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Impact of Climate Change on Sericulture

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Climate change is likely to pose problems to agriculture and its related industries in the future, which could result in both global and local development. The sericulture sector is impacted by climate change in a number of ways. Rising annual mean temperature, irregular rainfall, humidity, lack of management practices, accumulation of anthropogenic greenhouse gases in the atmosphere and lack of management practices will lead to reduced production of raw silk, mulberry leaf yield, silk content, breakage in silk thread during reeling or spinning, water stress, drought, risk of soil acidification and salinization, decomposition of organic matter, Nitrogen fixation, and mineralization of N, P, and S and unpredictable monsoon. The impact of global warming on silkworms is more concerned as they participate in several biotic interactions that are critical to the ecological functioning of our country and significantly boost its GDP.

Keywords: Climate change; Sericulture; soil health; mulberry.

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1. INTRODUCTION

Climate change is a major shift in either the mean state of the climate or its variability that lasts for a long time and may be brought on by internal natural processes, external forcing, or persistent anthropogenic changes in the atmosphere's composition or in how land is used. Worldwide, ecosystem integrity and species survival may be seriously threatened by climate change. It is widely acknowledged as the most imminent and pressing problem threatening human survival in the twenty-first century. An increase in worldwide atmospheric temperature rise is the key factor determining greenhouse gas (GHG) concentrations, such as those of carbon dioxide (CO2), methane (CH4), and nitrous oxide (NO2). "The burning of fossil fuels, rapid industrialization, deforestation, agricultural activities, luxury lifestyles, space explosion, grazing, wetland destruction, and land use change are all associated with rising GHG emissions" [1].

"Based on the increase in greenhouse gases, climate models predict a 1.4°C to 5.8°C average increase in global warming from 1990 to 2100, likely leading to a more rapid increase in temperature at the surface of the earth" [2].

According to the Intergovernmental Panel on Climate Change, if global temperatures increase by about 2.0^{o} C over the next 100 years, adverse effects would start to spread to most parts of the world. It is also anticipated that 20–30% of plant and animal species will likely face an increased risk of extinction. Industrialization and families directly contribute more than two thirds of the greenhouse gas emissions. The stock of greenhouse gases in the atmosphere would quadruple its preindustrial levels by 2050, or 550 ppm CO2, even if the yearly flow of emissions did not increase above its current rate. "It has been reported that over the past century or so, the atmospheric buildup of greenhouse gases caused by human activity has caused the average temperature in India to increase by roughly 0.5 °C" [3].

Bombyx mori L., the mulberry silkworm is a monophagous insect with significant economic importance that feeds on mulberry leaves and produces silk through spinnerets in the form of cocoon. Silkworms are cold-blooded creatures with body temperatures that are roughly similar to those of their surroundings; changes in air temperature have an impact on their behaviour, growth, and reproduction. The successful growing of the silkworm and the manufacturing of the final output of this enterprise, the silk, are determined by environmental parameters including temperature and humidity. The silkworms are sensitive to changes in ambient temperature and humidity, even a small change in these variables causes the crop to completely fail. Some insects exhibit a wide range of adaptations to these variations at a bearable limit despite the enormous variation in the surrounding environmental conditions, whereas silkworms are unable to withstand excessive natural variation. Temperature and humidity directly affect larval growth, development, and physiological activity, as well as nutrient absorption, digestion, blood circulation, and respiration, among other things [4]. Rising temperatures and daily changes in weather patterns are linked to global warming, which poses a threat to the sericulture industry for both India and other countries that are associated with it.

The insect pest situation in mulberry has changed as a result of changes in the climate and agro-ecosystem [5]. Environmental elements like temperature, relative humidity, light, and nutrition have a significant impact on the phenotypic expression of mulberries. Seasonal environmental differences have a significant impact on the expression of any hybrid in cocoon productivity due to disease incidence, which influences the performance of silkworm output. Bivoltine, in contrast to Multivoltine, are more susceptible to a variety of pressures, such as low leaf quality and incorrect silkworm rearing management, especially in the autumn, which causes crop losses due to diseases. The vulnerability of raw silk production relies not only on the host plants but also on post-cocoon technology and silkworm rearing, as well as variations in the frequency of floods or droughts. Silkworms and other beneficial insects are involved in several biotic interactions that are crucial to the ecological balance; the impact of climate change on them is more significant.

