International Journal of Zoology and Applied Biosciences **ISSN: 2455-9571**
Volume 9, Issue 4, pp: 13-25, 2024
https://doi.org/10.55126/ijzab.2024.v09.i04.004 **http://www.ijzab.com**

Review Article

CLIMATE CHANGE AND ITS IMPACT ON SERICULTURE

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Article History: Received 2nd April 2024; Accepted 17th June 2024; Published 1st July 2024

ABSTRACT

Climate change refers to the global phenomenon of rapid transformation in natural climate patterns like rain, wind, heat and more. Climate change poses a significant challenge to the existence of species and the stability of ecosystems on a global scale. The escalation in the Earth's atmospheric temperature is predominantly influenced by the heightened levels of greenhouse gases (GHG), including carbon dioxide (72%), methane (18%) and nitrous oxide (9%). (Bora *et al.*, 2022). Agriculture is directly dependent on climate change and weather in India. The climate change *viz.*, temperature, rainfall and carbon dioxide showed impact on crop growth and production in the country (Ram *et al.*, 2016). Temperature fluctuations impact silkworm behavior, development, survival, growth and reproduction as highlighted by Neelaboina *et al.* in 2018. Silkworms are ectothermic organisms meaning that, their body temperature closely aligns with their surrounding environment. Consequently, alterations in temperature can significantly impact insect behavior, distribution, development, survival, growth and reproduction. Elevated air temperatures particularly during the 4th and 5th larval instars pose a significant climatic challenge that can adversely affect both silkworms and cocoon crops. The issues arising from these unfavorable conditions can be effectively mitigated by adhering to the recommended silkworm rearing technologies as outlined by Tripath *et al.* (2017).

Keywords: Climate, Global Warming, Green House Gases, Environment, Silkworm, Rearing and Cocoon Production.

INTRODUCTION

Agricultural systems are currently undergoing rapid shifts owing to socioeconomic development, technological change, population growth, economic opportunity, evolving demand for commodities and the need for sustainability amid global environmental change. It is not sufficient to maintain current harvest levels; rather, there is a need to rapidly increase production in light of a population growing to nearly 10 billion by midcentury and to more than 11 billion by 2100 (FAO, 2016; UN, 2016; Popkin *et al.*, 2012). Current and future agricultural systems are additionally burdened by human-caused climate change, the result of accumulating greenhouse gas and aerosol emissions, ecological destruction and land use changes that have altered the chemical composition of Earth's atmosphere and trapped energy in the Earth system (IPCC, 2013; Porter *et al.*, 2014). This increased energy has already raised average surface temperatures by ~1ºC (Hansen *et al.*, 2010), leading early on to the term "global warming," but this phenomenon is now more accurately referred to as "climate change" because it also modifies atmospheric circulation, adjusts regional and seasonal precipitation patterns, and shifts the distribution and characteristics of extreme events (Bindoff *et al.*, 2013).

Food and health systems face increasing risk owing to progressive climate change now manifesting itself as more frequent, severe extreme weather events heat waves, droughts, and floods (IPCC, 2013). Often without warning, weather-related shocks can have catastrophic and reverberating impacts on the increasingly exposed global food system through production, processing, distribution, retail, disposal, and waste. Simultaneously, malnutrition and ill health are arising from lack of access to nutritious food, exacerbated in crises such as food price spikes or

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shortages. For some countries, particularly import-dependent low-income countries, weather shocks and price spikes can lead to social unrest, famine and migration.

What is climate?

Climate change refers to the global phenomenon of rapid transformation in natural climate patterns like rain, wind, heat and more. The emission of carbon and greenhouse gases from power plants, transportation, industries, etc., has led to food supply disruptions, extreme weather conditions, frequent wildfires, shorter life expectancy and more. Three main causes of climate change: Increased Use of Fossil Fuels, Deforestation, Intensive Agricultural Practices.

Climatic models predicted the average increasing in temperature 1.0 to 5.8^{O}C at the end of 21st century. In order to reduce the adverse effects of global warming, there is need to plant more and more trees to become carbon neutral rather carbon negative effects. Sericulture is being one of the important revenue generating crops of the states also has been found to have been under the effect of climate change especially with respect to mulberry sprouting behavior. It is felt that increased spring temperature has direct effect on the sprouting/bud bursting in trees including mulberry. (IPCC 4th AR, 2014). Human activities are the prime source for influencing the climate and increasing the Earth's temperature. Activities like burning fossil fuels, cutting down rain forests and farming livestock resources adds enormous amounts of greenhouse gases than to those than naturally occurring in the atmosphere, increasing the greenhouse effect and global warming. There are many gases in the atmosphere, which acts like a glass ceiling in a greenhouse, trapping the heat energy and stops it from leaking into the space. Since these gases are increased due to human activities the temperature of the earth increases.

