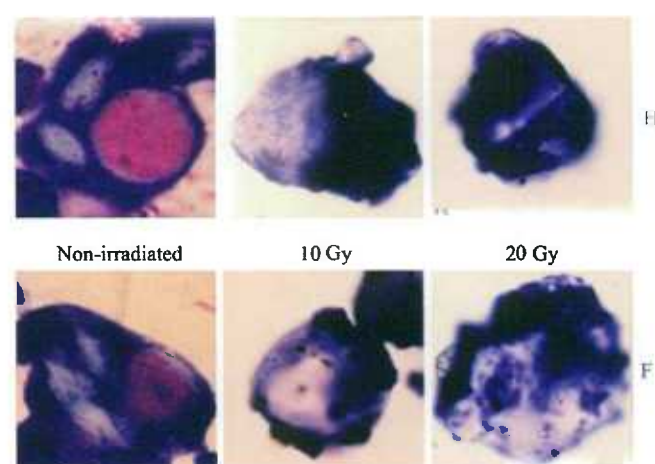


Figure 1: Haemocytes (100 X) of healthy and flacherie diseased *Bombyx mori* L. larvae from irradiated and non-irradiated groups. H-Healthy, F-Flacherie affected.

plasmacytes of 10 and 20 Gy dose treated, flacherie diseased larvae showed the same pathological changes due to bacterial infection as in the case of non-irradiated flacherie diseased larvae. It is worthy to note that irradiation lowered the number of clumps. Bacterial infection causes the appearance of new type of plasmacytes, phagocytes and adipohaemocytes. Adipohaemocytes are typically round or oval cells usually with very distinct fat-like or lipid-like droplets in the cytoplasm. Granular inclusions are also present. The nucleus is centrally located and pink in color on Giemsa staining.

Granular cells and spherule cells were reported to be

Table 1: The biological and commercial parameters (mean $\pm$ SE) in irradiated healthy *Bombyx mori* L.

	Control/healthy	10 Gy	20 Gy
Incubation period (days)	9.667 $\pm$ 0.33	8.353 $\pm$ 0.33	8.333 $\pm$ 0.33
Larval duration (days)	34.667 $\pm$ 1.33	34.353 $\pm$ 1.202	39.333 $\pm$ 0.33**
Larval mortality (%)	31.93 $\pm$ 10.22	35.987 $\pm$ 5	69.82 $\pm$ 0.175**
Pupation rate (%)	48.09 $\pm$ 7.18	54.759 $\pm$ 6.81	20.646 $\pm$ 0.324**
Cocoon weight ♂ (g)	1.11 $\pm$ 0.03	1.049 $\pm$ 0.03	0.740 $\pm$ 2.653***
Cocoon weight ♀ (g)	1.396 $\pm$ 0.04	1.327 $\pm$ 0.09	0.822 $\pm$ 0.037***
Cocoon shell weight ♂ (g)	0.247 $\pm$ 0.01	0.217 $\pm$ 0.009**	0.118 $\pm$ 6.11***
Cocoon shell weight ♀ (g)	0.259 $\pm$ 0.01	0.249 $\pm$ 0.009	0.152 $\pm$ 2.49**
Cocoon shell % ♂	22.198 $\pm$ 0.60	20.645 $\pm$ 0.39	15.568 $\pm$ 0.279***
Cocoon shell % ♀	18.653 $\pm$ 0.57	17.467 $\pm$ 0.24	13.328 $\pm$ 0.254***

P<0.001 highly significant (***) P<0.01 significant (**)

Table 2: Percentage of different blood cells in irradiated and non-irradiated healthy and diseased larvae of *Bombyx mori* L.

Blood cell	Healthy larvae (% $\pm$ SE)			Flacherie diseased larvae (% $\pm$ SE)		
	Control	10 Gy	20 Gy	Control	10 Gy	20 Gy
Proleucocytes	10.216 $\pm$ 1.31	4.850 $\pm$ 0.17	8.234 $\pm$ 0.17	29.424 $\pm$ 0.38***	12.507 $\pm$ 0.38***	27.276 $\pm$ 2.54***
Granular cells	51.892 $\pm$ 3.98	35.990 $\pm$ 0.81	31.230 $\pm$ 0.61	35.517 $\pm$ 0.57**	41.059 $\pm$ 0.50**	20.862 $\pm$ 2.93**
Plasmatocytes	31.968 $\pm$ 5.02	47.490 $\pm$ 1.38	48.402 $\pm$ 0.70	22.507 $\pm$ 1.38	33.058 $\pm$ 0.49**	15.283 $\pm$ 1.66***
Spherule cells	2.909 $\pm$ 0.67	3.949 $\pm$ 0.55	4.493 $\pm$ 0.26	1.103 $\pm$ 0.31	4.758 $\pm$ 0.20	2.308 $\pm$ 0.83***
Oenocytoides	3.015 $\pm$ 0.48	7.721 $\pm$ 0.47	4.258 $\pm$ 0.19	2.676 $\pm$ 0.51	5.068 $\pm$ 0.23**	2.242 $\pm$ 0.26***

P<0.001 highly significant (***) P<0.01 significant (**)

the major cell types responsible for rapid removal of bacteria from circulation *via* nodule formation. The mechanism behind this process was described by Ratcliffe and Rowley (1987) as a biphasic event. The first phase is initiated by granular cell, which rapidly recognize foreign particles and de-granulated to induce a localized coagulum. The second phase then take place, which involves the attachment of large numbers of plasmatocytes to the clot to form a multi-cellular sheath. The foreign particles were then walled-off and their invasion inhibited.

In the present study, percentage of spherule cells in flacherie diseased larvae showed a non-significant difference with that of healthy (control) ones of non-irradiated group (1.103, 2.909 %, respectively). The same trend was observed between those of 10 Gy irradiated

larvae (4.758 and 3.949 %, respectively) and 20 Gy irradiated larvae (2.308 and 4.493 %, respectively) of both the categories. Spherule cells are the least common haemolymphal cell types. They vary from oval to spherical in shape, the acidophilic nucleus is slightly eccentric and small. These cells have translucent or crystalline spherules that partially occupy the whole cell. The cytoplasm of spherules, which is basophilic, is very scarce but dense (Figure 1 D). Spherule cells represent 2.909 $\pm$ 0.6 % of total blood cell counts. Flacherie disease did not induce any pathological changes in cell morphology. Disease incidence lowered cell density in affected larvae. Irradiation with 10 and 20 Gy induced great morphological damage to healthy spherule cell as it shrunk and changed its staining properties. The nucleus appeared very small with the spherules still present (Figure 1 D). Higher dose caused more damage. Spherule cells of flacherie diseased larvae of the irradiated groups didn't

have any pathological changes.

Oenocytoids were supposed to be developed from granular cells due to the presence of granules and phenoloxidase synthesis (Lai-Fook, 1973). Oenocytoids unlike the other haemocytes, do not undergo mitosis (Aruga, 1994). They play a part in the metabolic processes concerned in growth and moulting (Wigglesworth, 1959). In the present study, no significant differences were observed between oenocytoids percentage of flacherie affected and healthy (control) larvae of non-irradiated group (2.676 and 3.015 %, respectively). For 10 Gy irradiated larvae, the flacherie diseased larvae showed a significant difference from healthy (control) larvae (5.068 and 7.721 %, respectively) and highly significant difference in the case of 20 Gy irradiated group (2.242 and 4.258 %, respectively). Flacherie disease caused a slight morphological change in cell shape of oenocytoids, without changing its staining properties (Figure 1 E). There were no bacteria attached to the cell surface. Mahmoud (1988) observed pathological changes in all haemocytes except oenocytoids in *B. mori* L. Irradiation with 10 Gy induced morphological deformations in cell shape. In healthy small oenocytoids, the cell lost its traditional shape, the nucleus increased in size and stained faint blue, the cytoplasm stained dark blue by Giemsa stain and the crescent inclusions did not appear any more. The large oenocytoids showed abnormal growth, the cell lost its nuclear boundaries and completely deformed. Irradiation with 20 Gy induced still more morphological deformations. Flacherie disease did not show any pathological changes on deformed irradiated cells with 10 and 20 Gy doses.

From the results obtained it was observed that, gamma irradiation reduces the percentages of proleucocytes and granular cells while it increases percentages of plasmatocytes, spherule cells and oenocytoids. Kumar and Srivastava (1991) found that, haemocyte densities were decreased due to irradiation. On the other hand, Tu-Zhen *et al.* (1999) stated that, the proleucocytes were increased due to irradiation. They also mentioned that, haemocyte densities in the irradiated silkworms were significantly lower than those of control during the middle

and late stages of the fifth larval instar.

The increase in certain blood cells was thought to be due to the presence of significant populations of sessile haemocytes, which got mobilized in response to infection (Wigglesworth, 1959; Ratcliffe and Gagen, 1976) or the infection might stimulate haemocytes to undergo mitosis (Jones, 1977; Barakat, 1997) for the rapid initial clearance of bacteria (Horohov and Dunn, 1982).

Low doses of gamma rays could be successfully applied to Bombycid moths (Grekov and Plovdiv, 1987; Kamelia and Souad, 1995) to induce tolerance to diseases within generations (Sivaprakasam and Rabindra, 1998) and reduce the number of nodules in the bacterial infected haemolymph as well (Rahmet-Alla and Rowley, 1990).

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Article scientifique

ETUDES BIOLOGIQUES ET HEMATOLOGIQUES SUR DES LARVES ATTEINTES DE FLACHERIE DE VERS A SOIE, *BOMBYX MORI* L. IRRADIES PAR DES RAYONS GAMMA

Souad M. Mahmoud¹, Akila M. El-shafei², Abulyazid I.³ and Rehab H. Taha^{1*}

¹Agricultural Research Center, Plant Protection Research Institute, Sericultural Research Department, Giza, Egypt.

²Ain Shams University, Faculty of Science, Cairo, Egypt.

³Atomic Energy Authority, Cairo, Egypt.

