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Effect of global warming on silk farming: A review

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Abstract

Sericulture stands for livelihood opportunity for millions owing to its high employment potential, low capital requirement, and remunerative nature. India being the second largest silk-producing country in the world, next to China, provides employment to over 8.5 million people in the entire silk production value chain from farm to fabric. The mulberry silkworms are domesticated for a long time, the adaptability of these silkworms in unfavourable climatic conditions is quite different from the wild silkworms and other insects. As silkworms are cold-blooded animals, the temperature will have a direct effect on various physiological activities. The vulnerability of raw silk production to climate change depends not only on the physiological response of the affected silkworm host plants but also on silkworm rearing and post-cocoon technology as well as changes in the frequency of droughts or floods. The effect of global warming on silkworms and other beneficial insects is of greater significance because they are involved in many biotic interactions which play a major role in the ecological functioning as well as they use to contribute a significant amount to the GDP of the country.

Keywords: Global warming, sericulture, GDP, climate change and silk

Introduction

The climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. Climate change is a significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer), which, may be due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or land use (IPCC, 2018) [14]. A key indicator for climate change is the expected global-mean surface temperature increase. According to the recent reports of the Intergovernmental Panel on Climate Change, the global average surface temperature over the 20th century has increased by around 0.60 °C (Singh, 2017) [39]. The temperature rise is mainly dependent on the concentration of greenhouse gases (GHG) like carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (NO_2). On the basis of the increase of greenhouse gases, the climatic model predicts a 1.4 to 5.8 °C average increase in global warming from 1990 to 2100, probably leading to a more rapid increase in temperature at the surface of terrestrial zones and more extreme local variations (Karl and Trenbeth, 2003) [15].
According to IPCC (2014) [13], industrialization and households directly contribute more than one-third (76%) of global greenhouse gas emissions in 2010 whereas agriculture, forestry and other land use contribute 24% which is approximately one-fourth of total global GHG emissions. Electricity-heat production and Industry sectors account for 25 and 21% of annual GHG emissions, respectively. Sector-wise annual GHG emissions are given in Fig. 1. Out of total global GHG emissions, fossil CO_2 emissions are the largest source of global GHG emissions, with a share of about 72%, followed by CH_4 (19%), N_2O (6%) and F-gases (3%) (Olivier and Peters, 2020) [24].
It has also been reported that the average temperature in India has risen by about 0.5 °C from the accumulation of anthropogenic greenhouse gases in the atmosphere during the past century or so. The effect of recent emissions will be manifested over several decades and given current trends, the temperature rise will likely exceed 2.0 °C. (Anonymous, 2012) [2].

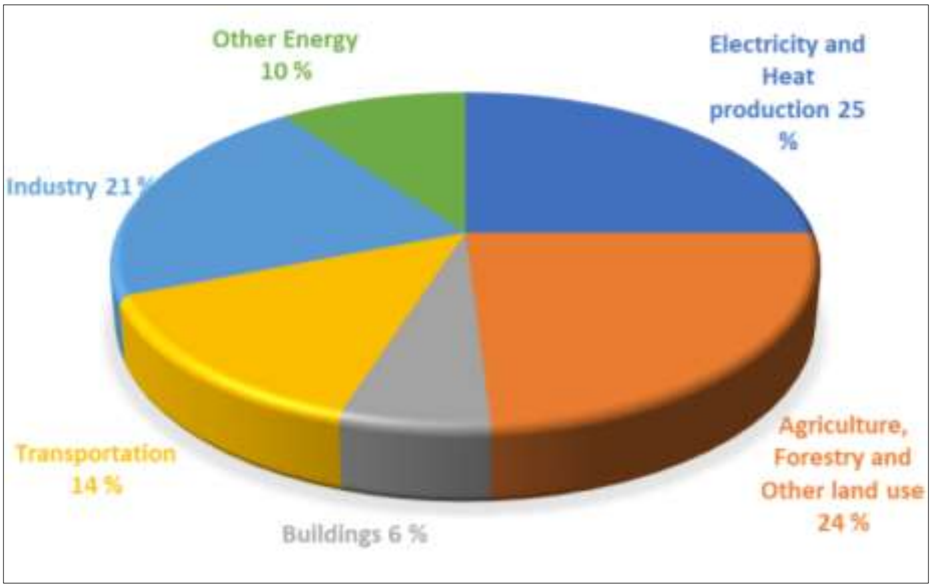

Fig 1: Schematic diagram of Sector-wise global annual emission of Greenhouse gases (IPCC, 2014) [14]

Based on the prediction of several researchers from various Indian institutions, the temperature may rise from 0.5 to 4.0 °C in the various parts of the country in the next few decades from the accumulation of anthropogenic greenhouse gases in the atmosphere, which may change practices and economy of Indian agriculture or sericulture drastically (Ram *et al*., 2016) [33].