Melting of ice glaciers

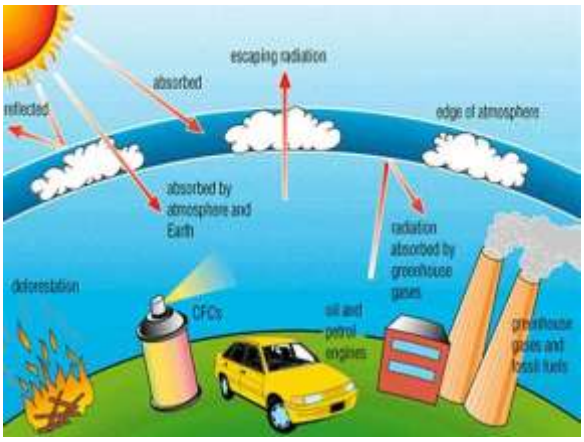
Sprouting/bud bursting in trees including mulberry.

Global Scenario of Climate Change

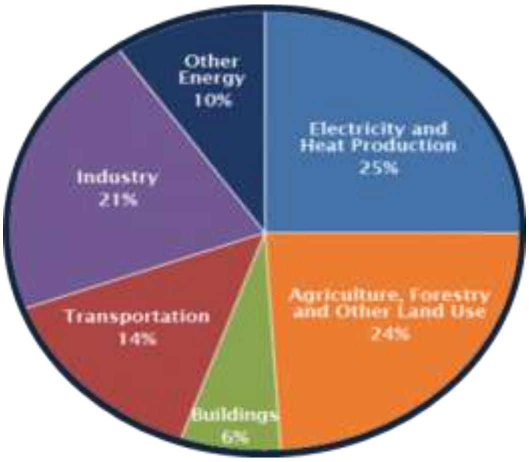
As per the IPCC report from 2007 the majority of global greenhouse gas (GHG) emissions in 2004 totaling 69.1% were directly attributed to industrialization and households. In contrast the agriculture and allied sector, including deforestation, contributed 30.9% accounting for approximately one-third of the total global GHG emissions. Within the overall GHG emissions, carbon dioxide (CO2) constituted 72%, making up almost two-thirds of the total, while methane (CH4) and nitrous oxide (N2O) contributed 18% and 9% respectively. Notably, the agriculture and its allied sector were identified as accountable for nearly one-third of total CO2 emissions half of total CH4 emissions and two-thirds of total N2O emissions.

National Scenario of Climate Change

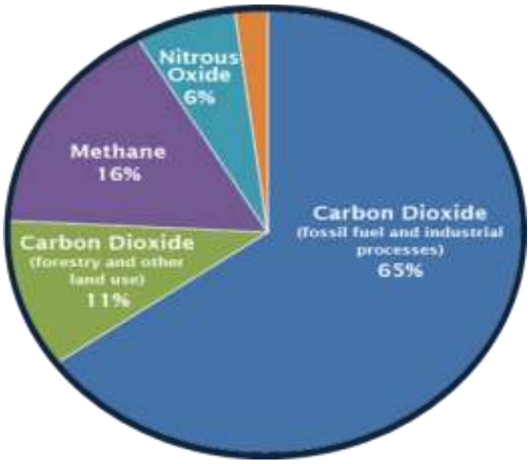
In India, the distribution of greenhouse gas (GHG) emissions across various sectors reveals that Energy, Industry, Agriculture and Waste contribute 58%, 22%, 17% and 3% to the net CO2 equivalent emissions respectively. Disturbingly certain coastal areas face the imminent threat of complete disappearance. The reliability of the summer monsoon, vital for 75% of India's rainfall and critical for agriculture is expected to diminish, resulting in unpredictable weather patterns, leading to floods in some regions and droughts in others. Over the past century the average temperature in India has increased by approximately 0.5°C due to the accumulation of anthropogenic greenhouse gases in the atmosphere. The repercussions of recent emissions will unfold over several decades and if current trends persist the temperature rise is projected to surpass 2.0°C. Various researchers from Indian institutions predict a temperature increase ranging from 0.5 to 4.0°C in different parts of the country over the next few decades due to the continued accumulation of anthropogenic greenhouse gases.



Causes for Climate Change



Global greenhouse gas emissions (by economic sector)



Global greenhouse gas emissions (by gas)

Effect of Climate Change on Agriculture

Indian agriculture is directly dependent on climate change and weather. The climate changes in temperature, rainfall and carbon dioxide concentration are expected to significantly impact the crop growth and production in the country. With climate change will prove to a stumbling block, the cycle of monsoons which originate from the Indian and Arabian Seas. Climate change results in longer growing season and warmer temperatures could lead to longer periods of crop growth and yield. There could be adverse impacts like reduced water availability and more frequent extreme heat. These conditions could put agricultural activities at a greater risk, as most of the agriculturalists are dependent on rain water. Experts have already predicted drop in wheat yields, which is around 5-10 per cent with every increase of 1°C and overall crop yields could decrease up to 30 per cent in India, Pakistan, Bangladesh other countries. It is also predicted that India could experience a 40 *per cent* decline in agricultural productivity around 2060s.

