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Factors affecting on quality muga silkworm (*Antheraea assamensis* Helfer) seed crop production: A review

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Abstract
Muga silk is the traditional heritage of Assam. Muga silk has a special status due to its natural golden yellow colour. Semi-domesticated muga silkworm (*Antheraea assamensis* Helfer) is multivoltine in nature and commercial rearing is conducted during spring and autumn seasons. The culturing of muga silkworm has its own problems and peculiarity. The success of sericultural crops mostly depends upon quality of seeds. On the other hand, good and healthy crop can only ensure quality seed production. Production of muga raw silk is not upto the mark in comparison to the other commercial silks of India. It is because, seed sector of muga silkworm is not properly organized till today. Therefore, required quality and quantity of muga seed is not available during the commercial rearing seasons. The factors responsible for the muga silkworm seed production are discussed in the present study.

Keywords: Muga silkworm, seed, production, multivoltine, commercial rearing

1. Introduction
Assam has a unique position in the world sericulture map for production of vanya silk especially for muga silk production. Muga silk is the first GI registered item of Assam. Though Assam is known for muga silk, major portion of the vanya silk produced in Assam is from eri silk. A little amount of muga silk is also produced in Meghalaya, Arunachal Pradesh, Manipur, Mizoram and Nagaland. Muga silkworm cultivation is newly introduced in West Bengal and Uttarakhand. In Assam 57,966 nos. of families are engaged in muga sericulture activities and area under muga silkworm food plants is 10371 ha [1]. Inspite of the glorious history, the production of muga raw silk is not upto the mark. The production of muga raw silk is 158 MT during 2014-15 in India and Assam shares 86.08% of the total production [2]. Slow increase of production might be due to shortage of food plants, non-availability of good seeds [3, 4], pest and parasites [5], diseases, abnormal changes of temperature, humidity, rainfall, wind velocity in different seasons [6], inbreeding depression [7] etc. Among these shortage of healthy seed is the main problem of muga sericulture industry. There is always a gap between demand and supply of muga silkworm seed. At present the muga dfl production is less than 120 lakh/year whereas the capacity is 133.65 lakh dfl/year and the requirement is 200 lakh dfl/year [8]. Besides rearing, the overall success of the muga silk industry hinges on a number of marketing factors [9, 10]. Several works have been carried out to increase muga seed production which are discussed in the present study.

2. Muga Silkworm seed organisation
Muga Silkworm Seed Organization (MSSO) is the nodal agency for production and supply of muga basic seed. The MSSO, Guwahati, Assam is functioning under overall control of Central Silk Board (CSB), Ministry of Textiles, Govt. of India to supply sufficient quantity and quality of muga seed. The Muga Seed Development Project (MSDP) was established by CSB in Guwahati, Assam during the year 1983 and it has been renamed as Muga Silkworm Seed Organization (MSSO) during 2005. The MSSO, Guwahati, Assam supports basic seed multiplication, and production of these races through two P4 units (located at Tura and Mendipathar, Meghalaya), six P3 units (Rompara, Nongpoh and Adokgiri in Meghalaya; Hahim and Narayanpur in Assam; Jia in Arunachal Pradesh), one Muga Silkworm Seed Production Centre (SSPC) at Kaliabari [11]. Basic seed required for the P4 and P3 are produced by the CSB units. The P2 layings are produced by the State department. The P1 layings are produced by private rearers or Adopted Seed Rearers (ASR).

Besides these, two muga seed zones have been established at Kalimpong (West Bengal) and Bageshwar (Uttarakhand) for production and supply of muga seed during summer and winter.

3. Seed Crops

Muga silkworm is multivoltine and there are 5-6 crops in a year with two commercial crops. To raise either of the two commercial crops *Jethua* (Spring) and *Katia* (Autumn), the four seed crops have to be raised in two separate rearing cycles [12, 9]. The seed crops such as *Saonia* (July-August), *Ahinia* (September-October), *Aghonia* (November-December) and *Chotua* (February-March) are to be raised for *Jethua* crop and *Jarua* (December-February), *Bohogua* (March-April), *Aherua* (June-July), *Bhodia* (August-September) seed crops are to be raised for *Katia* (Sept.-Oct./Oct.-Nov.) crop.

Multivoltinism is one of the major problem for which the maintenance of different seed broods of muga silkworm is difficult, time consuming, laborious and hazardous making the unavailability of good quality seed cocoons in specific seasons.

Dutta *et al.* [13] reported that muga silkworm has the potential to lay a good number of eggs (250-280) but realized fecundity (120-150) is comparatively poor even during the favorable seasons of *Jethua* and *Katia* compared to eri (440-470) and mulberry (450-550).