*E-mail: rehab_hosny1@hotmail.com

RÉSUMÉ

Nous avons appliqué trois doses différentes (10, 20 et 30 Gy) de radiations gamma à des vers à soie *Bombyx mori* au stade embryonnaire tardif. Des vers à soie naturellement malades (flacherie) et des vers à soie sains issus des progénies ont été étudiés pour connaître l'impact des rayonnements gamma sur leurs caractères économiques et biologiques. Nous avons étudié les manifestations possibles sur le développement de la flacherie. On observe des déformations des cellules du sang chez les larves naturellement malades des groupes irradiés et non irradiés. Les résultats indiquent que l'irradiation aux doses expérimentales choisies n'a pas d'effet sur les symptômes de la flacherie. La dose 30 Gy est fatale au stade embryonnaire lui-même. La dose 10 GY n'a aucun effet sur les paramètres étudiés alors que pour la dose 20 Gy tous les paramètres décroissent significativement par rapport aux témoins. Il y a une réponse positive vers 10 Gy en terme d'accroissement du nombre de cellules du sang qui stimule l'immunité permettant à l'insecte de résister à l'infection bactérienne avec pour conséquence une baisse de la mortalité. L'irradiation et la maladie induisent des déformations chez toutes les cellules du sang.

Mots-clés: Caractères commerciaux et biologiques, cellules du sang, *Bombyx mori* L., flacherie, irradiation gamma.



INFLUENCE OF BIOTIC AND ABIOTIC FACTORS ON THE INCIDENCE AND SEVERITY OF DISEASES IN TASAR FOOD PLANTS, *TERMINALIA ARJUNA* AND *T. TOMENTOSA*

V. P. Gupta*, A. R. Akand, S. Rai, A. K. Sinha and A. Sahay

Central Tasar Research and Training Institute,
Piska-Nagri, Ranchi - 835303, Jharkhand, India.

*E-mail: guptavp1010@yahoo.com

ABSTRACT

A survey was conducted to establish the influence of various biotic and abiotic factors on the occurrence and development of major diseases viz., leaf spot, black nodal girdling and powdery mildew of tasar silkworm food plants, *Terminalia arjuna* and *T. tomentosa*. These diseases were noticed in all the plots surveyed; however, their incidence and severity varied with *Terminalia* species, season and plant spacing. The incidence and severity of all the three diseases were observed to be higher in *T. tomentosa* as compared to *T. arjuna*. When compared to leaf spot and black nodal girdling, the rate of incidence of powdery mildew disease was much higher in both *Terminalia* spp. during the period of survey. Regression analyses between disease development and meteorological parameters indicated that temperature was the major contributing factor for development of all the three diseases. In the case of leaf spot disease, minimum temperature contributed significantly (at 5 % level) for the disease development in both *Terminalia* spp. However, in the case of black nodal girdling disease, both minimum and maximum temperature had positive regression coefficients and thus indicate significantly higher contribution for disease development in both the species. In the case of powdery mildew disease, maximum temperature contributed mainly for disease development in *T. arjuna*; however, in *T. tomentosa*, both minimum and maximum temperature contributed significantly for the disease development. Plant spacing also influenced the development of diseases in *Terminalia* species. The development of leaf spot disease was recorded to be high in closer plant spacing as compared to wider spacing in both spp. In the case of black nodal girdling disease, the disease development in *T. arjuna* was recorded to be higher in closer spacing than wider spacing. However, due to higher rate of disease occurrence in *T. tomentosa*, the trend of development of black nodal girdling disease in respect of plant spacing was not very clear. Since the incidence of powdery mildew disease was also high in both *Terminalia* spp., the trend of its development in respect of plant spacing was not noticeable.

Key words: Abiotic factors, diseases, incidence, severity, tasar food plants, *Terminalia*.

INTRODUCTION

Tasar silkworm (*Antheraea mylitta* Drury) is a polyphagous insect feeding primarily on *Terminalia arjuna* (Roxb.) W&A, *T. tomentosa* W&A and *Shorea robusta* Gaertn. F. Though all three primary food plants are found abundantly in tropical forests, *T. arjuna* and *T.*

tomentosa are also raised as block plantation and exploited for commercial production of tasar cocoons. Although availability of leaves on host plants decides the quantum of dfls to be brushed for silkworm rearing, the quality of leaves with respect to total moisture and primary metabolites viz., nitrogen, proteins, minerals, fibre and carbohydrate plays a significant role in promoting healthy

development of silkworm larvae which has a definite bearing on qualitative and quantitative production of tasar silk. In general, tasar culture is challenged with various biotic (pests, parasites, predators and diseases) and abiotic (extremes of temperature, humidity and rainfall) threats of its own due to wild nature and outdoor silkworm rearing on the trees. Being wild in nature, tasar food plants and silkworm are very much open to wide range of enemies/adversaries. Among them, the diseases of tasar food plants are one of the major limiting factors for tasar cocoon productivity and quality (Tewari, 1995; Srivastav *et al.*, 1998).

The losses caused by plant diseases are generally ignored due to (i) par visible nature of the pathogens with naked eyes and (ii) lack of knowledge and awareness on the types of symptoms and quantum of loss. The existing cause of plant diseases depends upon certain contributing characters of predisposing factors, especially temperature and relative humidity which contribute towards the quick multiplication of microorganisms in nature. Besides, plant species or variety and various agronomical/cultural practices also contribute towards development and severity of diseases. The pathogens drain out moisture and food material from plants in the form of proteins, carbohydrates, minerals, salts, *etc.* and thus make them sick and poor in production of quality leaves. The silkworm fed on inferior quality of leaves either do not spin or produce poor quality of cocoons. *T. arjuna* and *T. tomentosa* encounter a number of infectious and non-infectious deficiency diseases that cause direct losses of 15 to 20 % in foliage yield, in addition to deteriorating the leaf quality. These diseases vary in their seasonal occurrence, severity and extent of damage/losses caused to the plants.

The most common infectious diseases of *Terminalia* plants are leaf spot (*Pestalotiopsis palmarum*), black nodal girdling (*Uredo* sp.) and powdery mildew (*Phyllactinia terminalae*) which occur frequently and cause severe losses. Keeping in view the importance of these diseases in tasar silkworm food plants, the present study was undertaken on their occurrence and

development on *T. arjuna* and *T. tomentosa* in relation to various biotic and abiotic factors, so that suitable measures can be suggested to avoid the losses in leaf production and quality.

MATERIALS AND METHODS

A. Survey on incidence and severity of major diseases of *Terminalia* species

To determine the incidence and relative severity of diseases on *T. arjuna* and *T. tomentosa* during commercial crop season of tasar silkworm rearing *i.e.*, October 2011 to January 2012, a survey was conducted in *Terminalia* plantation maintained in about 60 acres of land at the farm of Central Tasar Research and Training Institute (CTRTI), Ranchi. These *Terminalia* trees are raised systematically in plots as economic plantation with various plant spacings *viz.*, 1.2 m x 1.2 m, 2.4 m x 2.4 m and 3.6 m x 3.6 m.

The disease survey was conducted in the plots with *T. arjuna* and *T. tomentosa* plantation raised under different plant spacings. In each plot, three plants were selected randomly and from each plant, three branches were selected for disease scoring. Disease incidence was assessed by using the following grading scale (Dimond *et al.*, 1952).

Grade 0	-	No infection
Grade 1	-	Up to 5 % leaf lamina affected
Grade 2	-	6 - 25 % leaf lamina affected
Grade 3	-	26 - 50 % leaf lamina affected
Grade 4	-	51 - 75 % leaf lamina affected
Grade 5	-	76 - 100 % leaf lamina affected

After arriving at the grade of infection, the disease incidence (DI) and per cent disease index (PDI) were calculated using the following formulae (McKinney, 1923).

$$DI (\%) = \frac{\text{Total No. of leaves depicting symptoms}}{\text{Total No. of leaves observed}} \times 100$$

$$PDI = \frac{\text{Sum of numerical values}}{\text{Total number of leaves} \times \text{Highest grade (i.e., 5)}} \times 100$$

(The numerical values were obtained by multiplying the number of leaves with their respective grading)

Meteorological data on maximum & minimum temperature (°C), maximum & minimum relative humidity (%), rainfall (mm) and number of rainy days were collected from the Field Observatory established at CTRTI. The disease incidence and severity were correlated with meteorological parameters. The instrument (Automatic Weather Station, ISRO No. 0971) used for recording meteorological conditions was of the standards of Indian Meteorological Department.

B. Data analysis

Data collected from each plant of *T. arjuna* and *T. tomentosa* in a particular plot with plant spacing were considered as replications (total 3 replications i.e., 3 plants per plot with different spacings and species) and their per cent values were subjected to the analysis of variance (ANOVA). The LSD was determined and the significance of variation in disease incidence and severity with respect to *Terminalia* species and plant spacing was determined at the magnitude of 5 % level. Regression analyses between disease indices (DI and PDI) and meteorological parameters were carried out to determine the influence of abiotic factors on disease development. Linear regression ($Y = a + bx$) was carried out with DI and PDI (Y) as dependent variables and meteorological parameters (Xi) as independent variable, 'a' is intercept and 'b' is Regression Coefficient.

RESULTS AND DISCUSSION

A. Survey on the incidence and severity of diseases in *Terminalia* plants

The disease survey was conducted during the commercial crop rearing season (October 2011 to January 2012) in the plots with *Terminalia arjuna* and *T. tomentosa* plantation raised under different plant spacings. Maximum temperature of 20.16 - 27.67 °C, minimum temperature of 6.61 - 17.96 °C, maximum relative humidity of 80 - 91 %, minimum relative humidity of 38 - 61 % and a cumulative rainfall of 55.25 mm with a total number of 8 rainy days were

recorded during the period. Disease incidence of leaf spot, black nodal girdling and powdery mildew was noticed in most of the plots of *Terminalia* plantation. However, the degree of disease occurrence varied with *Terminalia* species, season and plant spacing. It clearly indicates the effect of these variables on the development of diseases in *Terminalia* plantation (Table 1).