Effect of Climate Change on Soil Health

The soil serves as the essence of boundless life and acts as a repository for both vital and advantageous nutrients that sustain living organisms. Soil health is defined as the continued capacity of soil to function as a vital living system, by recognizing that it contains biological elements that are key to ecosystem function within land-use boundaries. These roles contribute to upholding the biological productivity of the soil preserving the quality of the surrounding air and water environments and fostering the well-being of plants, animals and humans. Nonetheless, soil quality is characterized as the capability of a designated soil to operate within the confines of natural or human-managed ecosystems. It encompasses the ability to sustain plant and animal productivity, uphold water and air quality and support human health and habitation.

Soil health indicators encompass a comprehensive array of measurable properties falling into three main categories: physical, chemical and biological. The physical indicators include properties such as soil texture, structure, porosity, aggregate stability, infiltration, bulk density, soil and rooting depths and soil water content. Chemical indicators involve factors like pH, electrical conductivity, rates of exchangeable cations and anions, acidification, calcification, alkalization, leachable salts, adsorption, cation exchange capacity and the availability of nutrients for plants. Biological indicators delve into soil organic matter, respiration, biomass of soil biota (e.g., earthworms, ants, nematodes), microbial biomass (e.g., PGPR and VAM), nitrogen and phosphorus mineralization capacity and enzyme activity. These indicators are closely tied to essential soil processes and play a crucial role in assessing the status of soil health. They can be valuable tools for evaluating the impact of various management practices and climate change factors on soil health.

When articulating soil health in the context of climate change, it is imperative to take into account the potential effects of various anticipated global change drivers. These include the escalation of atmospheric greenhouse gases (GHGs), particularly elevated levels of carbon dioxide (CO2), heightened temperatures, variations in precipitation patterns (rainfall) and the deposition of atmospheric nitrogen (N) onto the soil. It is crucial to assess how these factors may impact the chemical, physical and biological functions of the soil recognizing their interconnected role in shaping soil health under the influence of climate change.

Climate Change and Sericulture

Global climate change can have a direct impact on mulberry, soil, pests and silkworms through alterations in temperature, water regimes and carbon dioxide levels. Furthermore, European and Central Asian sericulture countries, despite being situated in the temperate and sub-tropical zones like Japan, Korea and parts of China exhibit distinct climatic specificities. In these regions characterized by temperate climates winters are typically cold and summers are hot but dry setting them apart from the climate patterns observed in Japan, Korea and parts of China.

The peak of rainfall during the mulberry vegetation period occurs in May and June, while July and August are characterized by the lowest precipitation levels. This stands in contrast to Japan and Korea where July and August mark the peak of rainfall during the mulberry vegetation period due to monsoons. Despite June being considered late spring the weather is typically very hot during the 5th larval instar leading to a quick coarsening of mulberry leaves. Additionally, there is significant temperature fluctuation during the spring rearing season in May and June, with night temperatures potentially dropping to half of the daytime temperatures. In early spring (March and April) the initially hot weather with temperatures ranging from 25 to 30°C undergoes abrupt changes to abnormally cold conditions sometimes even dropping below freezing. This fluctuation can adversely affect sprouted mulberry trees. If this climate change scenario unfolds addressing issues such as drought and high temperatures during silkworm rearing could be alleviated through increased investments in mulberry irrigation and the construction of suitable rearing houses with efficient insulation and air conditioning. The successful rearing of silkworms and the production of silk integral to the silk industry are heavily influenced by environmental factors such as temperature and humidity. Silkworms are particularly sensitive to variations in atmospheric temperature and humidity levels making them susceptible to complete crop loss with even slight fluctuations in these conditions. While some insects exhibit a broad range of adaptations to cope with environmental fluctuations within tolerable limits silkworms struggle to survive extreme natural variations.

The escalating temperature and the evolving day-to-day weather patterns attributed to global warming pose a significant threat to the sericulture industry. This concern extends beyond India, affecting other countries associated with silk production. The recent shifts in global climatic phenomena have drawn worldwide attention due to the consequential losses not only to muga silkworms (*Antheraea assamensis Helfer*) but also to other types of silkworms. The impact of climate change on silkworms and other beneficial insects holds substantial significance as they play vital roles in various biotic interactions crucial for ecological functioning. Additionally, these insects contribute significantly to the GDP of the countries involved in sericulture. It is predicted that, global warming affects the cultivation area of various crops including mulberry. Mulberry (*Morus alba*) is a C3 plant and it is inefficient in utilizing the atmospheric CO_2 whereas enzymes of C4 plants located in the mesophyll are efficient in fixing CO_2. In C3 plants CO_2 react with ribulose biphosphate (RuBP) in presence of the enzyme ribulose biphosphate carboxylase/oxygenase (RuB is CO), which is an inefficient enzyme with low substrate specificity.

