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6. Muga Silkworm: An Approach towards Climate Resilient Sericulture for Promoting Sustainable Development

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6.1 Introduction:

Muga silk fabric has been a vital part of the Assamese culture from time immemorial. As evident from Kautilya’s ‘Arthasastra’ and Edward A. Gait’s ‘A History of Assam’, Muga-silk has been adored for ages (Baruah, 2017). Muga silk is produced from Muga silkworms (*Antheraea assamensis* Helfer) that belong to non-mulberry, or Vanya silk and is mostly wild unlike mulberry silkworm-the domesticated counterpart. This variety of silk moth is monospecies and exclusively confined to the Brahmaputra valley of Assam, and the adjoining hilly area of North-east India- a part of the Indo Burma mega-biodiversity Hotspot (Myers et al., 2000; Chowdhury 1982). Muga silk was assigned Geographical indication (GI) tag in 2007.

The exquisite and shimmering golden silk has attracted global attention for centuries. Muga had put Assam on the famous silk route attracting consumers from far beyond and has helped secure remarkable status in the Silk map of the world. Currently, the state Assam produces 87% of India's silk production and much of it is contributed by muga silk.

In the recent years, silk has been widely used in bioengineering applications. This is owing to the improved biocompatibility with nominal adverse reactions in vivo, optimized physico-mechanical properties mimicking those of target tissues, ease of developing to meet cellular architectures as well as biodegradability, (Kundu et al., 2014; Gogoi et al., 2014). In addition, Muga silk has found application as nanomaterials (Asapur et al., 2020).

The avenue is highly employment-oriented and requires low capital-input. Therefore, it is an excellent option for development strategies targeted to generate sustainable employment and entrepreneurial opportunities in the rural areas.

However, there is several bottlenecks towards up-scaling productivity to meet consumer demand. The primary reason is of course the ecological isolation, that makes Muga silkworms phylogenetically less adaptive (Tikader et al., 2013). Muga silkworm possesses little genetic variation among populations, and it is less resistant to infection (Arunkumar *et al.*, 201. In addition, intensive agricultural practises, shrinkage in host plant habitats, age-old package and practises and lack of scientific insight hinders Muga economy from growing.

This chapter describes the status of Muga silk, its applications and scopes of productivity improvement in terms of horizontal expansion of food plants, improved package of practices and emphasises on muga-gut biota as a key driver to possible application for climate reselient muga cultivation.

6.2 Muga Silkworm Habitat, Host Plants and Taxonomy:

Muga silkworm (chromosome number, n = 15) habitat extend from West Garo Hills district of Meghalaya stretching East ward to Karbi Anglong and Hill districts of Assam, down to the Mon district of Nagaland (25.5736°N, 93.2473°E). The confined geographical presence of Muga silkworms indicates its special requirement for productivity and survival. Such prerequisite includes high humid temperate climate, availability of different host plants and suitable pristine ambience.

Muga silkworm is a polyphagous phytophagous insect with about 22 host plant species (Nath et al., 2008). The choice of food plants of muga silkworms is governed by the presence of unique allelochemics such as alkaloids, tannins and terpenoids as well as benzyl isoquinoline (Peigler 1989, Geissman et al. 1969). Preferably it feeds on primary host plants like Som (*Persea bombycina* Kost.) and Solao (*Litsea monopetala* Roxb.). In absence of primary host plants, muga silkworm feeds on secondary host plants- Dighloti (*Litsea salicifolia* Roxb.) and Mejankori (*Litsea cubaba* Lour.). Some other food plants of muga silk belong to Lauraceae family- *Actinodaphnae obovata* Nees (Blume), *A. Anquistifolia* (Blume) Nees, *Cinnamomum glaucescans* (Nees) Drury, *C. glanduliferum* (Wallich) Meisner and *Litsea nitida* (Roxburgh) Hooker f. Some of the less preferred tree species includes *Celastrus monospermus* Roxburgh (Celastraceae), *Michelia champaca* L. (Magnoliaceae), *Magnolia sphenocarpa* Hooker F. and Thomson, *Zanthozylum rhesta* (Roxburgh) D.C. (Rutaceae), *Gmelia arborea* Roxburgh (Verbanaceae), and *Zizyphus jujuba* (Rhamnaceae) (Neog et al., 2006).

