Review Article

IMPACT OF CLIMATE CHANGE IN PROSPECTS OF ERI SILKWORM SEED PRODUCTION IN ASSAM - A REVIEW

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KEYWORDS:

Climate change, Eri Silkworm, Seed Cocoon Production

ARTICLE INFO

Received on: 13.09.2019
Revised on: 12.01.2020
Accepted on: 22.01.2020

ABSTRACT

Eri silkworm rearing is legacy and age-old tradition, besides a source of livelihood for farmers in the North Eastern India. The eri silkworm *Samia ricini* (Donovan) is a multivoltine, domesticated insect that can be reared indoors on diverse host plants. Recently, government sponsored schemes have boosted expansion of eri silkworm rearing in many non-traditional eri rearing states besides North East India. Assam, being the home tract of Eri silkworm offers optimum climatic conditions for seed cocoon rearing and production of disease free layings. However, the impending climate change due to global warming poses one of the biggest threat to Ericulture. Temperature shifts in the summer and winter season with altered rainfall patterns influences the host plant maintenance and eri silkworm rearing extensively. A wide range of adverse impacts are experienced in eri silkworm seed production sector due to increasing temperature, heat stress and other changes in weather parameters. The present review paper addresses the issues and prospects of eri silkworm seed production in Assam with respect to the impending climate change and suggests the possibilities to explore avenues to mitigate the global warming effects.

INTRODUCTION

Eri silkworm rearing is legacy and age-old tradition, besides a source of livelihood for farmers in the North Eastern India. The eri silkworm *Samia ricini* (Donovan) is a multivoltine, domesticated insect that can be reared indoors on diverse host plants. It is often practiced without disturbing the natural ecosystem by availing the castor grown on roadsides. Eri silk is soft and durable with unique thermal properties. Apart from silk, eri pupae is also relished as a delicacy due to its nutritional value with high protein content. Castor, *Ricinus communis* is the primary host and other hosts are Kesseru (*Heteropanax fragrans*), Tapioca (*Manihot utilisima*), Jatropa (*Jatropa curcus*), papaya (*Carica papaya*), Borpat (*Ailanthus grandis*), Borkesseru (*Ailanthus excelsa*) and Payam (*Evodia fraxinifolia*) (Kakati and Chutia, 2009).

Assam state alone accounts for 62% of the total eri silk production in the country (CSB, 2019). Eri silk is produced in almost all parts of Assam especially in the districts of Kamrup, Udalguri, Goalpara, Nagaon, Golaghat, Dhubri, Kokrajhar, N.C. Hills, Karbi Anglong, Cachar, Darrang, Morigaon, Dhemaji, Lakhimpur, Jorhat, Sivasagar, Dibrugarh, and Tinsukia. The Brahmaputra valley of Assam and its neighbouring states together produce more than 90% of eri cocoons (Chowdhury, 1982). Commercial eri silkworm rearing is gaining impetus in Wokha, Mokokchung, Kohima, Tuensang, Zunheboto of Nagaland, Aizawl and Lunglei of Mizoram Imphal, Thoubal and Churachandpur of Manipur, East and West Garo hills, East and West Khasi hills and Ri-Bhoi districts of Meghalaya, Lohit, Khonsa, Papumpare and Tirap of Arunachal Pradesh (Singh and Benchamin, 2001), Tripura and Sikkim . In recent years, ericulture is practised in non-traditional states viz. Andhra Pradesh, Tamil Nadu, Odisha, West Bengal, Sikkim, Jharkhand, Bihar, Punjab and Uttar Pradesh (Sarmah *et al*., 2012).

It is predicted that the global temperatures are likely to increase 1.5°C between 2030 and 2052 if it continues to increase at the current rate (IPCC, 2018). A study conducted by Meteorology Department of Assam Agricultural University revealed that during last 60-years (1951-2010) both maximum and minimum temperature increased significantly to contribute higher annual mean temperature in Brahmaputra valley regions of Assam. Maximum increase was noticed in post-monsoon followed by winter seasons. Annual occurrence of warmer nights have increased significantly. In Assam the temperature has increased 1.6 times higher than the all-India average in the past 30 years (Borah, 2015). Heat waves and delay in the pre-monsoon showers further worsens the performance of agriculture, sericulture and all allied sectors. This reveals an alarming situation in the region and demands relief measures to combat the unprecedented increase in temperature and heat stress. Adaptation to the changing climate is unique for every ecosystem and creating uncertainty on sustenance of the existing biodiversity. Due to industrialization and deforestation, a greater change in the environment is experienced due to increased emissions of greenhouse gases. The rising temperature, elevated gas emissions and regional monsoon variation adversely affects the growth and development of each and every biotic component in the ecosystem.