Increased levels of CO_2 will effect plants yield through photosynthesis and stomatal conductance. The growing evidence suggest that C3 crops, may respond positively to increased atmospheric CO_2 in the absence of other stressful conditions The beneficial direct impact of elevated CO_2 can be offset by other effects of climate change, such as elevated temperatures, higher tropospheric ozone concentrations and altered patterns of precipitation.

Effect of Climate Change Hazards on Sericulture

Climate change hazards have profound effects on sericulture, impacting various aspects of the silk production process. Some notable consequences include:

1. **Heat Stress on Plants:** Elevated temperatures can adversely affect the growth and development of the plants involved in sericulture, particularly those supporting the silkworms.
2. **Changes in Soil Moisture and Temperature:** Alterations in soil moisture levels and temperature can disrupt the ideal conditions required for silkworm rearing and the growth of mulberry plants, essential for silk production.
3. **Loss of Soil Fertility through Erosion of Topsoil**: Increased erosion of the topsoil can lead to a decline in soil fertility, impacting the quality of the soil for mulberry cultivation.
4. **Availability of Less Water for Crop Production:** Reduced water availability due to climate change can pose a significant challenge to the irrigation needs of mulberry plants, affecting overall silk production.
5. **Changes in Height of Water Table**: Alterations in the water table height can influence the accessibility of water for irrigation, further complicating sericulture practices.
6. **Salinization of Freshwater Aquifer**: The intrusion of saltwater into freshwater sources can result in salinization, making water resources unsuitable for silk production.
7. **Loss of Land through Sea Level Rise:** Rising sea levels can lead to the loss of land, affecting the available space for sericulture activities.

The impacts of these climate change hazards are expected to be particularly severe in atoll islands such as Tuvalu and Kiribati. These regions already face challenges in agriculture due to poor soil quality, limited available land and water scarcity. The additional stressors from climate change exacerbate these existing difficulties posing a threat to the sustainability of sericulture in these areas.

Effect of Climate Change on Silkworm Host Plant

Silkworms exhibit polyphagous behavior relying solely on their host plants for sustenance. The physiological growth and development of these plants are intricately linked to various climatic and environmental factors, including rainfall, temperature, relative humidity and soil quality. Changes in climatic conditions have far-reaching effects on the activity and population of beneficial microorganisms resulting in a decline in soil quality and subsequently impacting the growth of host plants. The fluctuations in environmental factors contribute to negative impacts on both plant-pest populations. Changes in climatic conditions can lead to alterations in the dynamics of pest populations affecting their activity and abundance. Additionally, the variability in climate has been associated with an increase in disease occurrences among host plants (Bora *et al.*, 2022). This interconnected web of influences highlights the vulnerability of silkworms and their host plants to changes in environmental conditions emphasizing the need for sustainable practices and adaptive measures in sericulture.

Climate Change Triggers the Sprouting Pattern of Mulberry

Mehraj *et al.*, (2020) Climatic change affects the mulberry sprouting behavior and the unprecedented changes in the weather and climate are giving the segos of early sprouting in mulberry because conditions of some rise in the temperature.

Effect of Climate Change on Physiological Growth of Mulberry

Indeed, the physiological growth and development of plants hinge on a spectrum of environmental conditions encompassing factors such as rainfall, moisture, temperature, soil fertility and a notable variable, evapotranspiration. The intricate interplay between these environmental elements significantly impacts the life cycle of plants particularly influencing the process of photosynthesis. Global warming is anticipated to have repercussions on the cultivation areas of diverse crops, mulberry included. In the context of cereals and seed crops the manifestation of water stress conditions may result in diminished yields across various crops. Simultaneously, elevated temperatures associated with global warming are expected to abbreviate the growing season contributing to reduced yields. This dual impact poses challenges to agricultural productivity and underscores the importance of understanding and addressing the complex interactions between environmental variables and plant physiology in the face of climate change.

The physiology of mulberry being a C3 plant differs significantly from C4 plants. C3 plants, such as mulberry are characterized by relative inefficiency in utilizing carbon dioxide (CO2) as their photosynthetic apparatus is located in the outer mesophyll cells. To compensate for this inefficiency C3 plants like mulberry need to keep their stomata open for longer periods exposing them to potentially increased rates of evapotranspiration and respiration. Consequently, these plants thrive better in cooler moist environments with elevated concentrations of CO2. In contrast, C4 plants have a more efficient system for fixing CO2. The enzymes responsible for this process located in the mesophyll enhance the fixation of CO2, reducing the time stomata need to remain open. This result in decreased evapotranspiration and respiration rates compared to C3 plants. The efficiency of C4 plants in fixing carbon dioxide is attributed to the enzymes that have higher substrate specificity and are more effective than the enzymes in C3 plants. In C3 plants like mulberry the enzyme ribulose bisphosphate carboxylase/oxygenase (RuBisCO) is responsible for reacting CO2 with ribulose bisphosphate (RuBP). However, RuBisCO is considered inefficient and has low substrate specificity. It occasionally fixes oxygen (O2) instead of CO2 a process known as photorespiration. Additionally, it preferentially fixes 12CO2 over 13CO2, leading to isotope fractionation during carboxylation (Griffith H. 2006). This unique physiology contributes to the specific ecological preferences and adaptations of C3 plants like mulberry.