B. Disease development in relation to plant species

Irrespective of plant spacing, the incidence and severity of diseases were observed to be higher in *T. tomentosa* when compared to *T. arjuna*. These results are in conformity with the observations of Gupta *et al.* (2010) on the occurrence of leaf curl disease in *T. arjuna* and *T. tomentosa*. In the case of leaf spot disease, there was not much variation in incidence (DI) and severity (PDI) in *T. arjuna* (DI: 50.51 - 68.12 %; PDI: 21.51 - 31.75) and *T. tomentosa* (DI: 58.73 - 69.53 %; PDI: 25.45 - 31.85). The development of black nodal girdling disease was comparatively higher in *T. tomentosa* (DI: 32.70 - 69.34%; PDI: 9.16 - 25.91) than *T. arjuna* (DI: 29.80 - 58.71 %; PDI: 8.82 - 21.11). However, the development of powdery mildew disease in *T. tomentosa* (DI: 65.51 - 99.01 %; PDI: 28.46 - 82.31) was much higher than that in *T. arjuna* (DI: 5.83 - 95.69 %; PDI: 1.92 - 62.65) [Table 1]. Variations in disease development in *Terminalia* species may be attributed to their resistance reactions against the particular pathogen. Similar observations have also been recorded in different varieties of mulberry plant (*Morus alba* L.) against *Cercospora* leaf spot disease (Srikantaswamy *et al.*, 1999).

C. Disease development in relation to weather factors

The development of leaf spot disease in both the species of *Terminalia* was observed to be progressive during the months of October and November; however, it became static during December and January. In the case of black nodal girdling disease, though the incidence and severity were recorded to be lesser than leaf spot and powdery mildew diseases, its development was progressive during October to December and then became

Table 1: Seasonal incidence (DI) and severity (PDI) of major diseases in *Terminalia* species in relation to abiotic factors

Month	Plant species	Leaf spot		Black nodal girdling		Powdery mildew		Temperature (°C)		Relative humidity (%)		Cumulative rainfall (mm)	Rainy days (No.)
		DI (%)	PDI	DI (%)	PDI	DI (%)	PDI	Max.	Min.	Max.	Min.		
October	<i>T. arjuna</i>	50.51	21.51	29.80	8.82	5.83	1.92	27.67	17.96	91.00	41.00	11.00	4.00
	<i>T. tomentosa</i>	58.73	25.45	32.70	9.16	65.51	28.46						
November	<i>T. arjuna</i>	63.29	28.87	41.65	14.13	30.30	9.49	24.50	12.00	80.00	41.00	0.00	0.00
	<i>T. tomentosa</i>	66.22	30.16	51.35	17.05	88.51	47.68						
December	<i>T. arjuna</i>	68.12	31.75	53.64	20.05	60.90	26.56	22.00	8.00	81.00	38.00	0.00	0.00
	<i>T. tomentosa</i>	69.53	31.85	67.01	25.91	98.57	72.34						
January	<i>T. arjuna</i>	68.02	30.77	58.71	21.11	95.69	62.65	20.16	6.61	89.00	61.00	44.25	4.00
	<i>T. tomentosa</i>	68.89	30.49	69.34	25.05	99.01	82.31						

Table 2: Regression analysis to determine the influence of meteorological parameters on development of leaf spot disease in *Terminalia* species

Disease indices vs meteorological parameters	Regression equation	
	<i>T. arjuna</i>	<i>T. tomentosa</i>
DI vs Min Temp	$Y = -1.594x + 80.246, R^2 = 0.9554$	$Y = -0.9476x + 76.4, R^2 = 0.9471$
PDI vs Min Temp	$Y = -0.3741x + 37.964, R^2 = 0.9205$	$Y = -0.5017x + 35.076, R^2 = 0.8366$
DI vs Max Temp	$Y = -2.3946x + 118.96, R^2 = 0.8824$	$Y = -1.4163x + 99.241, R^2 = 0.8657$
PDI vs Max Temp	$Y = -1.2956x + 58.777, R^2 = 0.8276$	$Y = -0.7265x + 46.618, R^2 = 0.7179$

R^2 = Coefficient determinants

almost static during January. When compared to leaf spot and black nodal girdling, the development of powdery mildew disease was much higher in both *Terminalia* species during the period of observation (October to January). However, initiation of powdery mildew disease was earlier in *T. tomentosa* than *T. arjuna*, as higher level of disease development was observed in *T. tomentosa* (DI: 65.51%; PDI: 28.46) during the month of October, when compared to *T. arjuna* (DI: 5.83%; PDI: 1.92) [Table 1].

D. Regression analysis

Regression analysis was carried out in respect of disease development (dependent variables) vs

meteorological parameters (independent variables). Results indicate that temperature was the major contributing factor for development of all three diseases studied. In the case of leaf spot disease, minimum temperature contributed significantly (at 5 % level) for the disease development in both *Terminalia* spp. than maximum temperature (Table 2). However, in black nodal girdling disease, both minimum and maximum temperature had positive regression coefficients and thus indicate significantly higher contribution for disease development in both *Terminalia* spp. (Table 3). Regression analyses indicate that the maximum temperature contributed mainly for the development of powdery mildew disease in *T. arjuna* than the minimum

Table 3: Regression analysis to determine the influence of meteorological parameters on black nodal girdling disease in *Terminalia* species

Disease indices vs meteorological parameters	Regression equation	
	<i>T. arjuna</i>	<i>T. tomentosa</i>
DI vs Min Temp	$Y = -2.5225x + 74.057, R^2 = 0.9851$	$Y = -3.3218x + 92.115, R^2 = 0.9957$
PDI vs Min Temp	$Y = -1.1137x + 28.438, R^2 = 0.9866$	$Y = -1.5182x + 36.208, R^2 = 0.9696$
DI vs Max Temp	$Y = -3.9607x + 139.35, R^2 = 0.9938$	$Y = -5.1176x + 175.79, R^2 = 0.967$
PDI vs Max Temp	$Y = -1.7306x + 56.839, R^2 = 0.9747$	$Y = -2.3177x + 73.949, R^2 = 0.9248$

R² = Coefficient determinants**Table 4: Regression analysis to determine the influence of meteorological parameters on powdery mildew disease in *Terminalia* species.**

Disease indices vs meteorological parameters	Regression equation	
	<i>T. arjuna</i>	<i>T. tomentosa</i>
DI vs Min Temp	$Y = -7.2059x + 128.47, R^2 = 0.8893$	$Y = -3.0397x + 121.77, R^2 = 0.971$
PDI vs Min Temp	$Y = -4.4591x + 74.842, R^2 = 0.704$	$Y = -4.7078x + 110.15, R^2 = 0.9692$
DI vs Max Temp	$Y = -11.719x + 324.54, R^2 = 0.9624$	$Y = -4.5913x + 196.17, R^2 = 0.9064$
PDI vs Max Temp	$Y = -7.5511x + 203.23, R^2 = 0.826$	$Y = -7.4322x + 232.97, R^2 = 0.9885$

R² = Coefficient determinants

temperature. However, in the case of *T. tomentosa*, both minimum and maximum temperature contributed significantly for the development of powdery mildew disease (Table 4). This may be the probable reason for the higher rate of development of powdery mildew disease in *T. tomentosa* (Table 1). Similar types of regression studies have also been conducted in mulberry for the prediction of leaf rust disease development (Naik *et al.*, 2008).

E. Disease development in relation to plant spacing

Plant spacing also influences the development of diseases in *Terminalia* species. The development of leaf spot disease was recorded to be high in closer plant spacing as compared to wider spacing. In *T. tomentosa*, higher disease development (DI: 73.84 – 88.42 %; PDI: 33.58 – 42.50) was recorded in closer spacing of 1.2 m x 1.2 m and 2.4 m x 2.4 m when compared to wider spacing of 3.6 m x 3.6 m (DI: 41.10 – 54.62 %; PDI: 15.94 – 21.72). However, in the case of *T. arjuna*, disease development

was higher (DI: 51.97 – 67.30 %; PDI: 21.12 – 31.55) in closer spacing of 1.2 m x 1.2 m as compared to wider spacing of 2.4 m x 2.4 m and 3.6 m x 3.6 m (DI: 44.94 – 67.02 %; PDI: 17.73 – 30.79) (Table 5 A).

The development of black nodal girdling disease was higher in the plantation of *T. arjuna* under closer spacing of 1.2 m x 1.2 m (DI: 39.56 – 67.42 %; PDI: 13.63 – 25.47) than wider spacing of 2.4 m x 2.4 m and 3.6 m x 3.6 m (DI: 16.85 – 67.42 %; PDI: 4.15 – 24.64). However, due to higher rate of disease occurrence in *T. tomentosa*, the trend of development of black nodal girdling disease in respect of plant spacing was not very clear (Table 5 B). Similarly, since the incidence of powdery mildew disease was also high in both *Terminalia* spp., the trend of its development in respect of plant spacing was not noticeable (Table 5 C).

Low occurrence of disease in wider plant spacing may be attributed to better aeration and sunlight around the plants which creates congenial environment for plant

Table 5 A: Incidence (DI) and severity (PDI) of leaf spot disease in *Terminalia* species in relation to plant spacing (PS) and abiotic factors (AF)

Plant spacing (m x m)	<i>T. arjuna</i>								<i>T. tomentosa</i>							
	October		November		December		January		October		November		December		January	
	DI (%)	PDI	DI (%)	PDI	DI (%)	PDI	DI (%)	PDI	DI (%)	PDI	DI (%)	PDI	DI (%)	PDI	DI (%)	PDI
1.2 x 1.2	51.97	21.12	65.18	29.26	67.30	31.55	67.26	30.29	78.88	36.32	80.50	40.49	82.29	41.46	82.88	40.86
2.4 x 2.4	44.94	17.73	60.98	25.63	64.68	26.73	66.10	26.96	73.84	33.58	83.17	38.97	88.42	42.50	83.45	39.30
3.6 x 3.6	48.04	20.94	59.22	26.71	65.19	29.54	67.02	30.79	41.10	15.94	50.60	20.58	53.71	21.72	54.62	20.90
CD (p = 0.05) PS x AF	5.575 (DI)				3.469 (PDI)				CD (p = 0.05) PS x AF				4.424 (DI)			

Table 5 B: Incidence (DI) and severity (PDI) of black nodal girdling disease in *Terminalia* species in relation to plant spacing (PS) and abiotic factors (AF)

Plant spacing (m x m)	<i>T. arjuna</i>								<i>T. tomentosa</i>							
	October		November		December		January		October		November		December		January	
	DI (%)	PDI	DI (%)	PDI	DI (%)	PDI	DI (%)	PDI	DI (%)	PDI	DI (%)	PDI	DI (%)	PDI	DI (%)	PDI
1.2 x 1.2	39.56	13.63	51.82	19.44	61.28	24.08	67.42	25.47	48.08	14.43	58.18	20.56	69.86	25.88	65.66	22.80
2.4 x 2.4	32.25	9.61	44.36	15.01	63.21	24.64	67.24	24.34	28.73	8.01	49.03	15.41	58.01	20.99	60.79	20.64
3.6 x 3.6	16.85	4.15	27.49	8.36	34.61	11.44	44.55	15.35	27.00	7.10	49.10	16.12	70.09	28.38	75.45	28.37
CD (p = 0.05) PS x AF	6.452 (DI)				2.562 (PDI)				CD (p = 0.05) PS x AF				7.638 (DI)			