Sericulture stands for livelihood opportunity for millions owing to its high employment potential, low capital requirement, and remunerative nature. India being the second largest silk-producing country in the world, next to China, provides employment to over 8.5 million people in the entire silk production value chain from farm to fabric. Silk production has achieved remarkable growth in recent times. Silk production has increased from 21,005 MT in 2010-11 to 33,770 MT in 2020-21 at a compound growth rate of 4.6% per annum. Traditionally, sericulture is practiced in the states of Karnataka, Tamil Nadu, Andhra Pradesh, Telangala, Maharashtra, West Bengal, and Jammu and Kashmir in the temperate region. Besides that, sericulture is also practiced to a limited extent in Uttar Pradesh, Madhya Pradesh, Chhattisgarh, Bihar, Jharkhand and Assam, and entire North-Eastern India.

Sericulture is an agro-based industry. The vulnerability of raw silk production to climate change depends not only on the physiological response of the affected silkworm host plants but also on silkworm rearing and post-cocoon technology as well as changes in the frequency of droughts or floods. Several researchers working either in the field of agriculture or sericulture predicted the significant effect of climate change on silkworms' host plants, silkworm rearing and post-cocoon technology which directly affects the Indian economy (Ram *et al*, 2016) [33].

Rising temperature and day-to-day changing weather patterns linked to global warming which becomes a threat to the sericulture industry not only for India but for the other countries which are associated with this industry. The effect of climate change on silkworms and other beneficial insects is of greater significance because they are involved in many biotic interactions which play a major role in the ecological functioning as well as they use to contribute a significant amount to the GDP of the country (Bora and Saikia, 2022) [5].

Effect of Climate change on Mulberry, a silkworm host plant

Mulberry plants belong to the family Moraceae and are successfully grown under varied climates ranging from warm temperate to subtropical regions of Asia, Africa, Europe, and the United States of America with the majority of the species native to east and south Asia. The mulberry species like *Morus alba* L., *Morus indica* L., *Morus bombycis* Koidz., *Morus sinensis* and *Morus multicaulis* (Perr.) *etc*. are very important and successfully grown in India. The mulberry leaves are the basic food material for the silkworm, *Bombyx mori* L., and nutritious leaves are the most important growth-regulating factors for the above silkworm. Silkworm being a monophagous insect derives almost all the nutrients essential for its growth from the mulberry leaf itself. The bulk of the silk produced in the world by the mulberry silkworm is directly derived from the protein of mulberry leaves; hence, silkworms should be fed with good quality mulberry leaves in abundant quantity for successful cocoon production. The physiological growth and development of host plants depend on different climatic or environmental factors like rainfall, temperature and relative humidity along with the quality of the soil where they grow.

As mulberry is a C_3 plant and its physiology is different from C_4 plants. The C_3 plants are relatively inefficient in using CO_2 and have their photosynthetic apparatus in the outer mesophyll cells. To compensate for this inefficiency stomata must remain open longer exposing them to potentially increased evapotranspiration and respiration rates. As a result, these plants grow better in cooler moist environments with elevated CO_2 concentrations (Ram *et al*, 2016) [33].

Long *et al*. (2006) [17] and Polley (2002) [28] reported the effect of rising CO_2 on plants' yield through photosynthesis and stomatal conductance whereas the growing evidence suggests that C_3 crops, may respond positively to increased atmospheric CO_2 in the absence of other stressful conditions (Long *et al*, 2004) [18], but 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. The direct and indirect effects of climate change include: (1) direct effects from changes in temperature, precipitation, or carbon dioxide concentrations, and (2) indirect effects through changes in soil moisture and the distribution and frequency of infestation by pests and diseases (IPCC, 2001) [12].