Various stages of sprouting in SKM-31 Mulberry genotype

Long *et al.* (2006) and Polley (2002) reported the effect of rising CO2 on plants yield through photosynthesis and stomatal conductance whereas the growing evidence suggesting that C3 crops, may respond positively to increased atmospheric CO2 in the absence of other stressful conditions (Long *et al.,* 2004), Absolutely, while elevated carbon dioxide (CO2) levels can have direct benefits for certain plants by enhancing photosynthesis and water use efficiency these positive effects may be counteracted by other aspects of climate change. The IPCC (2001) highlights the intricate interplay of direct and indirect effects of climate change on ecosystems.

Direct Effects: Changes in temperature, precipitation, or carbon dioxide concentrations can directly impact plant physiology. Elevated CO2 for instance can stimulate photosynthesis and improve water use efficiency in some plants.

Indirect Effects: Climate change can also have indirect effects through alterations in soil moisture levels and shifts in the distribution and frequency of pests and diseases.

- Changes in precipitation patterns may lead to variations in soil moisture, influencing plant growth and ecosystem dynamics.
- Temperature changes can affect the distribution and behavior of pests and diseases, impacting plant health.

Higher tropospheric ozone concentrations resulting from pollution are another factor that can offset the beneficial effects of elevated CO2. Ozone can damage plant tissues and hinder photosynthesis counteracting the positive impact of increased CO2.Understanding both the direct and indirect effects is crucial for predicting the overall impact of climate change on ecosystems and agriculture. It emphasizes the complexity of these interactions and the need for comprehensive strategies to address the multifaceted challenges posed by climate change.

Impact of Climate Change on Pests Plant Interaction

Climate change can have a significant impact on the interactions between pests and plants, leading to various ecological and agricultural consequences. The complex and dynamic nature of these interactions makes it challenging to predict specific outcomes, but some general trends and potential impacts include: An increase in temperature may resulted in change in geographical distribution, Increase over wintering, Changes in population growth rate, Increases number of generations, Extension of their developmental seasons, Change in the time of occurrence, Changes in the crop-pest synchrony of phenology along with the risk of migrant pest. Coakley *et al., (*1999) reported that with an increase in temperature susceptibility of the plants to rust disease become higher.

Effect of Climate Change on Mulberry Disease and Pest

Plant-pest populations might be impacted by global climate change although this will rely on how the climate (temperature, precipitation, humidity etc.) interacts with other elements including soil moisture, atmospheric CO2 and tropospheric ozone (O3). These factors may have direct impacts on plants or indirect effects on the system, such as changes in the incidence of insect pests which can lead to changes in sericulture production.

The production and efficiency of mulberry leaves have been reported to be significantly limited by a number of pests and illnesses in recent years owing to intensive farming methods and the careless application of nitrogenous fertilizers and pesticides. In a worldwide context, a shift in insect pests' ability to survive the winter might be one of the main effects of climate change in the temperate zone. Because insect and host plant species have individualized responses to temperature, CO_2 and photoperiod it may throw off the synchronization between temperature and photoperiod. Increases in pathogen development and infection within predetermined temperature ranges are the basis of several mathematical models that have proven helpful in predicting plant disease outbreaks. According to Coakley *et al.* (1999) plants are more vulnerable to rust infections in warmer climates. Plant disease-causing fungi thrive in temperatures that are mild. If temperatures rise temperate climatic zones that have chilly average seasons are likely to see prolonged stretches of favorable weather for the growth and reproduction of pathogens.

Climate Change and Silkworm Rearing

The majority of insects, including silkworms, are ectothermic organisms with body temperatures closely aligned with their surroundings. Consequently, fluctuations in temperature can significantly impact insect behavior, distribution, development, survival, growth, and reproduction. For the uni-bivoltine highly productive silkworm races adverse rearing conditions include high temperatures (exceeding 26°C) elevated humidity (above 75%) during the 5th larval instar and cocoon spinning high rearing density, malnutrition resulting from low mulberry leaf quality, improper feeding amounts (either too high or too low) and inadequate ventilation during the 4th and 5th instars and cocoon spinning. Particularly the elevated air temperature during the 4th and 5th larval instars emerges as the most detrimental climatic factor, significantly impacting silkworms and cocoon crops. Fortunately, adhering strictly to the recommended optimal silkworm rearing technology can effectively resolve issues arising from these adverse conditions.