In recent years, a major threat to the silk industry in North East India has been increasing temperature and changing weather patterns due to global warming directly impacting silkworm seed production. Poor growth, failure to hatch and low yield are observed on the eri silkworms reared on months with mean higher temperatures compared to cooler months. Temperature modulated variations in yield and quality of leaves of host plants also are factors determining success of eri farming. Thus, the variations in rearing temperature directly as well as indirectly affects ericulture and economic returns of the farmers. One of the typical examples of effect of climate change on silkworm comes from the Sualkuchi, a small town in the Kamrup district of Assam near to Guwahati. Sualkuchi is known for silk weaving, and its residents are known for highly skilled silk weaving. However, during past two decades, silk production in Assam came down abruptly due to non-availability of raw material and many families opted for other livelihoods opportunities, leaving their traditional silk weaving (Borah, 2010). Assam is one of the Indian states with highest vulnerability index (0.72%) to climate change because of factors like low per capita income, deforestation, large number of small-marginal farmers, least area under irrigation, lack of alternative sources of income and high rates of poverty (Sharma, 2019). The present article provides an overview of the climate change and its impact on Eri silkworm seed production in Assam.

IMPACT OF CLIMATE CHANGE ON ERI SILKWORM SEED COCOON REARING

Weather plays a major role in determining the success of sericultural activities due to its impact on host plant maintenance and silkworm rearing. Silkworms being cold blooded organisms, their growth and physiological activities are directly influenced by several meteorological parameters. Temperature and humidity are key environmental factors that influence the physiology of silkworms (Benchamin and Jolly, 1986; Hussain *et al.*, 2011). Among all the silkworms, eri silkworm *Samia ricini* (Donovan) is hardy and comparatively more tolerant to fluctuations of temperature and humidity (Thangavelu, *et al.*, 1989; Prasad and Saha, 1992). Nevertheless, extreme rise of temperature in recent past is found detrimental to the development of eri silkworms. In mulberry silkworms, heat shock responses are expressed by set of heat shock protein (HSP) and being explored in breeding thermo-tolerant breeds (Craig, 1985; Basavaraja, *et al.*, 2005; Nagaraju, 2002; Joy and Gopinathan, 1995; Chitra and Sureshkumar 2005; Manjunatha, 2006). Temperature stress is reported to cause a number of abnormalities at the cellular level as the normal pattern of protein synthesis gets disrupted. Biological molecules like DNA, RNA, lipids are found vulnerable to heat stress (Sureshkumar *et al*., 2002; Denlinger and Yoccum, 1998). On the contrary, at low temperature, the growth is slowed down with prolonged lifecycle and extended larval and pupal period. The ideal temperature for rearing eri silkworms ranges between 22 and 26^0C, with a humidity level of 75 to 85 percent. Different developmental stages of eri silkworm require specific range of temperature and humidity to complete the stadium (Singh and Saratchandra, 2012).

INFLUENCE OF CLIMATE CHANGE ON HOST PLANT MAINTENANCE

The climatic variables that can profoundly influence host plant maintenance were maximum temperature, rainfall and relative humidity. The susceptibility to high temperature in plants varies with the stages of the plant development (Sanjoy, 2018). The host plants of eri silkworm generally belong to Euphorbiaceae, Araliaceae, Apocynaceae and Simaroubiceae family. They are castor, kesseru, tapioca, jatropa, papaya, borpat, borkesseru and payam. Castor is tolerant to drought and grows well in dry and warm regions of tropical belts with well distributed rainfall of 50- 75cm (Singh and Saratchandra, 2012). In heavy rainfall areas, castor grows luxuriously and assumes a perennial habit. However, they cannot tolerate floods and water logging conditions. A moderate high temperature of 20-26^0C with low humidity ensures maximum yields. River banks of Brahmaputra are found highly suitable for castor cultivation. Cassava is a perennial shrub grown in warm and humid climate. Kesseru, borpat, borkesseru and payam are woody perennial trees found grown wild in Assam. Ericulture provides excellent opportunities for conservation and utilization of these forest based resources.