Effect of Climate change on Mulberry insect pests and diseases

In recent years, many insect pests and diseases have been reported to be the major limiting factors affecting the production and productivity of mulberry leaves due to intensive cultivation practices and indiscriminate use of nitrogenous fertilizers and pesticides. There is also a change in the insect pest scenario in mulberry due to changes in climate and agro-ecosystem. It is seen that there is an early onset of insect attack on mulberry due to continued cloudy weather and high humidity. 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*. (Ram *et al*, 2016) [33]. It has been reported that the pink mealy bug, *M.hirsutus* has got 346 host plants and in mulberry, it causes leaf yield loss of 4500 kg/ha/year thus depriving the farmer of brushing of about 450 dfls/ha/year leading to a decline in cocoon production of 150 kg/ ha/year (Ravikumar *et al*, 2010) [35]. The leaf webber, *D. Pulverulentalis* has been noticed as a serious pest in Karnataka since 1995 and has also spread to Tamil Nadu and Andhra Pradesh on local, M5, MR2, S36 and V1 varieties. The infestation of *D. Pulverulentalis* is higher from October to February in the Krishnagiri area (Muthulakshmi *et al*, 2003; Samuthiravelu *et al*, 2004) [16, 37] and October to December in the Salem area (Qadri *et al*, 2003) [29]. Similarly, the pest caused the leaf yield loss of 12.8% with an average incidence of 21.77% (Rajadurai *et al*, 2000) [32]. The phenotypic expression is greatly influenced by environmental factors such as temperature, relative humidity, light and nutrition (Thiagarajan *et al*., 1993; Ramesh *et al*, 2009) [44, 34].

The effect of climate change on the pathogen of several crops has also been reported by several workers, for example, elevated CO_2 may modify pathogen aggressiveness and/or host susceptibility and affect the initial establishment of the pathogen, especially fungi, on the host (Plessl *et al*, 2005; Matros *et al*., 2006) [27, 20], increased infection and growth of some fungal pathogens under elevated CO_2 (Hibberd *et al*, 1996; Chakraborty *et al*, 2000) [11, 7] and greater plant canopy size, especially in combination with humidity and increased host abundance, can increase pathogen load (Chakraborty and Datta, 2003; Pangga *et al*, 2004) [6, 25]. Coakley *et al* (1999) [8] stated that plants are more susceptible to rust diseases with increased temperature. Fungi that cause plant disease multiply fast in moderate temperature ranges. Temperate climate zones that include seasons with cold average temperatures are likely to experience longer periods of temperatures suitable for pathogen growth and reproduction if climates are warm. They also stated that, more frequent and extreme precipitation, higher CO_2 concentration, and denser canopies with higher humidity favour pathogens.

Effect of Climate change on silkworms

The mulberry silkworm (*Bombyx mori* L.) is very delicate and highly sensitive to global warming and also unable to survive extreme fluctuations in temperature, rainfall, and humidity. As mulberry silkworms are domesticated for a long time, the adaptability of these silkworms in unfavourable climatic conditions is quite different from the wild silkworms and other insects. As silkworms are cold-blooded animals, the temperature will have a direct effect on various physiological activities. Parrey (2018) [26] studied the effect of temperature and humidity on mulberry silkworms. Among the abiotic factors, temperature plays a major role in the growth and productivity of silkworms (Ueda *et al*, 1975; Benchaminand Jolly, 1986) [45, 4]. The optimum temperature for the production of quality cocoons ranges from 22-27 °C and the quality of cocoons will be inferior above this temperature range (Datta, 1992; Krishanswami *et al*., 1993) [5, 16]. In general, the early instar larvae are resistant to high temperatures which also helps in improving the survival rate and cocoon characters. High temperature during silkworm rearing particularly in late instars accelerates larval growth and shortens the larval period. On the other hand, at low temperatures, the growth will be slow and the larval period will prolong (Rahmathulla, 2012) [30]. It has also been reported by several researchers that the optimum temperature for normal growth of silkworms ranges from 22 to 27 °C and the desired temperature for maximum productivity ranges from 23 to 27 °C. Temperature below 20 °C and above 30 °C directly affects the physiology of silkworms especially in early instars resulting in them becoming unhealthy and susceptible to various diseases. During silkworm rearing, high temperature adversely affects nearly all biological processes including the rates of biochemical and physiological reactions (Willmer *et al*, 2004) [46] and the silkworms were more sensitive in the fourth and fifth stages (Shirota, 1992; Tazima and Ohuma, 1995) [38, 43]. Thiagarajan *et al*. (1993) [44] and Ramesh *et al*. (2009) [34] reported that the phenotypic expression is greatly influenced by environmental factors such as temperature, relative humidity, light, and nutrition.