4. Influence of Climate and Season

One of the major factors affecting the muga silk industry is the gap in seed cocoon production as the seed crops always fall either in the hot and humid summer or in extreme cold and foggy winter making these crops uncertain. The optimum conditions for rearing of muga silkworm are 20–31 °C temperature and 65 to 95% relative humidity [14, 5]. Change of climatic factors, specially temperature and relative humidity affects almost every aspects of the life cycle of silkworm including their development and survival [15, 10]. Even, the change of season can influences the consumption and utilization of food in muga worms [16].

Muga silkworm is semi-domesticated and rearing is conducted in outdoor condition; they may not be able to adjust to the new changing environment [17] and thus the differential seasonal conditions greatly influence the growth and development of muga silkworm [18]. Because of unpredicted climatic conditions as well as other biotic factors, the seed crops are low productive (14-40% crop loss) and sometimes highly uncertain leading to uneconomic crops [19]. However, these seed crops are mandatory to maintain the linkage for production of commercial seed for *Katia* and *Jethua* crops. There is no clear cut demarcation of seed and commercial zone for muga silk worm rearing. Hence, quality muga silkworm seed, which plays vital role in productivity, sustainability and profitability of muga industry, continues to be the main constraint.

During last few decades, atmospheric pollution and the resultant variability in temperature and relative humidity due to global warming along with abnormal rainfall pattern, drought and flood has caused continuous failure of the crop or low crop yield in spite of all efforts and utilization of resources. Besides abnormal increase in temperature, the other reasons enlisted for the heavy loss of muga silkworm were air pollution caused by rampant use of pesticides in neighbouring tea gardens, pollution from the brick kilns and burning of natural gases emitting from oil wells and seismic survey by ONGC for oil exploration [20, 21]. Bhattacharyya [22] reported that large scale of muga culture was destroyed in Upper Assam by pesticides sprayed in nearby tea gardens.

5. Preservation of Seed Cocoon

Mulberry silkworm, *Bombyx mori* L. undergoes diapause in the egg stage [23]. Species of *Antheraea* undergo diapause in the pupal stage, except *A. yamamai*, which undergoes diapause in both the egg and pupal stages [24, 25, 5, 26]. For rearing commercial crops (either *Katia* or *Jethua*) four seed broods are to be maintained in a year. As seed broods are reared in unfavourable seasons induction of pupal diapause in order to delay the moth emergence by preserving the seed cocoons at low temperature may help in skipping the unfavourable seasons. Domesticated muga silkworm did not either over winter or diapause at high altitude [27]. Yadav and Sampson [28] reported that hot and humid climatic condition of Mamit sub-division located at an altitude of 2978 m above sea level in Mizoram was quite sustainable for muga culture. Haniffa and Thatheyus [29] reported that increase in the duration of preservation led to aging of male moths which was also attributed to less pairing efficiency and less productivity. Choudhury *et al*. [30] while analyzing the muga cocoon productivity in nine locations in Assam, Meghalaya and Arunachal Pradesh, highlighted pronounced effect of altitude, diurnal shift in temperature, variation of humidity and quantum of rainfall and rainy days. Khatri [31] also reported that rearing and grainage performance of muga silkworm during four crops *viz*., *Aherua, Jarua, Bhodia* and *Katia* over a period from 1998-2000 in Doon valleys were found to be better than those done in Assam.

Preservation of seed cocoons at 5 °C beyond 30 days led to detrimental effects on economic characters in muga silkworm [32-34]. Tolerance of this temperature beyond 30 days was fully detrimental, but its tolerance beyond 120 days showed almost complete pupal mortality [35].

Sahu *et al.* [36] were able to revive fertility in summer preserved lot as compared to control. These authors preserved cocoon from *Jethua* crop (April–May) at 10± 1.5 °C and RH of 80-85% for 25, 30 and 35 days and observed that reproductive physiology was affected when cocoons preserved beyond 30 days. They also observed that hatching percentage was 16-46% in treated lot as against 5% in control. Whereas, long term seed cocoon preservation upto 42 days was achieved by Rajkhowa *et al*. [37] following the double step preservation method without affecting the grainage parameters. Several other studies also revealed that refrigeration of muga seed cocoons at 5-12 °C for 10-120 days gave satisfactory results in terms of moth emergence, pairing, fecundity and hatchability [25, 38-42].