Among all the hosts, castor is the most preferred plant for eri silkworm rearing. Castor has a crop duration of 4-5 months and requires a well distributed rainfall. About 650 to 750 kg of castor leaves are required to rear 100 dfls. And about 80-85% of the total food is consumed during late instar stages. The quality of the eri cocoons depends largely on the nutritional content of the host leaves fed to the silkworms during rearing. The host leaves, in the eri silkworm rearing is highly influenced by the prevailing temperature and humidity. Based on the leaf withering, the feeding schedules are to be altered. The impending climate change is demanding need based alterations in the feeding intervals. During high and low temperature conditions the leaf consumption by larvae is relatively slow. This affects the growth of the larvae and wastage of plucked leaves to a greater extent.

INFLUENCE OF TEMPERATURE AND HUMIDITY ON GROWTH AND DEVELOPMENT

The nutritional quality of host plant leaves and rearing environment are two principal factors that determines the quality of cocoon production in silkworm rearing. Eri silkworms are completely domesticated and reared indoors in well ventilated houses. Optimal incubation temperature of eggs ranges from 24-26^{0}C with humidity 85-90^{0}C. Higher temperature and low humidity causes embryo death and desiccation of eggs. The egg stage and early instars can withstand high humidity conditions unlike later instars (Krishnaswami, 1994).

The temperature and humidity requirements of early larval instars are most critical and decisive in successful rearing. Optimum ideal rearing temperature (24-25^{0}C) in late instars accelerates larval growth and shortens the larval period. Temperature above 30^{0}C often have proved deleterious to the health of the worm. High temperature during early instars resulted in lesser vigour and growth while in late instars it lead to delay in maturation, increase vulnerability to diseases, mortality prior to spinning or after spinning. This resulted in availability of lesser seed cocoons qualifying norms for production of disease free layings. If the temperature is below 20^{0}C all the physiological activities are lowered leading to growth retardation and weak appearance in early instars and prolongation of larval period in late instars.

Spinning is one of the important process that determines the success of eri silkworm seed production. High temperature adversely affects the silk glands and thermal stress leads to mortality of the mature worms, before spinning. In lower temperature, secretion of silk thread is very slow resulting in loose flimsy cocoons. Ideal air circulation during spinning is ensured by proper mounting of mature worms in the appropriate mountage. Besides chandraki, traditional mountage 'jali' made of semi dry leaves and twigs were found favourable for spinning. Fluctuations in temperature and humidity showed adverse effects on spinning behaviour of silkworm (Ramachandra *et al.,* 2001, Manishankar *et al*., 2008).

IMPACT OF SEASONS ON SEED COCOON PRODUCTION

The highest seed cocoon yield per disease free laying (dfl) was recorded during autumn (215.92±6.2nos) followed by winter and late monsoon seasons. Lowest seed cocoon yield was recorded during early monsoon (128.43± 29.9) and summer (147.94± 15.3) (Lalitha *et al.,* 2018). The critical factors that reduces the seed cocoon yield per dfl during early monsoon and summer were low hatching percentage of eggs, mortality due to uzi fly infestation, diseases such as pebrine, flacherie and grasserie and high temperature exposure during spinning (Basumatary *et al*., 2003). The quality of the seed cocoon also degraded due to fluctuating environmental conditions as evidenced by poor cocoon parameters (Rahmathulla, 2012). It was observed that pebrine could be controlled in all seasons by proper disinfection and intermittent examination. However, mortality due to other diseases (grasserie, flacherie etc) were high during monsoon and summer seasons. The percent larval mortality during summer was significantly more due to uzi fly (11.52±2.2) and other factors (24.14±6.3) (Lalitha *et al.,* 2018).

In Assam, summer and early monsoon spanning from March to June experiencing a temperature ranging from 34 - 40^0 C was found unfavourable for seed cocoon rearing. In seed cocoon rearing spinning of cocoons is the most sensitive stage to yield optimum results in eri silkworm seed production. Higher proportion of non-emerged cocoons and emergence of crippled moths were observed in seed cocoons reared during this period (Lalitha, unpublished).