Kingdom: Animalia

Phylum: Euarthropoda

Class: Insecta

Order: Lepidoptera

Family: Saturniidae

Genus: Antheraea

Species: A. assamensis

Binomial name

Antheraea assamensis Helfer, 1837

6.3 Muga Silk and Socio-Economy of the Region:

From time immemorial, muga cultivation has been a mean of livelihood for many households. Muga silk industry is a prized export-oriented industry. Being endemic to the region, Muga silk has the potential to provide gainful occupation for rural mass and semi-urban areas of North-east Indian region. As per 2017-18 data, sericulture is practiced by more than 9935 villages and provides employment to more than 3.19 lakh families in Assam (Assam Economic Survey Report, 2017-18). During the time, amount of silk produced was 34.45 percent higher than the previous year (2016-17). The annual production of the Muga raw silk was about 233 MT in the year 2019–2020 (http://csb.gov.in/).

The export business of India from silk during 2008-09 (April-May) was worth Rs. 486.84 crore approximately and 429.88 crore in 2007-08 during the same period. The price per thousand of muga reeling cocoon, per KG of Muga Raw Silk (warf) and the weft has been Rs. 650.00, Rs. 5000.00 and Rs. 4500.00 respectively in the month of September 2008 at Sualkuchi Market while the price of the same in the previous year was Rs.600.00, 3900.00 and Rs. 3250.00 respectively (Phukan, 2012). At present, the business of Muga, the golden silk, is worth of Rs 200 crore. With proper management, the industry has potential to grow 10 times of its current size. In the international market price of muga silk is 242–346 US$ per kg raw silk (Central Silk Board, 2020) costliest among all silks produced in the world.

6.4 Cost Economics of Muga:

Muga cultivation is a labour-intensive practise as well as it requires larger farmland for host plants. The primary cost incurred during muga farming can be categorised into – Seed Cost, Labour cost, Depreciation cost, Expenditure on Host plants and related miscellaneous costs.

The income from sericulture can be categorised into return from Cocoon, seed cocoon, silk yarn as well as sell of garments. The gross cost per hectare in Muga cultivation is Rs. 8.05 Lakh including imputed labour cost and depreciation charges.

It is possible to earn net profit of Rs. 1.2 Lakh/ Hectare of muga farm with an ROI of 15.21% (Paul and Jena, 2017). Muga can be an attractive model for rural upliftment due to its high rate of return (Pandey, 2010).

6.5 Bottlenecks to Commercial Production and SWOT Analysis:

Muga cultivation has several bottlenecks that has caused its reduction. Following are the prime factors for it.

6.5.1 Ecological Factors:

Muga silkworm is semi-domestic in nature. From brushing to 5th instar stage, it is reared outside, while during cocooning, it is reared inside. The outdoor stage exposes silkworm larvae to nature's vagaries such as pests, predators and pathogens, seasonal fluctuation in temperature, rainfall, strong wind etc. inflecting heavy loss to the farmer (Barman and Ranjan, 2012).

6.5.2 Anthropological Factors:

Gradual land use change and shifting cultivation as well as increased use of pesticides has tremendously impacted muga silkworm. Moreover, various developmental activities as well as forest fragmentation has shirked muga habitat (Nath et al., 2008).

6.6 Traditional Rearing Practises:

Agricultural practises have been greatly benefiting from adoption of advancement of technological intervention and precision farming practises. However, Muga silk, being highly sensitive and semidomesticated nature, there exits several bottlenecks. Thus, there been little intervention from the scientific approach point of view. Muga-rearers even today do follow the age-old package and practises.

There is vast opportunity for addressing the woes of the sericulturists in terms of avoiding diseased Disease-Free-Laying (DFL), Nutrition management of host plant as well as the muga silkworms during active feeding stages and overall best practises to increase productivity.

SWOT matrix or SWOT analysis is a technique widely used in strategic planning and strategic management to identify strengths, weaknesses, opportunities, and threats related to business competition or project planning. It is also called situational assessment or analysis. For Muga farming, the SWOT matrix is as shown in Table 1.1.

Table 6.1: SWOT matrix of Muga farming in Assam

Strength	Weakness
• Supportive natural environment (soil, inclination, rainfall, etc.) for growth of som and sualu trees which is necessary for the muga silkworms to feed. • Access to indigenous knowledge, expertise, and skill	• Motivation among entrepreneurs • Lack of formal financial sources and Institutions • Smaller land holding

• Government policy crafted for handloom sector and area-specific schemes. • Easy availability of cheap labor with appropriate level of skill • Lower rate of investment and high rate of ROI and profitability • Growing demand.	• Age-old practises and lack of Scientific intervention. • Middlemen dominated supply-chain. • Lack of insurance, storing facilities, transportation, publicity etc. • Lack of centralized Muga silk processing facilities. • Absence of organized and regulated market. • Lack of forward linkage.
Opportunities	**Threat**
• Endemic nature of Muga • Growing market for hand-woven muga silk • Availability of online marketing channels • Promotion of Farmer Producer Companies (FPO) and supporting policies to safeguard the interest of the muga silk weavers.	• Natural environment and global warming. • Lack of open and regulated market • Competing agricultural practises • Rise in labour cost and unavailability of workforce.