2. IMPACT OF CLIMATE CHANGE ON SOIL

The root development and soil biological activities i.e. soil porosity, pore size distribution, and consequently soil functions are likely to be affected in unexpected ways by climate change scenarios such as high CO2 concentration, increase in temperature, variable and extreme rainfall events. A number of soil characteristics, such as porosity, field capacity, control the amount of water that is available to plants and the soil.

Climate change will have an impact on soil pH, organic matter status, carbon and nutrient cycling, water availability for plants, and ultimately plant production [6]. High and frequent rainfall brought on by climate change may cause base cations to drain from lower layers of the soil, increasing soil acidity and transferring alkalinity from the soil to rivers. “This process is influenced by the accelerated rate of organic matter degradation and loss as a result of high temperatures” [7]. Similar to this, there is a direct correlation between the available nutrients N, P, K, S, and micronutrients and climate change. Due to the close relationship between soil organic carbon and nutrient cycling, particularly N, causes of climate change such as increased temperatures, unpredictable precipitation, and atmospheric N deposition are anticipated to have an effect on these three elements as well as phosphorus and sulphate cycling.

“Climate change is likely to have an impact on all environmental parameters, including temperature, moisture, vegetation structure, and nutrient availability, which affect the activity and population of soil microorganisms” [8]. Soil bacteria are primarily responsible for the processes of CO2, CH4, and N2O GHG production and consumption. The metabolism of these GHGs can involve microorganisms in a variety of ways. By regulating the nitrogen cycle, soil microbes make nitrogen accessible to living things. Microbes release NO and N2O, two harmful greenhouse gases, into the atmosphere during the nitrification process. “Most of the nitrification's output of N2O is caused by the activity of autotrophic microorganisms that oxidise ammonia (NH3). On the other hand, denitrification is a long process in which every action is mediated by a definite group of microorganisms and the production of N2O is characteristically the result of partial denitrification” [9].

3. IMPACT OF CLIMATE CHANGE ON MULBERRY, A SILKWORM HOST PLANT

The bulk of the species of mulberry plants are indigenous to east and south Asia, however they may be successfully grown in a variety of climates from warm temperate to subtropical parts of Asia, Africa, Europe, and the United States of America. Mulberry plants are members of the Moraceae family. *Morus alba L.*, *Morus indica* L., *Morus bombycis* Koidz., *Morus sinensis*, and *Morus multicaulis* (Perr.) are a few of the mulberry species essential and has prospered in India.

Being a monophagous insect, the silkworm exclusively obtains the nutrients needed for growth from the mulberry leaf. Silkworms should be fed high-quality mulberry leaves in order to generate the silk, which is directly derived from the protein in mulberry leaves. A plant's physiological development and growth are influenced by a variety of climatic and environmental conditions, such as rainfall, temperature, relative humidity and the soil's quality.

The activity and population of various helpful microorganisms are significantly impacted by the climatic shift, which is reflected in the poor soil quality and, eventually, the poor growth of the host plants. The mulberry (*Morus alba*), a C3 plant, is ineffective at using ambient CO2, but C4 plant enzymes found in the mesophyll are effective at fixing CO2. In C3 plants, the enzyme ribulose biphosphate carboxylase/oxygenase (RuBis CO), an ineffective enzyme with low substrate specificity, reacts with ribulose biphosphate (RuBP) in the presence of CO2. To make up for this inefficiency, C3 plants' stomata stay open for longer, which increases evapotranspiration. Therefore, cooler, moister conditions with higher CO2 concentrations are favourable for C3 plant growth [1]. While emerging research suggests that C3 crops may respond favourably to elevated atmospheric CO2 [10] in the absence of other stressful conditions, increased CO2 levels will affect plants' output through photosynthesis and stomatal conductance [11,12]. However, other consequences of climate change, such as increased temperatures, greater tropospheric ozone concentrations, and changing patterns of precipitation, may wipe out the favourable direct effect of rising CO2.