It has been now well documented that the rising temperature recorded in the region year after year poses a biggest threat to sericulture in general and specifically to silkworm seed production activities. Negative correlation of temperature with effective rate of rearing (ERR) was reported by several workers (Basumatary *et al.,* 2003, Kumar and Elangovan, 2010, Sarkar *et al*., 2010, Sarmah *et al.,* 2015). Significantly highest ERR (%) was recorded in autumn (90.69±1) followed by winter (85.35± 4.3) (Lalitha *et al*., 2018). The prolongation of summer season in Assam due to climate change is expected to reduce prospects of Ericulture.

IMPACT OF CLIMATE CHANGE ON SEED PRODUCTION

Eri silkworm seed production primarily depends on grainage parameters such as moth emergence, coupling realization, fecundity and hatchability of eggs. Optimum valid moth emergence (>90%) with effective coupling is realized at temperatures between 20 and 22^{0}C and humidity 70-80%. However, presently, this combination of temperature and humidity occurs naturally only during September to November months in Assam coinciding with late monsoon and autumn season. Non- emergence of seed cocoons, low coupling recovery and higher emergence of cripple moths are encountered at temperatures exceeding 28^{0}C. This is due to thermal stress during seed cocoon rearing/ storage imposing a greater risk in seed production units. Relative humidity, dew point temperature and temperature humidity index also exhibits a positive correlation with moth emergence and other reproductive parameters. Natural mating occurred within 1-2 hours after emergence. After completion of 6 hours coupling, the fertilized female moths are placed in a traditional oviposion device "Kharika" and allowed for egg laying. Female moths that were in thermal stress could not adhere to kharika during the entire oviposition process for two days. They were weak and fell down after partial deposition of eggs. Generally such eggs were discarded due to their poor quality. The cocoon: dfl ratio determines the economic feasibility and acts as an indicator for success and failure of the seed production unit. The cocoon to dfl ratio is found to be ideal (4:1) during autumn and late monsoon followed by winter (5:1). The dfl recovery is found to be low during early monsoon (8:1) and summer (7:1) (Lalitha *et al.*, 2017).

The reproductive performance of silkworm is dependent on the physiological traits of the parent and environment. Environmental variation affects fertility, ovulation, coupling efficiency and realized fecundity. Female moths when exposed to high temperature during their spinning, had adverse effects on ovulation and oviposition. Earlier Mathur *et al*. (1988) reported decreased fecundity and increased retention of eggs in mulberry silkworm, at temperatures above 25◦C. Temperature induced sterility in male silkworm moths were also studied in detail. Male moths became weak and sterile when subjected to 32◦C for at least 4 days during their pupal stage. The male moths were found to become sterile when exposed to high temperature during spinning (Sugai and Takahanshi, 1981). Continuous exposure to high temperature (>9hrs) induced sterility in male silkworm (Sugai and Hanoaka, 1972). Hence, fluctuations in temperature and humidity during larval rearing resulted in low fecundity and decreased fertility of adult moths as in mulberry silkworm (Hussain *et al.*, 2011).

FUTURE STRATEGIES

Keeping in view of the huge potential for ericulture and the demand for high quality eri silk, there is an urge to protect the eri silkworm races from the adverse impacts of climate change. A clear understanding of the changing weather patterns will allow the seed production schedules to get rearranged in Assam. Extension of summer with heat waves in the region imposes a selection pressure on the eco races. An urgent need for strengthening eri silkworm breeding research for thermo tolerance is of high priority. On the other hand, shortening of winter period is more beneficial and increases the prospects of ericulture during November to January months.

Mitigation of global warming effects can be implemented by adoption of negative emission technologies like afforestation, restoration of degraded lands for cultivating host plants of silkworm. Growing plants/trees sequester large amounts of carbon dioxide from the atmosphere through photosynthesis. Unlike many agricultural crops, silkworm host plants do not require much tillage/ energy intensive farming operations. Hence, they provide opportunities for sequestration of atmospheric carbon and building soil organic matter.

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How to cite this article?

Lalitha, N., Singha, B.B., Das, B., Choudhury, B., 2020. Impact of climate change in prospects of eri silkworm seed production in Assam - A review. *Innovative Farming* 5(1): 10-14.