6. Incidence of Disease and Pest in Seed Crops

Disease and pest infestation is a serious threat to seed crop rearing. Muga silkworm is subjected to viral, bacterial, fungal and protozoan diseases that result in heavy crop losses up to 40% for individual diseases [43]. It is estimated that 20–30% of the loss is due to pebrine (microsporidian) disease, which sometimes kills an entire silkworm culture [44]. Flacherie is another common disease of muga silkworm. It is caused by a virus followed by secondary infection with bacteria. Incidence of this disease is highest in summer and this is thought to be due to sudden fluctuations in temperature coupled with poor food quality [45]. Grasserie disease is caused by a virus and can cause heavy crop losses. It infects larvae mainly in summer and rarely in winter. Muscardine is a less prevalent disease caused by a fungus (*Fusarium* spp.). It infects larvae

mainly in winter [14]. Patnaik [46] also stated that fungal infection is a rare occurrence in muga crops. The muga silkworm is attacked by a wide range of parasitoids and predators. During winter, the muga silkworm is prone to parasitisation by the uzi fly (*Exorista bombycis*), which can result in a crop loss of 80% [47].

7. Effect of Food Plant on Fecundity

The muga silkworm, *Antheraea assamensis* Helfer feeds on a wide range of host plants among which Som, *Persea bombycina* King and Soalu, *Litsea monopetala* Roxb. are the primary food plants of this silkworm [48-52, 5]. Soalu exhibited significant higher values than Som in all the seasons indicating its superiority as seed crop [53, 54, 10].

8. Indoor Rearing

Sengupta *et al*. [55] reported that during summer more than 50% loss was due to abiotic factors and 80% of the total loss of muga silkworm occurred in second/third instar only. Several workers experimentally practiced indoor rearing of muga silkworm applying different types of rearing devices, and some of them reported that it is effective over outdoor rearing [56]. Singh and Barah [57] conducted partial indoor rearing up to third stages with Som and Soalu twigs in bottle, iron and wooden tray and reported larval mortality could be reduced marginally as compared to outdoor rearing. Cellular rearing technique developed by Thangavelu and Sahu [58] for indoor rearing of muga silkworm was found suitable during different seasons for improvement in error (ERR) on Soalu plant, but female cocoon weight and fecundity were found significantly higher on Som plant. Similarly Bhuyan *et al*. [59] reported that indoor rearing in iron tray (3" × 4" × 4") with water and sand bed covered with slotted cover containing Som twigs showed better ERR (58.8%) as compared to control (51.3%). Barman and Rajan [60] were successful in rearing of muga silkworm in indoor condition by applying "leaf freshness technology". Saikia and Hazarika [61] while rearing of muga silkworm on the twigs of Som found 5%, 4.25% and 7% ERR in post-monsoon, pre-monsoon and monsoon season respectively.

Rao *et al*. [62] recorded 55.5 per cent ERR during August-September, 48.9 per cent during October-November and 10.7 per cent during December-January. Thangavelu and Sahu[63] obtained 16.5 per cent, 46.2 per cent and 47.1 per cent ERR on Som, Soalu, Digloti through cellular method of indoor rearing against 49.6 per cent ERR in outdoor. Samson and Isa [64] found better ERR (20.8%) of *A. assama* over outdoor rearing (11.0%). Goswami and Samson [65] recorded low ERR (41.3% and 38.7%, respectively) as compared to outdoor rearing (46%). Teotia and Bhattacharya [66] observed comparatively higher ERR when *A. assama* was reared indoor partially on Soalu (25.1%) followed by Som (12.7%) as compared to outdoor rearing (4.9%) during August-September. However, during March-April, indoor rearing was better on Som (23.4% ERR) than Soalu (6.5% ERR) against outdoor rearing. Talukdar [67] found higher ERR (70%) in indoor rearing compared to outdoor (20-30%). Raja Ram and Sinha[68] reported that indoor rearing of muga silkworms on Soalu branches inside perforated polythene bag gave highest ERR during July-August (70.0%) followed by September-October (23.5%) and May-June (15.5%).

Goswami and Samson [65]; Hazarika *et al*. [69] found prolonged larval duration by 4-7 days and 11 days respectively in indoor rearing of *A. assama*. Chatterjee [70] and Hazarika [71] also recorded prolonged larval duration of *A. assama* on artificial diet up to the fourth instar only, while Saikia and Hazarika [72], Hazarika and Deka [73] could able to rear the silkworm up to pupal stage .

9. Conclusion

Muga fabric has a great demand in India and abroad; but outdoor rearing of muga silkworms and shortage of seeds are causing problems for large scale production. A well-organized commercial seed production system has to be developed. Utilization of disease free seeds is a contributing factor for achieving higher production.

Although muga culture is a tradition of Assam, it has a great potential to earn good foreign exchange for the country. Indoor rearing upto third instar during summer season to escape from natural calamities; seed cocoon preservation or induction of diapause to escape from prolonged life cycle during winter season and quality host plants are the solution of the problems of unavailablity of quality seed in commercial seasons.

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