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Improvement of host plants of Muga silkworm (*Antheraea assamensis*) for higher productivity and better adaptation - A Review

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Abstract

Muga culture is an art and science dealing with rearing of the wild silkworm *Antheraea assamensis.* It is believed that muga culture originated in the Brahmaputra Valley of Assam, India. Muga silkworm is a wild silk producing insect feeding on the leaves of som (*Persea bombycina*), soalu (*Litsea monopetala*) and dighloti (*Litsea salicifolia*). The quality and quantity of the leaf affect significantly the growth and development of the silkworm. Since being left in the wilderness, these host plants received little attention from the scientific community. Consequently, agronomic, biochemical and morphological traits of these plants have not been studied well to formulate strategies necessary to improve the leaf productivity as well as adaptability to make muga silk production adequate enough to meet even the domestic demand of India especially in view of the confinement of muga culture to the northeastern states of India and to a small extent to the Coochbehar district of West Bengal. Thus, this article aims to present a comprehensive view on various aspects of the muga host plants and the need for improving the important morphological, biochemical and agronomical traits to make muga culture a sustainable agriculturally important activity in the north-Eastern region of India.

Keywords*:* Host plant, som, soalu, selection, improvement, silkworm.
Abbreviations: AMSL-Above mean sea level; MT- Metric ton; RMRS-Regional Muga Research Station.

Introduction

Muga silk, popularly known as the "golden silk", is one of the most precious silk fibers available on earth due to its uniqueness in silk fibers and rarity in presence, as this silkworm is present only in the North-Eastern region of India. Although muga culture has a rich tradition and heritage, it is increasingly being threatened for its very survival due to the rampant and irrational exploitations (Tikader et al., 2011a). Muga silk is produced by the silkworm *Antheraea assamensis* Helfer, a polyphagous insect feeding on a wide range of plants viz., som (*Persea bombycina*) and soalu (*Litsea monopetala*) being the primary host plants, and dighloti (*Litsea salicifolia*) and mejankori (*Litsea citrata*) as the secondary host plants (Bhattacharya et al., 1993; Tikader and Rajan, 2012). A few other minor host plants viz., *Cinnamomum glaucescens*, *Actinodaphnae obovata*, *Michaela champa*, *Zizyphus jujuba*, *Xanthoxylum rehsta*, *Celastrus monosperma* are also available and are considered tertiary in nature (Neog et al., 2005). Although, efforts have been made to domesticate this silkworm by rearing them under captivity, not much success could be obtained, hence, still left in the wilderness of the Northeastern India which has distinct tropical humid climatic conditions with evergreen and deciduous forests. In order to provide a better shelter for this silkworm, efforts have been made to cultivate the host plants in the border regions of the forest. However, lack of knowledge on the genetic makeup of most of these plant species successful cultivation and enhanced leaf production could not be achieved (Thangavelu et al., 2005). Nonetheless, these efforts have enabled to improve the production of the muga silk and similar efforts in other wild silk worms such as tropical tasar (*Antheraea mylitta*), oak tasar (*A. pernyi*) and Eri (*Samia recini*) made the silk production from the non-mulberry silkworm sector to an all-time high of quantity of 4,050 MT. However, considering the tremendous scope for increasing the production of muga silk by exploiting the congenial climatic conditions of North-Eastern India, it is felt necessary to improve the cultivation of the muga host plants by understanding the genetic makeup of the host plants and manipulating it to the advantage of higher leaf productivity and better adaptability. Since leaf quality has significant impact on quantity and quality of the silk fiber, for sustaining muga culture it is important to ensure availability of adequate quantity of qualitatively superior leaves. To start with the genetic improvement program all available genotypes of the host plants, especially of som and soalu, have to be collected, characterized and utilized for plantation as well as developing genetically manipulated superior cultivars.

Distribution of muga silkworm host plant

Muga food plants have wide distribution throughout the North-Eastern India and in some parts of Northern India. These plants are widely available in the states of Assam, Meghalaya, Manipur, Mizoram, Nagaland, Tripura, Sikkim, Himachal Pradesh, Uttaranchal, Uttar Pradesh, Gujarat, West Bengal and Pondicherry and sporadically available in Arunachal Pradesh (Table 1). It was also reported that they are present in Nepal, Myanmar, Malaysia, Indonesia, Bhutan and Srilanka (Tikader and Kamble, 2010). Northeast India lies in between 22°- 29° N latitude and 90°- 97° E longitude

Table 1. Distribution of food plants of Muga Silkworm.