Table 5 C: Incidence (DI) and severity (PDI) of powdery mildew disease in *Terminalia* species in relation to plant spacing (PS) and abiotic factors (AF)

Plant spacing (m x m)	<i>T. arjuna</i>								<i>T. tomentosa</i>							
	October		November		December		January		October		November		December		January	
	DI (%)	PDI	DI (%)	PDI	DI (%)	PDI	DI (%)	PDI	DI (%)	PDI	DI (%)	PDI	DI (%)	PDI	DI (%)	PDI
1.2 x 1.2	5.97	1.19	18.66	4.82	50.36	19.82	82.16	37.00	69.59	27.68	88.77	37.95	94.27	63.34	96.03	73.08
2.4 x 2.4	3.28	0.65	39.16	13.22	60.51	23.89	99.32	63.46	75.61	31.35	98.33	62.10	100.00	75.14	100.00	85.41
3.6 x 3.6	9.94	3.89	29.78	9.45	66.53	32.22	98.67	69.86	58.43	27.41	83.46	45.34	100.00	75.44	100.00	85.37
CD (p = 0.05) PS x AF	8.022 (DI)				3.944 (PDI)				CD (p = 0.05) PS x AF				6.229 (DI)			

growth on one hand and on the other hand, may be due to prevention of growth of microbial pathogens because of reduced relative humidity and increased temperature around the plants (Dubey, 1997).

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Article scientifique

INFLUENCE DE FACTEURS BIOTIQUES ET ABIOTIQUES SUR L'INCIDENCE ET LA SEVERITE DES MALADIES CHEZ LES PLANTES NOURRICIERES DU TASAR, *TERMINALIA ARJUNA* ET *T. TOMENTOSA*

V. P. Gupta*, A. R. Akand, S. Rai, A. K. Sinha and A. Sahay

Central Tasar Research and Training Institute,
Piska-Nagri, Ranchi - 835303, Jharkhand, India.
*E-mail: guptavp1010@yahoo.com

RÉSUMÉ

Une étude générale a été menée pour établir l'influence de divers facteurs biotiques et abiotiques sur l'occurrence et le développement de maladies importantes comme la tache de la feuille, l'anneau nodal noir et le mildiou poudreux des plantes nourricières du ver à soie tasar, *Terminalia arjuna* et *T. tomentosa*. Ces maladies sont présentes dans tous les lots observés ; cependant, leur incidence et leur sévérité varient selon les espèces de *Terminalia*, la saison et l'espacement des plants. L'incidence et la sévérité des trois maladies sont plus élevées chez *T. tomentosa* que chez *T. arjuna*. Le taux d'incidence du mildiou poudreux a été beaucoup plus élevé que celui des deux autres maladies chez les deux espèces de *Terminalia* pendant la durée de l'étude. Les analyses de régression entre le développement des maladies et les paramètres météorologiques indiquent que la température est le facteur principal contribuant au développement des maladies. Dans le cas de la tache de la feuille, la température minimale contribue de manière significative (au seuil de 5 %) au développement de la maladie chez les deux espèces. Dans le cas de l'anneau nodal noir, les températures minimale et maximale montrent toutes deux un coefficient de régression positif ce qui indique une plus forte contribution significative pour les deux espèces. Dans le cas du mildiou, la température maximale représente la principale contribution chez *T. arjuna* alors que chez *T. tomentosa* les deux températures contribuent significativement au développement de la maladie. L'espacement des plants joue également un rôle dans le développement des maladies chez les deux espèces de *Terminalia*. Le développement de la tache de la feuille est plus élevé dans le cas de plants serrés que dans le cas de plants espacés chez les deux espèces. La même chose est enregistrée pour l'anneau nodal noir chez *T. arjuna*. Cependant, compte tenu du fort taux de développement de la maladie chez *T. tomentosa* la tendance en fonction de l'espacement n'est pas claire. Bien que l'incidence du mildiou soit importante chez les deux espèces nous n'avons pas noté de tendance en fonction de l'espacement.

Mots-clés: Facteurs abiotiques, incidence et sévérité des maladies, plantes nourricières tasar, *Terminalia*.



STUDIES ON SILK CARPET PREPARED USING ERI NOIL YARN

Naveen V. Padaki^{1*}, Sainath Uppar², Uday C. Javali¹ and Kiran B. Malali¹

¹Central Silk Technological Research Institute, Central Silk Board, Bengaluru 560068, India.

²Govt. SKSJT Institute, KR Circle, Bengaluru 560001, India.

*Email: naveenvpadaki@gmail.com

ABSTRACT

India produces all the four varieties of silk, namely mulberry, eri, tussar and muga. Eri silk is the second largest variety of silk being produced in India. It is also known as 'Ahimsa Silk'. Since eri cocoons are open end in nature, unlike the other three varieties of silk, eri silk can't be reeled. Eri silk can be spun into coarse or very fine counts due to its long fibres used for spinning. It is one of the cheapest silk available and the properties are similar to that of cotton fibre. Hence, use of eri noil yarn offers a better option for producing silk carpets as they provide a niche appeal besides being affordable. This paper deals with the sequence of efforts behind the development of eri silk carpets using eri noil yarn and their characteristics. Noil from eri spinning in worsted system is used to spin 10's Nm on open end spinning to produce eri noil yarn. This yarn has been used as pile yarn for preparation of hand knotted carpets using Persian knots. The static loading, dynamic loading, compression and wear tests were conducted to assess the behaviour of the carpet developed. It was found that Persian carpet developed using eri noil yarn has acceptable characteristics to be used as wall carpets.

Key words: Eri silk, noil yarn, Persian carpets, Persian knot, silk carpets.

INTRODUCTION

Carpet is an ornamented textile fabric which is a thick heavy covering for a floor or wall. Carpets are usually made by weaving, knotting or tufting techniques. Carpet industry in India is one of the oldest and presently there are about 1200 carpet manufacturing units in India. India has an ancient heritage of carpet weaving, a craft that has assorted skills and expertise from lands as diverse as Persia, China and Afghanistan. Major centres of carpet industry in India are Kashmir, Jaipur, Agra and Bhadohi - Mirzapur. Kashmir carpet clusters are famous for hand knotted silk and woollen carpets. Pure silk carpets of Kashmir are of such high quality that they are woven with 324-600 knots per square inch to capture the fine lines of the intricate design patterns. Silk makes wonderful oriental carpets or rugs. Silk is also used as pattern highlights in woollen carpets. Silk carpets are known not

only for rich and royal delights but also as the most intricate, and often the most valuable, of all hand-knotted carpets. The fine yet strong silk fibres used in carpets allow more knots per square inch to be tied giving a sharp 'image' with more detail and enhanced real life like appearance. Silk carpets are rich, expensive and are usually made on the cotton foundation but a few may even have silk foundation as well. Silk carpets are highly preferred in soft, even and dry areas owing to the delicacy of the fibre.

To date, research conducted on silk carpets has been very scarce. The changes in the appearance of tufted pile carpets prepared using synthetic fibres have been studied by several methods and after mechanical wear (Pourdeyhimi and Sobus, 1993; Pourdeyhimi *et al.*, 1994, 1994 a, 1994 b). Studies to measure changes in carpet appearance due to traffic by fabricating an instrument that

directs a beam of light onto the carpet surface and measures the intensity of the scattered light using a photometer has been reported (Lamb *et al.*, 1993). Bugao, 1994 studied different techniques to assess shape, orientation, and spatial patterns for tuft characterization. Carpet performance evaluation using a tetra pod walker tester was reported to understand real situation walk test conditions (Kenneth and Gordon, 1967, 1968). Image analysis techniques applied to the objective measurement of carpet texture using controlled wear treatments in the Hexapod tumbler tester have been reported (Wood, 1989, 1993). Evaluation of tuft withdrawal force for different hand knotted carpets has shown that Persian, Turkish and Kiwi hand knotted carpets displayed better tuft withdrawal resistance among the five types of hand knotted carpets tested (Liu *et al.*, 2002). Although synthetic tufted, woven (cotton), spun-bonded and non-woven (needle-felt) carpets have been subjected for research studies, literature on hand-knotted silk carpets are very scarce.

Efforts are needed to produce cost effective silk carpets. Eri is the cheapest variety of silk available today. Eri silk is one of the cost effective spun silk yarn which is produced abundantly in India. Presently, niche silk carpets produced in Kashmir valley make use of spun mulberry silk yarns. The silk carpets so produced are also very costly and their exports have been dwindling due to high input cost and reduced weaver communities in Kashmir region. Silk carpets made from eri noil yarn will not only have niche appeal but also be much affordable. Silk carpets using eri noil yarn could be economically advantageous but yet the properties of the silk carpets produced using eri noil yarn are not known. Hence, an attempt has been made to study the important properties such as compression behaviour, static/dynamic loading and flammability characteristics of silk carpets prepared using eri silk noil yarn by hand knotting technique.

MATERIALS AND METHODS

Silk noil yarn preparation: Silk noil yarn is prepared

by using noil which is the waste generated from combing process during silk spinning process. The silk noil yarn is prepared using open end spinning system in a spun silk mill. Table 1 presents the noil yarn characteristics.

Table 1: Silk noil yarn characteristics

Silk noil yarn	Count in Ne	TPI	Ply	Twist
	10	9.4	0	Z

Carpet preparation: The Persian hand-knotted silk carpet samples of size 1' x 1' (7 nos.) were developed in collaboration with Indian Institute of Carpet Technology (IICT), Bhadohi, Uttar Pradesh, India on vertical carpet handloom at Bhadohi carpet cluster. The sequence of operations followed during carpet sample manufacture is displayed in the following chart.