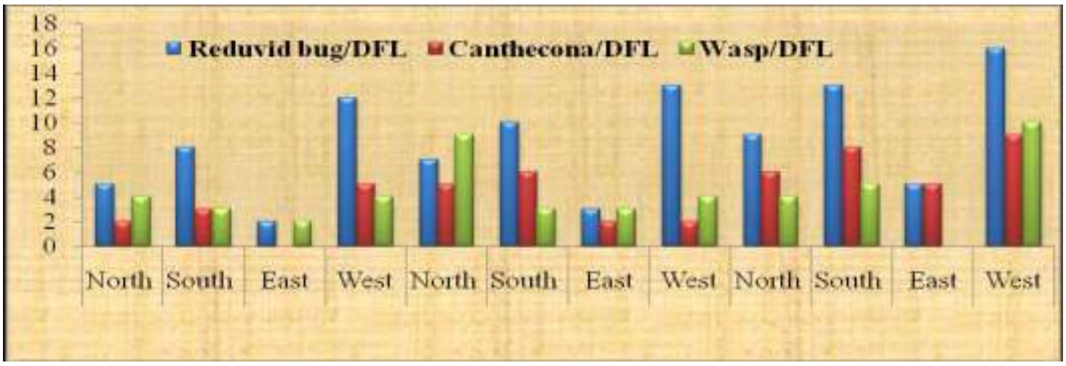
Effect of Climate Change on Muga Silkworm Due To Abiotic Factors

Based to this sharp drop in temperature Assam, the state in northeastern India that holds the title for producing golden silk might lose its production monopoly. Due to their extensive involvement in biotic interactions that are critical to the maintenance of ecosystems and their substantial contribution to the nation's GDP, silkworms and other beneficial insects are more vulnerable to the effects of climate change.

Muga silkworm is affected by various abiotic factors

Temperature, Humidity, Rainfall, Bright sunshine hours, Hailstorm, External stimulus, Pollution. Change of climatic factors, specially temperature and relative humidity affects almost every aspects of the life cycle of silkworm including their development and survival. Optimum temperatures for rearing - 24 – 25°C. Above 30°C, directly affects the health of the worm. Increase in temperature - larval growth accelerated and larval period shortened. Low temperature – slow growth and prolonged larval period. Temperature lower than 20°C - retarded growth in the early stages. Increase temperature - changing geographical distribution, increased overwintering, changes in population growth rate, increased number of generations, extension of their developmental seasons, change in the time of occurrence, changes in crop pest synchrony of phenology along with the risk of migrant pests of muga silkworm.

Assam climate - alternate cool and warm periods with a highly humidity (May to November). The optimum humidity - 75% to 85% Relative humidity - more than 80% and temperature above 30°C - associated with severe disease incidence. Third to fifth instar larvae - the rise in temperature and humidity beyond the threshold gives rise to incidence of flacherie disease. Higher humidity makes it difficult to guard the somoni (Som plantation) during the growth period of worm - makes the weaving difficult to weavers in traditional Tat Hal (Weaving machine set) in cottage sector.



Effect of brushing date and direction on predator infestation in Tasar silkworm

Climate Change and Silkworm Rearing

Weather Based Forewarning of Predators in Tasar Silkworm (*Antheraea mylitta D*) at Kathikund

Singh *et al.* (2018) reported that Weather Based Forewarning of Predators in Tasar Silkworm (*Antheraea mylitta D)* On the basis of interactive approach between weekly weather and predators' data, we found that congenial weather condition was favorable for high infestation of predators during 31st standard meteorological week (SMW). After and before 31st SMW, the predator's infestation was very low or absence in all date of brushing and direction, which indicates after and before 31st SMW week, weather condition was unfavorable for predators. Tasar sericulture farmers for adapting best integrated pest management practices before 31st SMW or any weeks weather going to congenial for predators during 1st crop rearing.

Raising of Tasar Host Plant

Carbon trade is the buying and selling of credits that permit a company or other entity to emit a certain amount of carbon dioxide or other greenhouse gases. In the past decade global carbon dioxide emissions have increased at an annual rate of 1.3%, equivalent to 300 MT. Carbon emissions were in the range of 300 to 500 million MT per year in the developing countries. It crossed the 1,600 million MT mark in the developed countries. Though GHGs can be reduced by reducing the consumption of fossil fuels, it is not practically feasible. Raising tasar host plants in private wastelands not only has the potential to store carbon but also addresses the need for alternative livelihoods for the tribal populations.