Host plants	Scientific name	Distribution
I. Primary food plants	1.*Litsea monopetala*	Northeastern India, Western Himalayan region
	2.*Persea bombycina*	Northeastern India, Nepal
II. Secondary food plants	3.*Cinnamomum camphora*	Northeastern India
	4.*Cinnamomum tamala*	Northeastern India
	5.*Litsea citrata*	Northeastern India
	6.*Litsea salicifolia*	Northeastern India, Nepal
III.Tertiary food plants	7.*Actinodaphne augustifolia*	Northeastern India, Bangladesh
	8. *Actinodaphne obovata*	Northeastern India
	9.*Celastrus monosperma*	Northeastern India
	10.*Cinnamomum cecicodaphne*	Northeastern India
	11.*Cinnamomum glanduliferum*	Northeastern India
	12.*Cinnamomum obtusifolium*	Northeastern India
	13.*Gmelina arborea*	Northeastern India
	14.*Litsea nitida*	Northeastern India
	15.*Litsea salicifolia*	Northeastern India, Nepal
	16.*Machilus odoritissima*	Northeastern India
	17.*Magnolia pterocarpa*	Northeastern India
	18.*Michelia champaca*	Northeastern India, Nepal, Bangladesh, Myanmar
	19.*Michelia oblonga*	Northeastern India
	20.*Symplocas grandiflora*	Northeastern India
	21.*Symplocas paniculata*	Northeastern India
	22.*Symplocas ramosissima*	Northeastern India

Table 2. Variability in leaf morphology of soalu (*Litsea monopetala)*.

Morphotype	Leaf wt.(g)	Leaf length (cm)	Leaf breadth (cm)	L x B cm²	Vein no.	Petiole length (cm)
Morph-1	1.7	15.4	7.0	108.0	21.9	1.6
Morph-2	2.1	15.1	9.1	138.4	19.1	1.7
Morph-3	1.4	12.2	7.7	95.1	18.9	1.2
Morph-4	2.7	14.7	10.4	153.9	21.0	1.6
Morph-5	2.3	17.3	8.9	155.7	19.6	1.4
Morph-6	2.3	15.4	8.6	133.9	20.0	1.7
Morph-7	1.8	13.7	8.5	116.7	18.1	1.6
Morph-8	2.0	16.8	6.8	116.1	19.3	1.7
Morph-9	1.9	12.8	9.0	116.7	18.7	1.7
Morph-10	2.6	18.6	8.9	168.1	21.1	1.4

with a geographical area of 2, 55,000 sq. km. Sixty five percent of the area is mountainous and 35% is almost level land mostly lies in the Brahmaputra valley. The altitude ranges from 30- 4500m above mean sea level. *Litsea citrata* Pers. is growing spontaneously in the eastern Himalaya, Assam, Manipur up to the altitude 2700 m AMSL. The tree locally called as "mejankari" in Assam is a secondary food plant of muga silkworm. The silk produced by the silkworm grown on this plant is very attractive and several times costlier than the silk produced by silkworms from other host plants (Choudhury, 1981; Choudhury et al., 2012). All the muga host plants grow well in wet and warm climatic conditions with high rainfall and soil pH range of 4.0- 6.8. Muga silkworm host plant, som (*Persea bombycina* Kost.) is a heterogeneous wild deciduous tree available abundantly in natural forest of northeast India. It exhibits variability in several desirable and undesirable traits. Plants with suitable traits are to be selected for further improvement and commercial use. The seed characters vary depending on the altitude and they show large variations in their characters. So, standardization of seedling / saplings characters is must for commercial exploitation.