Eri silk noil carpet manufacturing sequence

Carpet testing: Carpet thickness and the height of the pile yarn (eri noil) were evaluated on carpet thickness tester. Compressibility of the carpet subjected to external load is a very important characteristic. Compression behaviour of the developed eri noil silk carpets was assessed with respect to compressibility tests, static loading test and dynamic loading tests. During use of carpet, abrasive wear could influence the life of carpet and hence carpet wear and abrasion tests were also carried-out. Flammability characteristic is of immense importance for carpets due to its use in home interiors. The silk carpet samples developed were evaluated for carpet performance properties at Textile Testing Laboratory, Central Silk Technological Research Institute (CSTRI), Bengaluru, India and IICT, Bhadohi as per available IS and ASTM standards detailed in Table 2.

Table 2: Tests conducted on eri silk noil yarn carpets and relevant standards

Test parameter	Test standard
Pile height of floor coverings	IS: 7877(PART: IV):1976
Compressibility test	BS 4098 : 1975
Carpet wear and abrasions	IWS/TM – 283
Static loading test	ISO 3416-1986
Carpet dynamic loading test	BS/ISO: 2094:1999
Flammability test	BS 4790 : 1993

RESULTS AND DISCUSSION

The eri noil silk carpets were successfully developed on vertical carpet handloom and the base fabric of carpet samples had an average of 12 ends per inch and 6 picks per inch thread density. Average carpet thickness was 18.9 mm, average pile height in the carpet samples was 11 mm and average pile density was 383 g/m²/mm. The carpet samples had an average of 4200 gsm aerial density.

The compressibility test result with respect to thickness recovery is shown in Figure 1. The average thickness recovery (instantaneous) is 75.4 % and compression recovery (time elapsed) is 49.1 %, which are in acceptable range. Static loading test results show thickness loss after 24 hours of loading in the range of 9.36 mm (max) and 7.7 mm (min). The recovery after 1 min, 1 hour and 24 hours shows that the recovery improves as time passes.

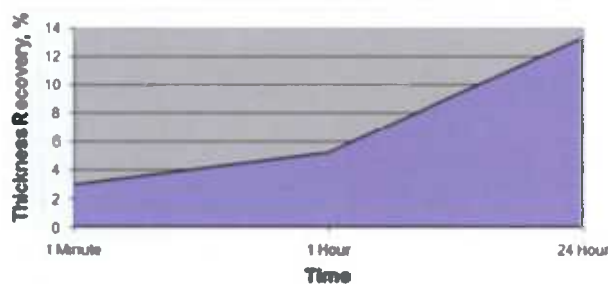


Figure 1: Thickness recovery vs time for silk noil carpets

Dynamic loading test results are displayed in Figure 2. The dynamic load was applied and thickness loss of the carpet sample was noted at 50, 100, 200, 500 and 1000 impact cycles and the respective average loss in carpet

thickness values are displayed in Figure 2. It can be observed that thickness loss increases as number of impact cycle increases. From 500 to 1000 impacts, the thickness loss is doubled *i.e.*, around 2 mm. The results indicate that as dynamic impact loading increases, thickness loss also increases regularly.

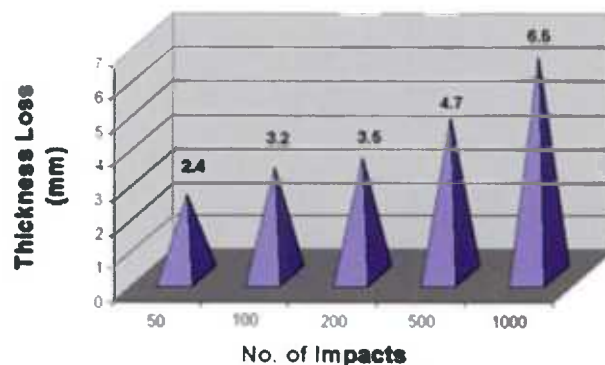


Figure 2: Thickness loss vs time for silk noil carpets

Abrasion resistance is the property of the carpet in which the pile material displays minimal loss due to wear. The silk noil carpets under study demonstrated average abrasive weight loss of 54.8 mg. Abrasion weight losses in eri noil carpets could be slightly on the higher side compared to other silk carpets, which would be due to use of noil yarn as pile. Still these eri noil yarn carpets could be used for applications such as wall carpets where abrasion is minimal.

The flammability test is done to understand the resistance of carpet on exposure to flame. The eri silk noil yarn carpet samples were tested for flammability by exposing it to controlled flame, and then radius of char on sample was measured. Flammability test results are given in Table 3. Compared to the wool standard (below 70 mm char), result of greatest radius of char observed in silk noil yarn carpets was 25 mm which demonstrates better resistance to flammability. Also the silk carpets displayed burn on face side only without any damage occurring on the back side as the ignition doesn't reach there. This demonstrates the better flame extinguishing properties of silk fibres. The flammability tests portray very good acceptability of these eri noil yarn carpets for home textiles.

Table 3: Flammability test on eri silk noil yarn carpet sample

Flammability characteristic	Value
Greatest radius of char (mm)	25
Elapsed time in sec from the instant of the nut to the extinction of the flame	36
Time in sec after glow and for smouldering to removal of the nut and to extinction of the flame	11
The specimen is ignited or not	Yes
Whether ignition reaches till the clamp ring	Yes

CONCLUSION

Carpets have been developed successfully using eri noil as pile on cotton base with satisfactory properties. Compression recovery behaviour of eri noil carpets is observed to be very good. Results of static loading and dynamic loading tests point to better thickness recovery behavior of the eri silk carpets. Abrasion weight losses in eri carpets are slightly on the higher side, which could be attributed to the use of noil yarn as pile in the carpets. Flammability characteristics of the developed eri noil carpets also demonstrate self extinguishing behaviour along with better results in comparison with the wool carpet standards. The developed eri noil carpets can be utilized for niche applications such as ornamentation carpets and also as wall carpets.

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Article scientifique

ETUDES SUR DES TAPIS DE SOIE PREPARES A PARTIR DE FILS ERI

Naveen V. Padaki^{1*}, Sainath Uppar², Uday C. Javali¹ and Kiran B. Malali¹

¹Central Silk Technological Research Institute, Central Silk Board Bengaluru 560068, India.

²Govt. SKSJT Institute, KR Circle, Bengaluru 560001, India.

*Email: naveenvpadaki@gmail.com

R É S U M É

L'Inde produit les quatre types de soie, la soie mûrier, la soie eri, la soie tussa et muga. La soie eri est la deuxième plus importante production de soie en Inde. Elle est également connue sous le nom de « Soie Ahimsa ». Comme les cocons eri sont à bouts ouvert, contrairement aux autres trois variétés de soie, la soie eri ne peut être dévidée. La soie eri peut être filée en fils épais ou très fins en raison de ses longues fibres. C'est l'une des soies les moins chères et ses propriétés sont similaires à celles des fibres de coton. Aussi, l'usage de fil eri noué offre une meilleure option pour produire des tapis de soie en fournissant une niche en plus d'être abordable. Cet article concerne la séquence des efforts derrière le développement des tapis de soie eri et leurs caractéristiques. Le filé provenant du filage de soie eri avec les plus mauvais systèmes est utilisé pour filer 10 Nm sur un bout ouvert pour produire le fil de soie eri. Ce fil a été utilisé comme base pour la préparation des tapis noués à la main utilisant les nœuds persans. La charge statique et dynamique, la compression et des tests textiles ont été conduits pour évaluer le comportement des tapis produits. Nous avons trouvé que les tapis persans obtenus ont des caractéristiques suffisantes pour être utilisés comme tapis muraux.

Mots-clés: Soie eri, filé, tapis persans, noeud persan, tapis de soie.



ASSESSMENT OF WOMEN PARTICIPATION IN SERICULTURE ACTIVITIES IN THREE SOUTHERN STATES OF INDIA

G. S. Geetha^{1*}, M. Rekha¹, G. Punithavathy², Ambika³ and M. Raghupathi⁴

¹Central Sericultural Research and Training Institute, Central Silk Board, Mysore 570008, India.

²Regional Sericultural Research Station, REC Udumalpet 642125, India.

³Regional Sericultural Research Station, Kodathi 560035, India.

⁴Regional Sericultural Research Station, Ananthapur 515001, India.

*E-mail: geethashivaram@yahoo.com

ABSTRACT

Sericulture and women are indivisible and in concert since its evolution for centuries. Sericulture activities provide a perfect choice for the women because of the very nature of the activities that can take place close to the habitations. The recent economic developments such as globalization-growth in communication technology, free market, invention and development of new technologies, social development, infrastructure development, introduction of new policies and programmes by government *etc* have brought out certain changes among lives of sericulturists in general and women in particular. With this backdrop, the present study was conducted to understand and evaluate the gender-wise participation in different on-farm and off-farm economic activities of sericulture, time spent on each activity, impact of socio economic status of women on different on-farm and off-farm activities of sericulture and constraints faced in sericulture participation in the villages of south India. The results of the study provided comprehensive information on the time spent in sericulture and other household activities and enabled the realistic mapping of labour intensive and recurring activities mostly done by women. The findings of the survey facilitated us for a realistic planning for employment, skill training and formulation of policies on development and welfare and gender perspective of sericulture women.

Key words: Constraints, gender, gender perspective, participation, sericulture, socio-economic status, women.

INTRODUCTION

In India, the state has co-opted sericulture industry for rural development in general and for empowerment of rural women in particular. Sericulture can effectively supplement agricultural sector in bringing about rural development. The uniqueness of sericulture in promoting rural development lies in the fact that it includes farmers (small and marginal) and agriculture labour, (Rao, 1984; Hanumappa, 1986) in generating regular higher income compared to agricultural crops. Sericulture provides employment to families in general and women in particular (Hanumappa, 1986) besides creating an avenue for higher export potential (Balasubramanian, 1986; Central Silk Board, 1991). In view of its high employment potential and quick returns, sericulture is being considered as an important and effective tool of alleviating rural poverty. It has thus received due attention

in rural development programmes both at the state and the central levels

Sericulture activities provide a perfect choice for women because of the very nature of the activities that take place close to their place of habitation. Women play a major role in sericulture both in terms of operations performed and time invested. Indirectly, they also contribute to management as well as decision-making.

A few studies were conducted in the recent past to understand the participation of women in sericulture activities. According to Karanth (1995), participation of women in sericulture is up to 60 % and employment potential is up to 51 % (Vasanthi, 1992). The gender wise distribution of human labour employed in mulberry sericulture is 41.54 % male and 58.46 % female in mulberry cultivation, and 45.87 % male and 54.13 %

female in silkworm rearing (Lakshmanan, 1998).