4. IMPACT OF CLIMATE CHANGE ON INSECT PEST

Due to intensive agricultural practises and the indiscriminate application of nitrogenous fertilisers and pesticides, numerous insect pests and diseases have recently been found to be the main problems restricting the output and productivity of mulberry leaves. Due to changes in the climate and agro-ecosystem, the insect pest situation in mulberries has also changed. The combined impacts of climate, including temperature, precipitation, humidity, and other factors including soil moisture, atmospheric CO2, and tropospheric ozone (O3), will determine the potential influence of global climate change on plant-pest populations. The population, range, or status of insect pests of crops could all be significantly impacted by climate change. Changes in phenology, dispersion, community composition, and ecosystem dynamics are among the effects of climate change on insect pest populations that ultimately result in species extinction. Expanded pest host ranges, disturbance of the synchronisation between pests and natural enemies, and more frequent pest outbreaks and upheavals are all possible consequences (Fig. 1). Due to their dynamic behaviour, insect populations react to the effects of climate change in various ways, changing their position as pests in the process.

Depending on an insect species' development strategy, different temperatures have different effects on insect pests [13]. An increase in temperature may cause changes in crop-pest synchrony of phenology, geographical distribution, overwintering, population growth rate, number of generations, extension of their developmental seasons, change in the time of occurrence, and the risk of migrant pest [14]. This has led to a number of minor pests becoming significant pests, several pests switching from secondary to primary status, and the emergence of new pest issues in some areas. Most organisms and overall biodiversity will be negatively impacted by climate change [15,16,17,18,19].

“Pests can have detrimental effects on the environment and the economy when they are introduced to new places. Due to the persistent clouds and excessive humidity, it is evident that insect attacks on mulberries begin earlier than usual. These pests are Bihar hairy caterpillar (*Diacrisia* (=*Spilarctia*) *obliqua* Walker), Pink mealybug (*Maconellicoccus hirsutus* (Green)), Thrips (*Pseudodendrothrips mori* Niwa), Leaf webber (*Diaphania pulverulentalis* (Hamp.)), Mites (Bud mites) and diseases are Root-knot nematode (*Meloidogyne incognita*), Powdery mildew (*Phyllactinia corylea* (Pers.) P. Karst.), Leaf rust (*Peridiospora mori*) and Leaf spot (*Cercospora moricola*) *etc”* [1]. According to reports, the pink mealy bug, *M. hirsutus*, has 346 host plants and damages mulberry leaves for 4500 kg/ha/year, which prevents farmers from brushing their fields for 450 dfls/ha/year and reduces cocoon production by 150 kg/ha/year [20]. In the Krishnagiri region and the Salem region, the D. Pulverulentalis infestation is highest from October to February [21,22] and from October to December [23]. respectively Likewise, the insect resulted in a 12.8% reduction in leaf yield, with an average incidence of 21.77% [24].