The golden silk producer, muga silkworm (*Antheraea assamensis* Helfer) is semi-domesticated and undergoes 5-6 generations in a year. As it is reared in outdoor conditions, slight variations in temperature and humidity can pose a threat to it which leads to crop loss. Autumn and spring are considered the best seasons for muga rearing to get maximum output. But during the last few years, the temperature is increasing in the autumn season, so farmers are shifting the rearing season by 10-15 days during the commercial crop *Katia* (autumn) (Sahana Ghosh, 2018) [36]. Eri silkworm (*Samia ricini* Boisduval) is completely domesticated, so fluctuations in these factors can be controlled upto some extent. Tasar silkworm is reared in outdoor conditions. According to Sinha and Chaudhury (1992) [40], phenological parameters are dependent on ambient temperature and relative humidity during larval and pupal development in tropical tasar silkworms (*Antheraea mylitta* Drury).

Effect of Climate change on post-cocoon technology

The quality, quantity, and efficiency of a cocoon play a very important role in the economical growth of the sericulture industry. The significant variations in shape and size of hybrid cocoon results in the variation in filament size and the quality of the reeled threads (Nakada, 1993) [22]. The thread breakage, hindrance due to slugs, poor cooking, poor reelability, decreased raw silk recovery, variation in raw silk denier and poor neatness also result in irregular and nonuniform cocoon (Takabayashi, 1997) [42]. Akahane and Subouchi (1994) [1] recommended that the water content of the cocoon layer should be below 20% in order to obtain good-quality cocoons with better reelability. Gowda and Reddy (2007) [10] studied the effect of temperature on cocoon and reeling parameters of new bivoltine hybrids during the spinning period, however, Rahmathulla *et al*. (2004) [31] evaluated the influence of various nutritional and environmental stress factors on silk fiber characters of the bivoltine silkworm. According to Srivastava *et al* (1998) [41], variations occur in cocoon weight, shell weight, filament length, silk yield, denier, and sericin percentage due to changes in environmental conditions. Due to a lack of proper investigation in this field, very limited information is available on the combined effect of different temperatures and humidity on various cocoon characters and reeling parameters at different stages during the rearing and spinning of silkworm larvae which in turn will provide valuable information to the technology developers who are engaged in the improvement of quality and quantity of silk acceptable to the level of international standard (Mathur, 2000) [19]. The researchers involved in the spinning sector need to pay much attention to the combined effect of climate change on the quality, quantity, and efficiency of a cocoon for the betterment of reelers and the sericulture industry.

Ram *et al*. (2016) [33] opined that the rise of annual mean temperature, irregular and heavy rainfalls, high humidity, unpredictable monsoon, top soil erosion accumulation of anthropogenic greenhouse gases in the atmosphere and lack of management practices will lead to a reduction 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, decomposition of organic matter, N fixation and mineralization of N, P and S, soil erosion, runoff, the longer growing season of insect pests, shorter growing period of silkworms, high probability of bacterial and fungal infection, less stomatal opening of mulberry leaves and crop-weed competition *etc*.

The effect of climate change on sericulture is based on prediction and not yet proven. It can be concluded that tropical regions such as Karnataka, Tamil Nadu, Andhra Pradesh, Telangana, Maharashtra, West Bengal, Uttar Pradesh, Madhya Pradesh, Chhattisgarh, Bihar, Jharkhand, and Assam will be severely affected due to climate change however, a marginal loss can be noticed in Jammu Kashmir and Sub-Himalayan region of North-Eastern India (Neelaboina *et al*., 2018; Ram *et al*, 2016) [23, 33].

Conclusion

Worldwide attention has been attracted by recent changes in global climatic phenomena and consequent loss of not only mulberry silkworm but also muga silkworm, tassar silkworm, and eri silkworm. The effect of climate change on silkworms is of greater significance because it contributes a significant amount to the GDP of the country in the form of raw silk. As the exact effect of climate change on the sericulture industry is not yet proven, so on the basis of available research findings future research needs to be focused on these areas for the sustainability and prosperity of this industry.

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