6.7 Trends in Muga Productivity Enhancement:

6.7.1 Host Plant Propagation and Management:

One of the critical requirements in Muga farming is the healthy host plant. Som (*Persia bombycine*) and Soalu (*Litsaea polyantha* Juss)- the primarily host plants are propagated by seeds.

The seeds are sown in the nursery and is nurtured till ready to plant in the farmer’s field. After systematic plantation in the field as per package and practise, it is essential for management of management of pest and disease of the host plants for profitable muga farming.

6.7.2 Improvement by Muga Breeding:

The genetic diversity of muga silkworm in culture rapidly decreases (Tikader et al., 2013).

Muga being found on host plants that differs by their abscission cycle, it influences Muga hibernation cycle (Kakati, 1991, 1993).

There exist several bottlenecks to improvement of Muga by breeding and there are not many reports available in this regard.

6.7.3 Indoor Rearing of Muga:

One of the primary reasons to loss in muga is due to its outdoor rearing mode. Out of the 5 to 6 broods, only the commercial cycle falls during favourable weather period, while the other crops fall prey to harsh weather.

Thus, there has been efforts to raise muga indoor. Such efforts include feeding host plant leaves in indoor conditions (Barman and Rana, 2011) as well as enhancing feeding behaviour in Muga silkworm by application of Nutrient Supplemented Phago-stimulants (Barman and Rajan, 2012). Muga silkworm grows till the 5^{th} instars in outdoor conditions after which it is maintained indoor. Thus, the prime motive behind indoor rearing is to support the early instars (till the onset of 3^{rd} instars).

6.7.4 Muga Artificial Diet:

Semi-synthetic diet for muga is an emerging field in Muga research. This has been tried by many researchers, however, has tremendous scope of improvement to be practically useful in commercial rearing practise. Saikia and Hazarika (2015) reported supporting larval growth using semi-synthetic Muga-diet. It is essential to know the chemical profile of Muga host plants for designing artificial diet. Neog et al., (2011) studied the phytochemicals present in Muga host plants.

They observed that β –sitosterol content in the tender leaves was significantly that β –sitosterol content is highest in tender leaves. The prime bottleneck during designing semi-synthetic diet is to prevent growth of pathogens on the diet while at the same time mimicking the natural flavour and nutrients in the diet to support growth of the insects. Successful recreation of natural host plant-like artificial diet is an opportunity towards climate resilient Muga farming.

6.7.5 Application of Beneficial Gut Microbiota in Silk Farming:

Another potential field of emerging research is the foliar application of beneficial bacteria *in-vitro* for supporting muga growth by helping digestion and resistance to pathogenic microbes. This research is in the nascent stage and has wide prospects towards improving rearing performance.

Bhuyan et. al., (2018) isolated cellulase degrading gut bacteria from Muga silkworm for potential application as foliar spray to help improving silkworm health thereby improving rearing performance. Gandotra et al., (2018) reported the presence of various digesting enzyme producing bacteria in the gut of healthy Muga silkworm.

6.7.6 Ecological Engineering:

In a broader perspective, ecological engineering involves the restoration of ecosystems that have been disturbed by human activities. The prime tools of ecological engineering are incorporation of biofertilizers, particularly mycorrhiza for improving soil health and help up taking critical macro and micronutrients by the crops (http://niphm.gov.in).

Restoring the natural condition helps orchestrating and reviving the productivity and strength within crops and that operational parameters and process configuration can act as selective forces on the community (Augelletti et al., 2019; Sree Latha and Jesu Rajan (2018). In terms of Muga silk, ecological engineering may include creating buffer zone to prevent reach of agrochemicals, plantation of healthy host trees and maintaining pristine condition in the surroundings.

6.8 Conclusion:

Muga rearing is a traditional practise with potential futuristic avenue for designing development strategies for the North-East India region.

However, there lies plenty of gap areas yet to be addressed to help the tradition to sustain and prevent being lost. Thus, there is dire need to adopt informed policy framing, calculated approaches and farsighted action plans to help Muga silk to reach the global stage.

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