Rearing Performance of Eri Silkworm Samia *ricini* in Monsoon Season of Uttar Pradesh

Eri silkworm, Philosamia ricini (Donovan) is a multivoltine sericigenous insect and largely reared by the farmers of North Eastern India, particularly in Assam. In recent years, the farmers of several other states viz. Andhra Pradesh, Madhya Pradesh, Tamil Nadu, Karnataka, Maharashtra, Uttaranchal, Uttar Pradesh, Jharkhand, Bihar, West Bengal, Orissa and Sikkim have taken up eri culture (Sahu *et al.,* 2006). The eri culture is being carried out throughout the year in traditional areas because of the abundant availability of castor plants in the rural areas. It is an ideal subsidiary occupation for a large number of rural tribal populations in India. The eri silkworms are hardy and less susceptible for diseases. However, due to unstable climatic conditions of Uttar Pradesh eri silkworms were susceptible to several diseases. The ambient temperature during rearing affects larval growth, survival rate, cocoon parameters and silk quality. The quality of silk is directly related to the quality of cocoon which depends upon rearing technologies, seasons and silkworm breeds. The quality of feed plays a remarkable role for growth and development of the silkworm and ultimately on the economic traits of cocoons. The ideal range of temperature for the growth of eri silkworms is from 20°C to 40°C, however, increase in temperature beyond 35°C causes less spinning, mortality of larvae and pupae and poor moth emergence and sterility at adult stage. The low humidity influenced the survival rates of insects.

Effect of Climate Change Chawki and Late Age Rearing

The mulberry silkworm (*Bombyx mori L.*) is known for its delicate nature and high sensitivity to global warming making it particularly susceptible to extreme fluctuations in temperature, rainfall and humidity. Domestication over a long period has shaped the adaptability of these silkworms in ways distinct from their wild counterparts and other insects. As cold-blooded animals, silkworms are directly influenced by temperature changes which affect various physiological activities. Temperature among abiotic factors plays a pivotal role in determining the growth and productivity of silkworms. The optimal temperature range for the production of high-quality cocoons is typically between 22°C and 27°C with cocoon quality diminishing above this range. Early instar larvae exhibit resistance to high temperatures enhancing survival rates and cocoon characteristics. Elevated temperatures especially during the later instars accelerate larval growth and shorten the larval period. Conversely, lower temperatures result in slow growth and prolonged larval periods.

Several researchers have indicated that the optimum temperature for normal silkworm growth falls between 22°C and 27°C while the desirable temperature for maximum productivity ranges from 23°C to 27°C. Temperatures below 20°C and above 30°C have a direct impact on silkworm physiology particularly in early instars rendering them unhealthy and susceptible to various diseases. High temperatures during silkworm rearing negatively affect nearly all biological processes including rates of biochemical and physiological reactions. Silkworms are particularly sensitive in the fourth and fifth stages of development. Environmental factors such as temperature, relative humidity, light and nutrition significantly influence the phenotypic expression of silkworms as reported by researchers like Thiagarajan *et al.* (1993) and Ramesh *et al.* (2009).

Effect of Climate Change on Post Cocoon Technology

The quality, quantity and efficiency of cocoons are pivotal factors in the economic growth of the sericulture industry. Variations in the shape and size of hybrid cocoons directly impact filament size and the quality of reeled threads. Irregular and non-uniform cocoons contribute to issues such as thread breakage, slugs hindrance, poor reelability, inefficient cooking, decreased raw silk recovery, variation in raw silk denier and poor neatness. Research by Akahane and K. Subouchi (1994) emphasized that maintaining the water content of the cocoon layer below 20% is crucial for obtaining high-quality cocoons with improved reelability. Studies by Gowda and Reddy (2007) explored the impact of temperature on cocoon and reeling parameters of new bivoltine hybrids during the spinning period. Additionally, Rahmathulla *et al.* (2012) evaluated the influence of various nutritional and environmental stress factors on silk fiber characteristics of bivoltine silkworms.

Despite these efforts there remains a limited understanding of the combined effects of different temperature and humidity conditions on various cocoon characteristics and reeling parameters at different stages during the rearing and spinning of silkworm larvae. This knowledge gap hinders the development of comprehensive strategies for improving the quality and quantity of silk in alignment with international standards. Consequently, further investigation into the combined effects of climate change on cocoon quality, quantity and efficiency is essential. Scientists and researchers in the spinning sector of the sericulture industry should prioritize studying these combined effects to enhance the overall performance and sustainability of the sericulture industry.

Effect of Climate Change on Economy of Sericulture Industry

Sericulture being an agro-based industry is susceptible to the impacts of climate change. The vulnerability of raw silk production is influenced not only by the physiological response of silkworm host plants but also by factors related to silkworm rearing and post-cocoon technology along with changes in the frequency of droughts or floods. Researchers in both agriculture and sericulture have predicted significant effects of climate change on the production and productivity of silkworm host plants, silkworm rearing and post-cocoon technology ultimately impacting the Indian economy. In agriculture climate variability is anticipated to result in crop losses ranging from 10% to 40% leading to substantial revenue losses especially with a 2°C rise in average global temperature. The projections indicate that losses could be even higher when considering additional effects such as damage to land and livelihoods due to sea level rise and coastal erosion increased incidence of diseases, forced displacement and property loss from flooding and landslides (The Hind, 2012).