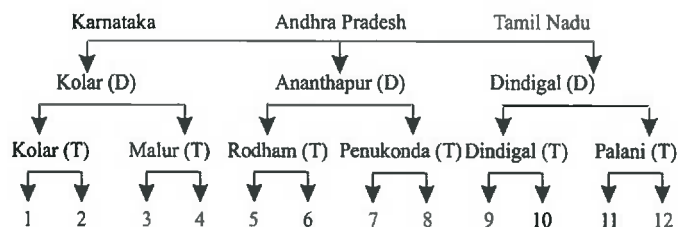
Most of the research results date back to 1990's. But in the past one-decade, many changes have occurred in terms of social development, technology development, infrastructure development, introduction of new policies and programmes by government *etc* to enhance participation of women in silk industry. Subsequently, certain changes were brought in in the lives of sericulturists especially women. Increased individual capacities such as health, education, knowledge, physical mobility, control over fertility, access to information and increased house hold decision making ability boosted women's self confidence and participation level. Provision of micro credit loans through self helps groups; increased employment opportunities and increased access to education were the main strategies that clearly enhanced women's well being to some degree. As such, a few studies after 1990 have attempted to assess the impact of these developments on women's participation in sericulture. With this backdrop, the study was formulated to understand the participation level of women and time spent on each sericulture activity in the villages of south India with the below listed specific objectives.

- To understand the socio-economic status of women involved in sericulture activities
- To examine the extent of participation of women in economic activities through different aspects of sericulture employment
- To quantify time spent in detail in the different tasks done by women
- To identify socio-economic constraints faced by women

METHODOLOGY

The study was conducted in three sericulture southern states such as Karnataka, Andhra Pradesh and Tamil Nadu. Multi stage random sampling method was followed for the selection of the sample. The three districts such as Kolar, Ananthapur and Dindigal were purposively selected from Karnataka, Andhra Pradesh and Tamil

Nadu, respectively based on the concentration of sericulture households. Two taluks from each district were selected randomly for the purpose of eliciting data. Within these two taluks, four villages, two in each taluk were selected purposively for data generation as shown in the following chart. The selection of the sample villages was based on the criteria of concentration of more number of women sericulturists in those villages.



Sample selection flow chart (Total 360 samples)

- | | |
|----------------------|------------------|
| 1. Kammandahalli | 7. Konnapuram |
| 2. Byrandahalli | 8. Moovapalli |
| 3. Byrahalli | 9. K.N.Pudur |
| 4. Yalaguli | 10. Kannivadi |
| 5. Thirukalapattanam | 11. TKN Pudur |
| 6. Patarpalli | 12. Puliyampatty |

D – District; T - Taluk

A total of thirty sericulture farmers (fifteen male and fifteen female) from each village were selected randomly. The total number of sericulture farmers thus amounts to 360.

For collecting empirical data for the study, a structured interview schedule was developed. This tool consisted of questions relating to socio economic status, asset possession, activities involved, time spent on each activity, drudgery involved in participation and other related issues.

RESULTS AND DISCUSSION

The data presented in Table 1 indicate the personal characteristics of the sericulture women. It was found that majority of women were in the age group of 25-45 years (42 %) followed by 24 % of women in the age group of below 25 years. Most of the sericulture women were married with no schooling (36 %) and a family size of 3-5 members (67 %). Significantly more women belonged to

backward caste communities. The major castes of sericulture practicing women were Gorava, Boya (Andhra Pradesh), Gownder, Mudaliyar ((Tamil Nadu) and Vokkaliga (Karnataka). Women had an experience of 0-10 years (58 %) and 10-20 years (34 %) in mulberry cultivation and silkworm rearing practices.

Table 1: Personal status of sericulture women

Sl. No.	Variable	Percentage	Number
I	Age		
	Less than 25	24	86
	25-35	42	151
	36-45	18	65
	46-55	6	22
	56 & above	10	36
II	Marital Status		
	Married	100	360
	Not married	—	—
III	Education		
	Illiterate	36	129
	Primary school	13	47
	Middle school	10	36
	High school	27	97
	PUC	11	40
	Graduation & Post Graduation	3	11
IV	Family Size		
	Below 3 member	26	94
	3 to 5 member	67	241
	5 & above member	7	25
V	Caste		
	Vokkaliga	27	97
	Backward caste	72	259
	SC/ST	1	4
VI	Sericulture Experience		
	Less than 10 yrs	58	209
	10-20 yrs	34	122
	20-30 yrs	7	25
	30 yrs & above	1	4

The results indicated in the above table clearly show that sericulture is more accepted and practically taken up by small families with a size of 3-5 members. It disproves the earlier conception that sericulture is more suitable for joint families as it provides employment for unemployed and aged. In the present context, it can be said that sericulture as an agro based rural industry is very well

suited for small family with lesser land holding for regular income compared to other agro based industries. The above table also provides a clear picture for a conclusion that majority of the sericulture practicing women are new entrants to sericulture industry with an experience of less than 10 years. They are the target group for sericulture extension personnel in terms of both transfer of technology and empowerment besides sericulture human resource development.

Table 2: Socio economic status of sericulture women

Sl. No.	Variable	Percentage	Number
I	Total land holding (ac)		
	Less than 5	77	277
	5 to 10	18	65
	11 to 15	5	18
II	Land under mulberry (ac)		
	Less than 2	77	277
	2 to 4	19	68
	> 4	4	15
III	Annual income (lakhs)		
	Less than 2	69	248
	2 to 4	24	86
	> 4	7	26
IV	Income from sericulture (lakhs)		
	Less than 2	69	248
	2 to 4	23	83
	> 4	8	29
V	Race reared		
	Cross breed	38	136
	Eivoltine	31	112
	Cross Breed & Bivoltine	31	112

The data in Table 2 clearly explains the socio economic characteristics of the women involved in silkworm rearing activities. It is evident that majority of the farmers belong to small farmers category with a mulberry land holding of less than two acres (77 %) with annual income of less than 2 lakhs of rupees mainly from sericulture. Income from silkworm rearing source was considered as annual income of the family that in turn determines the socio economic status of the family.

This gives an indication that sericulture has been taken up as a main occupation, source of main income and farmers' livelihood.

The field observation gives an evidence for collapsing of some social institutions such as joint family system, caste system besides fragmentation of land. This could be one of the main reasons for prevalence of small holdings with nuclear families in the rural area. Obviously, the rural households are left with no free or extra male family member to shoulder the sericulture activities. For this reason, the women members in the family were forced to take up the responsibility of rearing of silkworms besides routine work attached to her viz., upbringing of children, cooking and looking after domestic animals *etc.*

Table 3: Exposure status of sericulture women to extension and mass media

Sl. No.	Variable	Percentage	Number
I	Exposure (lone visit) to nearby places		
	No exposure	34	122
	Exposure	65	238
II	Extension worker contact		
	Never	9	32
	Occasional	64	231
	Regular	27	97
III	Participation in extension communication activities		
	Never	55	198
	Occasional	43	155
	Regular	2	7
IV	Training attended		
	Attended	48	173
	Not attended	52	187
V	Membership to SHG		
	Member	48	173
	Not member	52	187
VI	Ownership of land		
	Own	100	360
	Rented /leased		
VII	Possession of sericulture tools / equipment		
	Own		
	Rented	100	360
VIII	Loan status		
	Availed	48	173
	Not availed	52	187
IX	Indebtedness		
	Yes	48	173
	No	52	187

Presently, they are overloaded and overburdened with many responsibilities which hold them back from participation in extension communication activities which are mainly meant for and used for transfer of technologies. At this juncture, extension personnel need to understand the situation and organize training or extension communication programmes at a place feasible and convenient for rural women participation.

According to Table 3, women were found to have exposure to nearby villages alone without male member escort (66 %). They had occasional access to extension personnel (64 %) and participated occasionally in the extension communication programmes organized by Department of Sericulture (DoS) as well as Central Silk Board (CSB) field units. Majority did not attend the training programmes organized under State/CSB units under the guise that they are organized away from village. Membership to local civil societies- Women Self Help Groups (SHGs) were found quite considerable (48 %).

Looking at her mammoth participation in sericulture activities, industry sustainability mainly depends on presence of skilled and resourceful women. The development of skilled human resource particularly sericulture women is the urgent need of the hour. The prominent sericulture states particularly southern states besides CSB may formulate some women friendly, local/ village based training and extension programmes in near

Table 4: Participation of women in mulberry cultivation activities

Mulberry cultivation activity	Male (%)	Female (%)
Land preparation	100.00	0
Ploughing	88.00	12
Manure application	16.96	83
Fertilizer application	21.00	79
Irrigation	97.00	2.97
Weeding	2.97	97
Preparation of pesticides	90.00	9.9
Application of pesticides	65.00	35
Pruning	72.00	28
Collection of pruned sticks	4.44	95.6
Shoot harvest	5.05	95
Transportation of shoots	93.88	5.75
Average	51.23	48.38

future for effective participation. Local civil societies- Women SHGs may be utilized as a platform for the transfer of technologies.

Table 4 reveals that women participation in mulberry cultivation practices (on-farm activities) is up to 48.38 % whereas, male participation is recorded as 51.23 %. Women participation is mainly centered on activities viz., application of manure (83 %), fertilizer (79 %), weeding (97 %), collection of pruned sticks (95.6 %) and shoot harvesting (95 %). Whereas, the activities viz., land preparation, ploughing, irrigation, preparation of pesticide and transportation of shoots were not mostly or very less involved by women. During the last decade, women participation was recorded as 41.54 % (Lakshmanan, 1998), however, at present, the level of women participation recorded was 48.38 %, showing an increase by 6.84 %. This clearly indicated the increased participation of women in men dominated on-farm activity *i.e.*, mulberry cultivation. The main reasons for increased participation of women could be shortage of male family member, exorbitant wage for hired male labour as reported earlier elsewhere.