Present status of muga silkworm food plants improvement

Although, collection of muga plant genetic resources was initiated in 1988 by the Regional Muga Research Station (RMRS), Boko, Kamrup, Assam, only fourteen cultivars of som and ten cultivars of soalu could be collected from Assam and Meghalaya. After initial evaluation, 8 som and 10 soalu genotypes were selected for further studies. These genotypes were characterized based on morphology, floral biology, propagation, chemo-assay and bioassay (Hazarika et al., 1996; Paliwal and Das, 1989; Raja Ram, 1998; Siddiqui et al., 1998, 2000; Singh et al., 2000; Thangavelu et al., 2005; Tikader and Kamble, 2010). Morphologically the som and soalu genotypes showed wide variations in number of rachis per inflorescence, rachis length, number of flowers per rachis, flower size, perianth and peduncle length (Table 2& 3) (Thangavelu et al., 2005). The time taken for buds sprouting after pruning was 30 days to 82 days. The biochemical estimation of 14 morphotypes of som germplasm revealed crude fiber ranged from 8.52-11.32%, lipid 5.42-7.10%, crude fiber 19.62-28.07%, total ash 3.72-5.09%, lignin 7.84-16.0%, cellulose 20.27-35.9% and moisture content 46.0 -65.0% (Table 4). The propagation of som (Table 5) and soalu is primarily through seed. Since the parental trees are highly heterozygous the seedlings showed wide variations which in turn resulted in unequal leaf production. To avoid such variations in the orchard, selected trees were propagated through vegetative means to get true to type plant. Vegetative propagation can be done through stem cuttings, leaf bud cuttings, grafting, layering etc. (Sengupta et al., 1993). In general vegetative propagation is cumbersome and needs proper care during the initial establishment.

Table 3. Variability in reproductive biology of Som *(Persea bombycina* King).

	Morphotypes							
Distinguishing characters	I*	II	III	IV	V	VI	VII	VIII
Bud development period (days)	35	46	60	82	30	52	34	43
Rachis per inflorescence	6-7	3-4	3-5	6-8	5-6	4-6	10-13	3-6
Length of rachis (cm)	9.9	7.1	3.6	8.1	2.7	2.1	6.3	3.4
Flowers per rachis	19.6	23.3	13.3	38.8	11.4	13.5	9.1	9.6
Perianth length (cm)	0.56	0.50	0.41	0.66	0.60	0.40	1.07	0.52

*- Morphotypes I to VIII.

Table 4. Biochemical estimation of leaf samples of 14 morphotypes of Som (*Persea bombycina)*.

Morppho type	Crude Protein	Lipid %	Crude Fibre %	Total Ash %	Lignin %	Celulose %	Total Carbo-hydrate%	Moi- sture %	Calc-ium %	Phos phorous %
Som-1	10.2	6.6	19.6	3.9	11.2	28.0	79.2	41.2	1.2	0.3
Som-2	10.9	6.7	23.9	4.5	14.1	20.2	77.9	41.5	1.2	0.3
Som-3	11.3	5.4	28.1	4.7	8.9	32.2	78.6	43.0	1.7	0.4
Som-4	10.2	5.7	22.3	4.9	10.7	35.3	79.2	38.7	1.3	0.3
Som-5	10.1	6.9	19.7	3.9	13.0	28.7	78.9	43.2	1.9	0.3
Som-6	8.5	5.5	23.2	6.0	10.4	32.0	79.9	46.4	1.8	0.3
Som-7	10.1	7.5	24.1	4.5	10.3	28.1	77.9	43.9	1.8	0.3
Som-8	9.3	5.7	23.7	4.8	7.8	35.9	80.1	39.5	1.3	0.2
Som-9	9.9	6.2	20.3	4.8	13.7	28.3	79.0	37.5	1.8	0.3
Som-10	8.8	5.9	22.3	3.7	17.2	28.3	81.7	38.4	1.8	0.3
Som-11	9.9	7.1	21.2	4.4	15.9	29.0	78.5	31.0	1.6	0.3
Som-12	4.5	6.3	21.5	5.0	11.2	26.5	78.0	40.2	1.7	0.3
Som-13	10.0	6.6	21.2	4.4	15.5	26.0	79.0	34.7	1.5	0.4
Som-14	10.3	6.1	23.4	5.0	10.7	32.8	78.5	34.0	1.3	0.3
CD (5%)	0.4	0.4	0.3	0.1	1.6	2.4	0.6	2.5	0.1	0.02

Grafting is adopted when vegetative clone cannot be generated by cuttings (Tikader and Thangavelu, 2006). However, the stem/root grafting and air layering give less survival but the leaf bud cutting produces up to 70% of survival in the commercially exploited genotype like S3 of som (Table 5). In another effort, 39 som genotypes were collected by the Central Muga Eri Research and Training Institute, Lahdoigarh, Assam. These genotypes were characterized based on a set of characters as detailed in Table 6. Based on superiority on growth and yield attributes, infestation of pests and diseases, chemo assay and bioassay (Table 7), three accessions were selected for further assessment at farmer's field. In general, som trees have the potential of yielding 22-24 MT /ha/year leaf but presently only 16-18 MT/ha/year is obtaining. So, there is an yield gap of more than 8MT/ha/year. To fill up this gap, agronomic and cultural practices need to be improved. Likewise, some natural hybrids of Dighloti (*Litsea salicifolia*) and Soalu (*Litsea monopetala*) were also collected which need to be characterized for further utilization. Crossing among some of the genotypes of soalu and dighloti produced hybrids and the bioassay of this combination appeared to be promising (Tikader, 2012a). These studies clearly indicated the possibility of developing hybrids that are capable of yielding high quantity of good quality leaf.