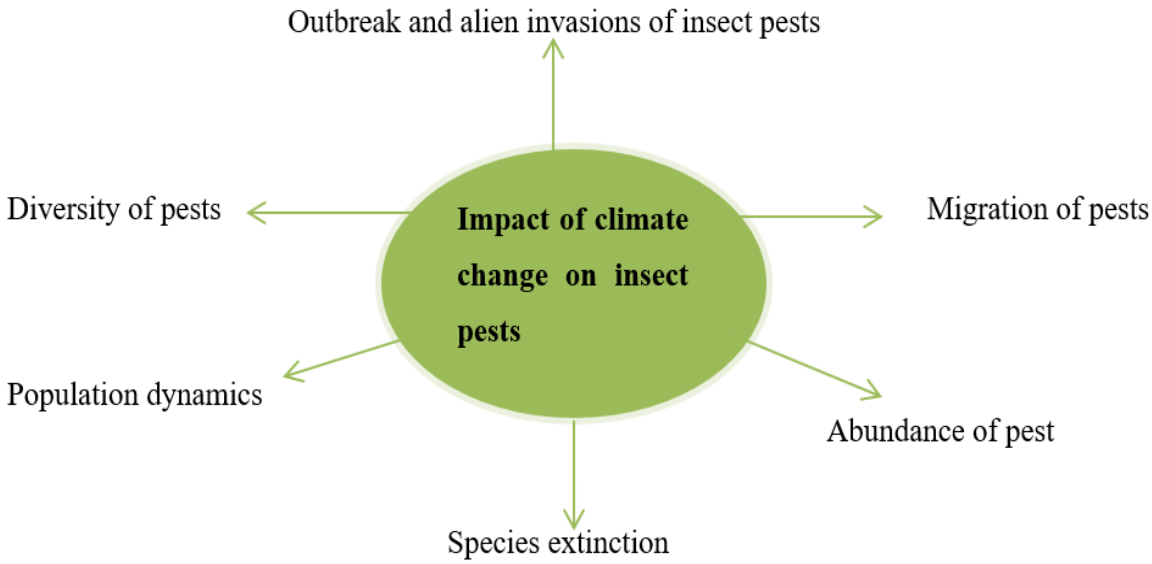

Fig. 1. Impact of climate change on insect pests

"Elevated CO_2 may modify pathogen aggressiveness and/or host susceptibility and affect the initial establishment of the pathogen, especially fungi, on the host plant. Greater plant canopy size, particularly in conjunction with humidity and increased host abundance, can increase pathogen load. Plants are more vulnerable to rust infections with a rise in temperature" [25]. In temperatures that are mild, fungi reproduce quickly. In increased CO_2 levels, more frequent and intense precipitation, and denser canopies pathogens thrive more.

5. IMPACT OF CLIMATE ON THE DEVELOPMENT AND GROWTH OF SILKWORM

The silkworm *Bombyx mori* is a poikilotherm, highly sensitive to surrounding temperature. The overall production and outcome of the silkworm are described by a combination of abiotic and biotic variables. Among the four types of commercially exploited silkworm, mulberry silkworm, which is fully domesticated, is more sensitive to sudden changes in temperature, humidity, and other abiotic variables.

Mulberry silkworms (*Bombyx mori* L.) grow normally in the temperature range of 20-28ºC, and the preferred range of temperature is 23-28ºC for maximum productivity [26]. Temperature is one of the major abiotic factors that affects the growth and productivity of silkworms [27,28]. The physiology of silkworms is directly impacted by temperature, particularly in the early instars, which causes them to become unwell and prone to numerous diseases. The temperature range of 22–27ºC is more conducive to producing cocoons of good quality, while above the range, the quality declines [29]. High temperatures have a negative impact on almost all biological processes during silkworm rearing, including the rates of biochemical and physiological reactions [30]. The early instar larvae are typically heat-resistant, which helps to increase survival rates and the characteristics of the cocoon. High temperatures during silkworm rearing accelerate the larval growth and the larval phase gets shortened, especially in late instars. On the other side, growth will be slow and the larval period would lengthen at low temperatures.

6. IMPACT OF CLIMATE CHANGE ON COCOON PRODUCTION AND SILK

Sericulture is an agro based industry. The vulnerability of raw silk production to climate change depends on the physiological response of the affected silkworm host plants, as well as on silkworm rearing and post cocoon technology as well as on the changes in the frequency of droughts or floods. Proper shape, size, and compactness of a cocoon are necessary for filament length as well as the quality of reeled thread. Uneven and non -uniform cocoons are also caused by thread breakage, slug obstruction, poor cooking, poor reelability, decreased raw silk recovery, variations in raw silk denier, and neatness.

Different characteristics of silkworms and cocoons are influenced by environmental factors such as temperature, humidity, air current, and others in addition to genes. The ambient temperature, the season, and other environmental factors have a significant impact on the quality of the cocoon and silk. The quality of the cocoon is affected by temperature changes, which causes variations in filament size and reeled thread quality. Changes in environmental circumstances cause differences in cocoon weight, shell weight, filament length, silk yield, denier, and sericin % [31].

The cocoon layer's water content should be lower than 20% to get greater reelability and higher-quality cocoons [32]. Decrease in mulberry leaf yield and raw silk production, silk content, breakage in silk thread during reeling or spinning, water stress, drought, risk of soil acidification and salinization, and decomposition will result from an increase in annual mean temperature, irregular and heavy rainfalls, high humidity, unpredictable monsoon, and top soil erosion.

7. CONCLUSION

Recent changes in the climate and the resulting loss of not just the mulberry silkworm but also the muga, the tassar, the eri and other silkworm species have drawn attention from all over the world. The sericulture sector is affected by climate change in many different ways. Temperature control systems can be built for mulberry silkworm rearing to prevent crop loss. Care should be given to the food plants on a regular basis, including pruning and pollarding, checking the soil for pest infestation and quality, and applying the right amount of manures and fertilisers. During spinning of cocoons, care should be given to maintain the necessary humidity and temperature levels. Future research in this area is required for the benefit of the sericulture business as the precise impact of climate change on this industry has not yet been established. It is really necessary to address this new issue with some sustainable methods in order to protect our resources.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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