While there is limited estimated data specifically on the net revenue loss in the sericulture industry, Kumar and Parikh (1998) highlight the potential economic impacts, with farm-level adaptation offering only partial mitigation. Sanghi *et al.* (1998) calculated that a 2°C rise in mean temperature and a 7% increase in mean precipitation could reduce net revenues by 12.3% for the entire country. These findings emphasize the need for comprehensive strategies to address the multifaceted impacts of climate change on the sericulture industry and the broader agricultural sector in India.

Suggestions to Mitigate the Effects of Climate Change

To mitigate the adverse impacts of global warming, it is imperative to intensify tree planting initiatives with the aim of achieving carbon neutrality rather than exacerbating carbon-negative effects. Additionally, there is a crucial need to advance the development of new mulberry varieties that exhibit resilience to both cold and drought conditions. Simultaneously, efforts should be directed towards cultivating silkworm races that can adapt to elevated temperatures especially in conjunction with heightened moisture levels. These proactive measures are essential for fostering sustainability in sericulture practices amid changing climatic conditions. Establishing an effective management system for silkworm disease prevention and control becomes imperative particularly in light of the accelerated growth of pathogens facilitated by high temperatures and moisture. Concurrently, there is a need to devise appropriate methods for managing elevated humidity and carbon dioxide levels both during the rearing and cocoon spinning stages. Creating favorable economic conditions for farmers is essential to stimulate interest and enable increased capital investments in the enhancement of mulberry cultivation and silkworm rearing facilities. This could involve implementing policies or incentives that encourage sustainable practices, providing financial support or subsidies, and offering educational programs to empower farmers with the knowledge and skills needed for modernized and climate-resilient sericulture practices.

External methods used to decrease the temperature

Suggestions to Mitigate the Effects of Climate Change in Muga Silkworm

To avoid crop loss during rearing in case of muga silkworm, indoor rearing can be conducted for early stage worms. Rearing can be done inside nylon nets to avoid heavy rainfall and pest infestation. For mulberry silkworm rearing, temperature control system can be installed to avoid crop loss. Now a day, shifting of rearing season in case of muga is accepted by the farmers to mitigate the loss. Regarding the food plants, frequent care should be taken by checking soil quality and pest infestation, providing adequate amount of manures and fertilizers, pruning and pollarding. Care should also be taken during spinning of cocoons by maintaining required temperature and humidity throughout the period.


External methods used to decrease the temperature
False ceiling with thermocol
False ceiling with thermocol
False ceiling with thermocol
False ceiling with wooden logs
Wet gunny cloth hanged in corridor
Wet gunny cloth hanged in door and windows
Wet gunny cloth hanged in windows
Coconut leaves shading to doors and windows
Wet sand bed with ragi seeds sown near bottom ventilators


External methods used to decrease the temperature
Shade nets covered on roof top
Coconut leaves and dry grass cover on roof top
Coconut leaves covered on roof top
Coconut leaves covered on roof top
Thermocol covered on roof top
Coconut leaves covered on roof top
Coconut leaves hangings with drip liners

CONCLUSION

The sericulture industry and soil health are indeed vulnerable to the impacts of climate change. The projected rise in temperatures ranging from 0.5 to 4°C in various parts of the country over the next few decades due to the accumulation of anthropogenic greenhouse gases poses challenges for sericulture practices. This temperature increase may have drastic implications for the sericulture industry in temperate regions while its effects may be marginal or even beneficial in tropical regions of India. Climate change is a result of various factors, including the use of pesticides and industrial growth contributing to alterations in weather patterns and overall climatic conditions. Man-made activities have influenced the climate leading to consequences that affect agriculture and allied industries including sericulture.

Given the inevitability of these changes, it becomes crucial for humans to develop alternatives and adaptive strategies to cope with the impacts of climate change. This might involve innovations in sericulture practices adjustments to cropping patterns and the development of resilient varieties of silkworms and host plants. Additionally, sustainable and environmentally friendly practices can play a vital role in mitigating the adverse effects of climate change on soil health and the sericulture industry. Adopting climate-smart and eco-friendly approaches is essential for maintaining the viability of sericulture and ensuring the sustainability of soil health. Such initiatives can help reduce the industry's carbon footprint and enhance resilience to changing climatic conditions fostering a more sustainable future for sericulture in the face of climate change challenges. It is essential to develop drought varieties and hardy silkworm races. Raising tasar host plants in private wastelands not only has the potential to store carbon but also addresses the need for alternative livelihoods for the tribal populations. With the help of meteorological data and bionomical studies strengthen the pest and disease forecasting and forewarning system In order to provide timely messages to the farming community for undertaking effective advocated /needed measures to minimize the crop loss. Proper Government interventions are important for the survival of this industry.

ACKNOWLEDGMENT

The authors express sincere thanks to the head of the Department of Sericulture, Forest College and Research Institute, Tamil Nadu Agricultural University, Mettupalayam, India for the facilities provided to carry out this research work.

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