Improvement through breeding

The genetic variability in germplasm is the raw material for improvement of the plant species through different breeding programmes. The breeding objectives are to be set considering the need of the silkworm and availability of the genetic diversity. The genetic base of the germplasm can be broadened by adding new gene pools through exploration, collection and characterization. After characterization and evaluation of the germplasm accessions prebreeding is carried out to bring desirable traits into one or a few accessions which can then be used for cultivar development. Keeping this in view, a crossability study was carried out to test the possibility of crossing soalu (*Litsea monopetala*) with dighloti (*Litsea salicifolia*) as they belong to same genus and has same chromosome number; also they flower in the same season. The hybrids, thus, developed were fertile and the bioassay with muga silkworm showed very encouraging results (Tikader, 2012a). Other than these few attempts not many efforts have been made to cross som (*Persea bombycina*) with soalu or any with other species. Since, vegetative propagation is possible, improvement through polyploidy breeding was another area of research that has recently attracted much attention. Tetrapolids are developed through colchicine treatment of the diploid ones. Initially colchicine of different concentrations i.e., 0.2%, 0.3%, 0.4% and 0.5% were tested in diploid (2n=24) for different durations such as 12h, 24h and 36h (Das et al., 1970). Based on the results, 0.4% and 0.5% colchicines for 24h duration were found optimal. Tetraploids developed through this method showed increase in number of branches, leaf yield/plant, leaf area, and leaf thickness. However, a decrease was also noticed in plant height, growth rate/day and intermodal length. Thus, in order to harness the benefit of higher growth rate coupled with better leaf quality; it is necessary to develop triploids by crossing tetraploids with desirable diploids.

Genetic enhancement through introgression of wild genes

Breeding in any crop is mainly targeted to improve or enhance desirable characters by crossing between parents of divergent traits. As most of the cultivating crops lack several desirable traits/genes, it is necessary to broaden the existing

Table 5. Rooting behaviour in different morphotypes of Som (*Persea bombycina*).

Characters	Range	Mean	S.E.	C.V.
Rooting %	16.66-53.33	32.7	4.79	41.43
No. of primary roots	2.8-40.3	3.61	0.18	14.40
No. of leaves in new sprout	1.7-3.1	2.53	0.16	17.73
Mean length of new sprout (cm)	1.4-2.6	1.81	0.14	22.09

Table 6. Growth performance of selected three year old plus trees of Som (Adapted from Annual Report of CMER&TI, Lahdoigarh 2006-2007).

Accession	Plant height (m)	No. of branches	Internodal distance (cm)	Laminar length (cm)	Laminar width (cm)	No. of leaves	Leaf yield/plant (kg)
PB009	2.31	25.45	2.96	16.70	5.85	2726	2.18
PB010	3.14	26.75	2.94	12.21	3.69	2320	2.23
PB011	3.15	27.50	3.94	12.33	4.55	2940	2.85
PB012	2.76	25.50	2.98	13.76	5.38	2897	2.74

Table 7. Rearing performances on different Som cultivars.

Morphotypes	Characters					
	Larval wt. (gm.)	ERR (%)	Cocoon wt. (gm.)	Shell wt. (gm.)	Shell Ratio (%)	Absolute Silk (gm.)
Som-1	11.37	50.74	5.03	0.45	8.91	70.25
Som-2	11.43	49.66	5.21	0.44	8.58	67.63
Som-3	11.66	55.91	5.29	0.45	8.54	74.82
Som-4	11.61	54.25	5.41	0.46	8.44	73.72
Som-5	11.58	55.08	5.11	0.42	8.18	68.35
Som-6	11.91	61.16	5.47	0.47	8.61	87.65
Som-7	11.18	44.16	5.39	0.44	8.13	64.55
Som-8	11.17	47.91	5.56	0.47	8.41	68.99
CD (5%)	-	3.35	-	-	-	4.77

Table 8. Egg hatching and muga silkworm growth on different host plants.