From Table 5, it can be observed that activities such as cleaning of rearing house (80 %), cleaning of rearing equipment (97 %), bed expansion (77 %), disinfection of mountages (91 %), feeding of worms (98.98 %), picking of ripe worms (99.96 %), mounting of worms (93 %), watch and ward of mountages (91 %), harvesting of cocoons (99.96 %), deflossing of cocoons (99.95 %) and disposal of rearing waste (62.97 %) were carried out mainly by women. According to the studies conducted by Lakshmanan (1998), 54.13 % female were involved in silkworm rearing activities. However, at present, the women participation level augmented to the tune of 74.01 %. The results also reveal that most of the operations carried out by women are repetitive, manually done and drudgery involved compared to her male counterpart. This clearly indicates the feminization of sericulture activities.

As evident from the data in Table 6, the female respondents spent 4.18 hours per day as against 3.34 hours spent by male in activities related to mulberry cultivation and silkworm rearing. Women spent 1.31 hours alone for

Table 5: Participation of women in silkworm rearing activities

Silkworm rearing activity	Male (%)	Female (%)
Cleaning of rearing house	20	80
Cleaning of rearing equipment	3	97
Preparation of disinfection solution	32.97	66.96
Disinfection of rearing house	62.72	37.22
Feeding of worms	0.95	98.98
Preservation of leaf	38	62
Application of bed disinfectant	50.95	48.88
Maintenance of temperature and humidity	58	42
Bed expansion	23	77
Disinfection of mountages	9	91
Picking of ripe worms	0.04	99.96
Mounting of worms	7	93
Erecting of mountages	70	30
Watch and ward of mountages	9	91
Harvesting of cocoons	0.04	99.96
Deflossing of cocoons	0.05	99.95
Cocoon packing	85	15
Disposal of rearing waste	37.03	62.97
Average	26.09	74.01

Table 6: Time spent for sericulture activities /day in hours

Silkworm rearing activity	Male (h)	Female (h)
Shoot harvest	1.24	1.31
Transportation of shoots	1.18	0.15
Preservation of leaf	0.10	0.18
Maintenance of temperature & humidity	0.12	0.12
Feeding of worms	0.10	1.52
Application of bed disinfectant	0.50	0.20
Cleaning of rearing house	0.10	0.30
Total time spent/day	3.34	4.18

harvesting of shoot, 1.52 hours for feeding of worms, 0.30 hours for cleaning of rearing house, 0.20 hours for application of disinfectant, 0.18 hours for preservation of leaf and 0.12 hours for maintenance of temperature and humidity.

The results revealed that most of the repetitive, manually done and drudgery related operations were done by women. The findings highlighted the fact that there is a need for technology forecasting with respect to women participation and time spent.

Table 7: Constraint expressed by women farmers

Constraint	Percentage
Inadequate access to credit	35
No separate rearing house	32
Lack of technological know-how	59
Lack of family labour	15
Land located at distances	33
Lack of sericulture inputs	16

A perusal of Table 7 shows that majority had a constraint of technology know-how (59 %) followed by access to credit (35 %), land located at distances (33 %), no separate rearing house (32 %), lack of sericulture inputs (16 %) and lack of family labour (15 %).

Inferences and recommendation

It is distinctly evident from the study that women participation has increased considerably from last decade particularly in silkworm rearing activities. The gender-wise participation in overall sericulture activities was 38.66 % in the case of male and 61.19 % in the case of female.

Since majority of women never attended the extension communication programmes, occasional contact with extension worker was found very less. It shows the prevalence of extension gap of dissemination of new technologies. Women had also expressed lack of technology know-how as their major constraint (59 %). Hence it can be inferred here that there is an existence of extension gap subsequently followed by adoption gap. In order to reduce extension as well as adoption gap of new technologies concerned, DoSs of all three southern states may be advised to take up large-scale technology adoption surveys to understand the plight of sericulture women and accordingly formulate the training curriculum particularly at Sericulture Training Institutes located at various regions of states. Besides this, all-southern states may take up short duration training programmes at village levels for effective and meaningful participation of women.

During XII plan, many developmental schemes have been implemented under Central Silk Board and DoSs

viz., Cluster Promotion Programme (CPP), Catalytic Development Programme (CDP) *etc.* The extension communication and training programmes proposed under these schemes may mainly target women sericulture farmers.

Looking at the women participation and time spent on each sericulture activity, innovation of new technologies/equipment/machines may be thought of. Simple and cost effective easy handling devices/equipment *viz.*, mulberry shoot harvester, silkworm feeder, device to pick ripe worms and its mounting, cocoon harvester, cocoon deflosser *etc.* may be designed and fabricated for reducing drudgery among sericulture rural women. These devices/equipment may be made available through local SHGs/Seri Poly Clinic/any other local civil society on rental basis. They may also be provided through subsidized rates under development programmes *viz.*, CPP, CDP *etc.*

Majority of the farmers were found to be doing sericulture in portion dwelling houses and had expressed it as major constraint. In this regard designing, fabrication and construction of low cost rearing houses may be thought of by considering the local region specific climatic conditions. Appropriate proposals may be sent to NABARD, ATMA, NGOs and other agencies for funding.

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Article scientifique

EVALUATION DE LA PARTICIPATION DES FEMMES DANS LES ACTIVITES SERICICOLES DANS TROIS ETATS DU SUD DE L'INDE

G. S. Geetha^{1*}, M. Rekha¹, G. Punithavathy², Ambika³ and M. Raghupathi⁴

¹Central Sericultural Research and Training Institute, Central Silk Board, Mysore 570008, India.

²Regional Sericultural Research Station, REC Udumalpet 642125, India.

³Regional Sericultural Research Station, Kodathi 560035, India.

⁴Regional Sericultural Research Station, Ananthapur 515001, India.

*E-mail geethashivaram@yahoo.com

RÉSUMÉ

La sériciculture et les femmes évoluent de concert depuis des siècles. Les activités séricoles fournissent un choix parfait pour les femmes en raison de la nature des activités et de leur proximité avec les habitations. Les développements économiques récents comme la globalisation des technologies de communication, le libre marché, l'invention et le développement de nouvelles technologies, le développement social, le développement des infrastructures, l'introduction de nouvelles politiques et programmes gouvernementaux *etc* ont entraîné certains changements dans la vie des sériculteurs en général et des femmes en particulier. Cette étude a été conduite pour comprendre et évaluer la participation des genres dans différentes activités économiques séricole à l'intérieur et à l'extérieur de la ferme, le temps passé pour chaque activité, l'impact du statut socio-économique des femmes et les contraintes liées à la participation à la sériculture dans les villages du sud de l'Inde. Les résultats fournissent une information complète sur le temps passé à la sériculture et les autres activités domestiques et permettent une cartographie réaliste des activités récurrentes et intensives principalement effectuées par les femmes. Ces résultats nous facilitent le planning réaliste de l'emploi, la formation et la formulation de politiques sur le développement et le bien-être et les perspectives des femmes en sériculture.

Mots-clés: Contraintes, genre, perspective des genres, participation, femmes, sériculture, statut socio-économique.



ODEMiŞ İPEK: A LOCAL CASE STUDY ON EFFECTIVE UTILIZATION OF SILK AND LOCAL HAND CRAFTS

E. O. Adanir*, S. Kuleli and O. D. Goknur

Faculty of Art and Design, Department of Fashion and Textile Design, Izmir University of Economics, Izmir, Turkey.

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

ABSTRACT

Silk being a valuable textile material, its producers pay more attention to the many ways they can make use or recycle the fabric. Different solutions as sustainable design strategies are preferred by companies which operate in silk industry. A local weaving company producing silk fabric in Odemis / Izmir proves a good example of it. Odemis İpek which is a silk weaving factory in Ödemiş was founded in 1977. The family began weaving by “hand looms” in 1927 and offers a diverse product range from clothing fabrics to home textile fabrics. This company provides silk fabrics to primary home textile brands in the industry. It makes benefits of recycling second quality fabrics or excess fabrics, in various ways. Even the tiny yarn pieces dropped on the floor are sold to recycle companies which spin staples of silk as yarn. They take advantage of having a retail store in Odemis. Traditional souvenirs and home textiles such as handkerchiefs, sachets, table runners and table clothes are produced and they are usually up-cycled by local hand craft arts. Every sort of defective, stained fabric are cut through problematic parts and even 5 x 5 cm² pieces are embroidered or decorated with needle tatting or crochet in an attempt of value addition of wasted fabrics. This study is intended to report ways of transforming defective industrial silk fabrics into valuable, desirable and sustainable products by using fabrics of production failure, in adherence to hand craft arts of the region.

Key words: Hand crafts, Odemis İpek, recycling, silk.

INTRODUCTION

Sustainability thrives on a system which is expected to be supported continuously in terms of environmentalism and social responsibility. Today, the factors commonly referred to as the three pillars of sustainable development are ecologic, economic and social compatibility.

All products and services have environmental impacts, from the extraction of raw materials for production to manufacture, distribution, use and disposal. “Yesterday’s textiles are tomorrow’s toxins”. It does not matter natural or manmade when the use of textiles is no longer possible, the remainder goes to either a textile recovery facility or tonnes of fabric waste ends up in landfills each year (Quinn, 2010).

Recycling is a process to change waste materials into new products. Most recycling involves converting a product or extracting useful materials out of it to create a different one. The form of recycling is classified into two main approaches: Downcycling and upcycling. The upcycling concept was developed by Gunter Pauli in 1996 (http://www.gunterpauli.com/Gunter_Pauli/ZERI.html) and it was later incorporated by McDonough and Braungart who state that the goal of upcycling is to prevent wasting potentially useful materials by making use of existing ones. Downcycling involves converting materials and products into new materials of lesser quality (Braungart and McDonough, 2002; Black, 2011).

1. Waste hierarchy

Developed countries target zero waste and make

evaluation of waste through the waste management hierarchy. Countries of European Union and Australia use a guide for prioritising waste management practices. The **waste hierarchy** in Figure 1 describes priority of environment protection stages. The waste management hierarchy is usually presented diagrammatically in the form of a pyramid and indicates an order of preference for action to reduce and manage waste. The objective of the waste hierarchy is to achieve optimal environmental outcomes. It sets out the preferred order of waste management practices, from the most to the least preferred (<http://www.zerowaste.sa.gov.au/about-us/waste-management-hierarchy>).



Figure 1: Waste hierarchy

(<http://www.zerowaste.sa.gov.au/about-us/waste-management-hierarchy>,
<http://ec.europa.eu/environment/waste/legislation/a.htm>)

Avoid (waste prevention or source reduction): The highest stage in the hierarchy is called 'avoid' or prevention in different sources. The purpose is reducing waste at the source and challenge in this stage is "zero waste". It has an emphasis on eco-efficiency.