Host plant	Egg hatching (%)	Growth behavior of different stages of silkworm (length in cm)				
		I*	II	III	IV	V
Som	86.80± 3.20	0.89± 0.03	1.59± 0.06	2.79± 0.03	4.82± 0.02	8.59± 0.15
Soalu	81.00± 2.24	0.72 ± 0.01	1.82± 0.02	3.22± 0.06	5.30± 0.06	9.21± 0.07
Dighloti	73.00± 1.87	0.70± 0.03	1.46± 0.03	2.10± 0.09	4.20± 0.08	7.80± 0.12
Soalu x Dighloti	87.00± 3.80	1.12± 0.02	1.82± 0.02	2.82± 0.03	4.85± 0.04	9.25± 0.06
Mean	80.88± 2.78	0.86± 0.02	1.67± 0.03	2.73 ± 0.05	4.79± 0.05	8.80± 0.09

* Growth stages

genetic base by bringing in new traits and genes. Results of genetic enhancement through introgression have already highlighted the significance of using wild species (Tikader and Dandin, 2001; 2007; 2008; Tikader and Kamble, 2008a). The wild species generally possess several important traits like abiotic and biotic tolerance which can be introgressed through wide crossing and repeated back crossing with the desirable parent (Tikader and Kamble, 2008a). Thus, wild genetic resources provide significant scope for target oriented selective breeding to incorporate the characters of importance including drought, frost, water logging and disease resistance into popular cultivated varieties. Such efforts are essential to enhance the leaf yield, quality and wider adaptability in muga silkworm host plants.

Bioassay study with host plant

Efforts have also been made to rear muga silkworm on different host plants and examine the effects on various characters (Table 8). Variations in cocoon characters due to host plants were already reported (Ahmed et al., 1998; Barah et al., 1992; Tikader, 2011). It is found that muga silkworm reared on hybrids developed from soalu and dighloti showed faster growth of larvae, shorter moulting duration and better cocoon characters (Tikader and Rajan, 2012), though the hybrids possessed more of soalu characters. In general, som is the preferred food plant as the worms reared on it showed uniform growth and higher silk ratio. So, som is used for producing good quality of silk thread at commercial level. Although, dighloti is available in nature abundantly, it is considered only as secondary food plant because the larvae reared on it showed slow growth, higher larval duration and low silk ratio. However, the hybrid developed from these food plants has better characters than the parents. Thus, further attempts need to be made in this direction.

Future strategies

The major constraints identified for muga silk industry in North-Eastern India are described hereunder:

The genetics of the host plant is yet to be studied in details.
Molecular characterization of host plant has not been carried out to select genetically divergent parents for breeding purpose.
Appropriate agronomical practices have not been developed to obtain quality leaf.
No standard method is available for vegetative propagation of the plants.
Not much effort has been made to enrich the gene pool of the host plants for utilization.
Thus, it is essential to formulate long term strategies not only to conserve the genetic resources of these precious plants but also to enhance the genetic diversity through concerted efforts by integrating various disciplines of biological science. Enhancement of diversity among the morphotypes/ cultivars of muga silkworm host plants can be achieved through employing various breeding techniques. Considering the close association between the welfare of the tribal community and the successful rearing of the silkworm, Central Muga and Eri Research and Training Institute, Lahdoigarh, Assam has initiated several both short terms as well as long term programs for exploration, collection, characterization and utilization of muga silkworm host plants.

Conclusion

Thus, it is clear that muga culture has great potential to act as a catalyst to preserve the biodiversity of the North-eastern region of India as almost all the muga host plants are forest trees, protecting them would help in conserving the forest, especially at a time when rampant deforestation and urbanization is very common. Since availability of quality leaf decides the sustainability of muga culture, improvement of host plants through collection, characterization, evaluation of new germplasm accessions and utilization of them in breeding programs will help in improving the genetic base of the currently available host plants. Hybrids developed by crossing som (*Persea bombycina*) with dighloti (*Litsea salicifolia*) showed better characters. Similar kind of hybridization experiments are to be undertaken with compatible species to produce hybrids with higher leaf production and better adaptability to expand the muga culture to other areas of northeast India to meet the growing domestic demand for silk and silk related products and also to provide a sustainable livelihood to the local population.

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