Reduce requires less energy by designing out waste

before it is created. Waste is an indicator that systems and processes could be designed better. Costs are faced twice; first, for creation of the waste, second, for its disposal. (<http://www.zerowaste.sa.gov.au/about-us/waste-management-hierarchy>)

Reuse is any operation where products or materials are used again for the same purpose for which they were intended and requires less energy than recycling, although designs which are both adaptable and durable are essential to its success. Other factors, such as the consumer desire for 'newness', can conspire against reuse.

Recycle is any activity that includes the collection of used, reused, or unused items that would otherwise be considered waste. Recycling involves sorting and processing the recyclable products into raw material and then remanufacturing of the recycled raw materials into new products. Consumers provide the last link in recycling by purchasing products made from recycled content. Recycling reduces the need for new landfills and combustors.

Recovery of waste is further separated into categories: the recovery of materials and the recovery of energy. Whichever of these two choices is better for the environment and human health is the preferred option. The recovery of materials is preferred most often and includes activities such as recycling and composting. Recovery of energy, such as incineration, is usually the less preferred option. Energy recovery from waste is the conversion of non-recyclable waste materials into useable heat, electricity, or fuel through a variety of processes, including combustion, gasification, pyrolyzation, anaerobic digestion, and landfill gas (LFG) recovery. This process is often called waste-to-energy (WTE).

Treat is when by-products of waste are collected and used. For example fuel from decomposing waste can be used to generate electricity. The incineration of used textiles as an alternative fuel source is generally done in Europe (Hawley, 2009).

Disposal is the last stage after elimination of other alternatives. Disposal neither creates value nor energy recovery. It functions by dumping and incineration of waste.

(http://www.sepa.org.uk/waste/moving_towards_zero_waste/waste_hierarchy.aspx)

2. Textile recycling

Environment laws and costs of non-pollution measures are increasing the pressure on textile industry to take textile recycling into consideration. Currently, in all areas of textile processing, companies are trying to minimize waste. For example, elimination of high toxic and limited biodegradable materials is frequently preferred. By using new environment friendly materials, special attention is given to sustain the existing manufacturing procedures and product quality (Buschle-Diller, 2006).

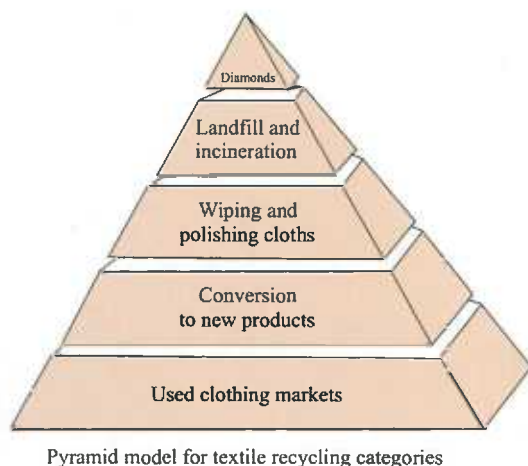


Figure 2: Pyramid model of textile recycling (Hawley, 2009)

The textile recycling by volume is shown in the pyramid model depicted in Figure 2. This pyramid was formed by Hawley using statistics of textile recycling of the world (2009).

The bottom stage is named “used clothing markets”, including apparel that are exported to developing countries by 48 %, the next stage is “conversion to new products” woven and knit products are converted to new products through different mechanical processes from

open recycling or redesign by 29 %, cut into “wiping and polishing cloths” which basically is downcycling t-shirts into house cleaning materials by 17 %, dumped into “landfills or incineration” for energy by 7 %, and finally they are ‘mined’ as “diamonds” by 1-2 %, which refers to the clothings’ vintage value (Hawley, 2009).

3. Making use of production waste for silk: A local case of Ödemiş

This study is intended to report ways of transforming discarded industrial silk fabrics into valuable, desirable and sustainable products by using fabrics of production failure, in adherence to hand craft arts of the region.

In this research, efficient and sustainable ways of utilization of silk fibre by a local producer were examined. In this case, the company has minimum environmental concern.

A local weaving company producing silk fabrics in Ödemiş/Izmir makes a good example of it. The company is a family owned business founded in 1977 by Eyup Bayındır. His father Halil Bayındır, was a master silk weaver like his grandfather who started weaving in 1927. Halil Bayındır worked as a silk weaver for 67 years in Birgi which is a town famous for its silk fabrics for centuries. At present, Eyup Bayındır’s two sons and his daughter are running the business. Hasan and Halil run the factory whereas his daughter Nergiz runs the retail store in city centre. The company offers a diverse product range from clothing fabrics to home textile fabrics and provides silk fabrics to primary home textile brands in the industry.

The company makes benefits of recycling second quality fabrics or excess fabrics, in various ways. Hasan Bayındır stated that even the tiny yarn pieces dropped on the floor are collected in bags and sold to recycle companies which produce spun silk. They take advantage of having a retail store in Ödemiş centre. Even though there is a corner in the store where they sell stained or damaged fabrics, they usually prefer up-cycling them.



1: Gold coin sac



2: Lavender sachet



3: Dowry lingerie sac

Figure 3: Re-cycled and up-cycled products of Odemis Ipek, out of defective and rejected silk fabric

Considering the dimensions of the damaged piece, they produce traditional souvenirs and home textiles such as handkerchiefs, sachets, table runners and table clothes. These items are up-cycled by local hand crafts, some of them are decorated with machine embroidery. They use every sort of defective or stained fabric. The problematic parts are cut through and even 5 x 5 cm² pieces are embroidered or decorated with needle tatting or crochet in order to value add these materials.

CONCLUSION

Efficient raw material consumption and increasing profit margins are their major motives. High value of the silk as a fibre and therefore the huge amount invested towards input prompts the investor to pay more attention to the manufacturing processes so that even tiny bits of fabric pieces or even yarn edges must be avoided to be wasted unnecessarily. The company also targets to avoid paying the cost of waste processing. The high value of silk is the factor that underlines the necessity of using efficient ways to produce fabric.

Different solutions as sustainable design strategies are preferred by this company which operates in the silk industry of this region, as well as the others. Nergiz Bayındır stated that the company also facilitates work potential for the women of the region. Women knit, crochet or do hand tatting around or over the defective silk materials, creating small house decoration and home textile items thereby increasing its value and targeting to avoid waste as well.

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Rapport Technique

ODEMIŞ İPEK: UNE ETUDE DE CAS LOCAL SUR L'UTILISATION DE LA SOIE ET L'ARTISANAT LOCAL

E. O. Adanir*, S. Kuleli and O. D. Goknur

Faculty of Art and Design, Department of Fashion and Textile Design, Izmir University of Economics, Izmir, Turkey.

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

RÉSUMÉ

La soie étant un matériel textile de valeur, les producteurs sont attentifs aux nombreuses voies qu'ils peuvent utiliser ou au recyclage des tissus. Différentes solutions comme les stratégies de dessins durables sont préférées par les compagnies de l'industrie de la soie. Une compagnie locale de tissage produisant des tissus de soie à Odemis/Izmir en donne un bon exemple. Odemis İpek une usine de tissage d' Odemis a été fondée en 1977. La famille a commencé par le tissage à bras en 1927 et offre divers produits qui vont du vêtement au tissu d'ameublement. Cette compagnie fournit des tissus de soie à des marques textiles primaires de l'industrie. Elle fait des profits en recyclant des tissus de seconde qualité ou en excès de diverses manières. De petites quantités de fils tombés à terre sont vendues à des compagnies de recyclage qui transforment en fils par filage. Ils tirent avantage de posséder une boutique à Odemis. Les souvenirs traditionnels et les textiles d'ameublement comme les mouchoirs, les sachets, les chemins de table et le linge de table sont produits et sont généralement améliorés par les artisans locaux. Tous les tissus défectueux, tachés sont découpés en pièces de 5x5 cm, brodés ou décorés avec l'aiguille ou le crochet afin d'ajouter de la valeur aux déchets de tissus. Cette étude montre des voies de transformation des tissus de soie industriels défectueux en produits de valeur, désirables et durables en utilisant des tissus de production ratée et en associant les artisans de la région.

Mots-clés: Artisanat, Odemis İpek, recyclage, soie.

NEWS CORNER

Executive Committee and 24th Conference of ISC held at Mumbai, India on 25th & 26th July, 2015



Dr. H. Nagesh Prabhu, India elected as the next Secretary General of International Sericultural Commission



Dr. H. Nagesh Prabhu, India has been elected as the next Secretary General of International Sericultural Commission (ISC) during the 24th ISC Conference held at Mumbai on 25th & 26th July, 2015. Dr.H.Nagesh Prabhu is the Chief Executive Officer & Member Secretary of Central Silk Board, Ministry of Textiles, Govt of India, which is the national agency for the development of sericulture and silk industry in India. Dr. Prabhu is an officer from the elite Indian Forest Service (IFS) and served in various capacities of different Government departments for the last 31 years. Dr. Prabhu holds a Ph.D. in Forest Science. Dr. Prabhu will assume the charge of Secretary General on 1st January, 2016 for a three year term.

The Executive Committee and 24th Conference of ISC was held at Hotel Leela, Mumbai, India on 25th & 26th July, 2015. The meeting witnessed the participation of 31 delegates from 9 countries, viz., Afghanistan, DPR Korea, Egypt, France, Japan, India, Iran, Romania and Thailand. Besides electing the next Secretary General, the meeting discussed and decided on various issues concerning the functioning of ISC.

24th Congress of International Sericultural Commission - Schedule and Venue finalised



During the 24th Conference of ISC held at Mumbai, India, the Thai delegation announced the decision of conducting the 24th Congress of International Sericultural Commission at Bangkok, Thailand during August, 2015. The Congress is planned for a period of 5 days to coincide with the 84th birthday of Her Majesty the Queen Sirikit. The official announcement of the Congress is expected shortly.



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Sericologia

International Sericultural Commission

CSB Complex

BTM Layout, Madiwala, Bengaluru - 560068

Karnataka, India

Phone: +91-80-26282191

+91-80-26680162

+91-80-26681663

Fax: +91-30-26681663

Email: sericologia@gmail.com

Website: www.inserco.org