Review Article

A Comprehensive Review of the Effect and Mitigation of Climate Change on Sericulture

Abstract

Sericulture, the practice of silkworm cultivation to produce silk, has been around for thousands of years and is even a part of cultural significance in Asia. But, the changes in climate change have created so many problems due to physical and physiological factors that are affecting silkworm larvae (*Bombyx mori*) as well as mulberry plants which is primary food of silkworm. In this review, we address about the influence of climate change on sericulture by discussing pertinent studies in relation to rising temperatures and temperature changes; self-defensive responses related with heat waves; precipitation changes. Growth and cocoon quality in the optimal range for silkworm are so critical to temperature and humidity, that deviating from them lowers silk production while higher numbers can deteriorate death rates. In addition, climate change results in shifts of mulberry plant physiology and pest dynamics which are additional complications to sericulture practices.In alignment with the above, research and development is oriented toward climate-resilient silkworm breeding lines, improved mulberry cultivation practices, and modern technologies like remote sensing and GIS for efficient resource management. Works of planned future interest include bettering the quality of genetic research for the development of more resilient silkworm strains and the performance of comprehensive vulnerability assessments to formulate suitable adaptation strategies. Ensuring the resilience and economic viability of the sericulture industry in the face of climate change is crucial for sustaining long-term silk production if the mitigation measures discussed in this paper are put in place

Key words: Sericulture, Climate change, Silkworm Cultivation, Mulberry Cultivation, Adaptive strategies

1. Introduction

The history of silk is as old as the practice of rearing silkworms. Sericulture is believed to have originated in ancient China, where some archaeological records indicate that silk production began around 3630 BCE (Sun *et al.,*2012). This marked the time when people started domesticating *Bombyx mori* – a species derived from its wild relative *Bombyx mandarina*, which is considered an important event in agricultural and biotechnological history (Sun *et al.,* 2012). According to a Chinese legend, Empress Xi Ling Shi discovered how to make thread by dropping cocoons into tea until they dissolved into fine fibres (Borgohain and Borah, 2023). However, for many centuries after this discovery became known outside China's borders it remained tightly protected within them; anyone caught smuggling silkworm eggs or revealing methods used to produce silk faced severe punishment (Borgohain and Borah, 2023).

Silkworms underwent significant genetic and morphological changes during their domestication which made them amenable for human handling. These included alterations in body colouration, cocoon size and loss of flight ability that rendered *B. mori* entirely reliant on man for its existence and perpetuation (Sun *et al.,* 2012). The art of sericulture spread gradually across Asia from China before reaching Europe and America. References to India's more than two millennia old tradition of silk manufacturing can be found in ancient texts such as Ramayana and Arthashastra (Borgohain and Borah, 2023). Different varieties of silkworms have been developed because of the expansion in silk industry that are adapted to different climatic zones and production requirements (Chakraborty *et al.,* 2022).

To enhance quantity as well as quality of silk produced it was necessary to study biology and genetics of silkworms. Different researches have revealed that environmental factors play a vital role in the growth and development of silkworms particularly temperature (Chakraborty *et al.,* 2022). For example, larval weight, cocoon weight, shell weight was found to be higher in silkworms reared at 26-28°C than those at 23-25°C by Chakraborty *et al.,*2022).

Biotechnology and genetic researches in sericulture are closely related to the development of this sector. Sun *et al.,* (2012) conducted a genome-wide analysis to study the phylogeny and evolutionary history of silk moth, which explains how it has been domesticated genetically differentiating varieties used at different times for silk production. The finding also provides insight into insect domestication process understanding and suggests new ways for enhancing silk production through advanced breeding methods based on these discoveries (Sun *et al.,* 2012).

Recent genomic studies have accelerated the use of silkworms as model organisms in life sciences. Liu *et al.,* (2014) showed that CRISPR/Cas9-mediated genome editing is efficient in silkworms, hence creating new opportunities for genetic manipulation and improvement of traits. Also, some silkworm genes were discovered to be highly homologous with human hereditary disease related-genes thus can serve as models for investigating human health (Liu *et al.,* 2019).

The advancement of sericulture largely owes to remote sensing and geographic information system (GIS) among other things. Indian Space Research Organisation (ISRO) employed these technologies together with Central Silk Board of India to identify potential areas for mulberry cultivation as well as suitable regions for rearing silkworms (NESAC). This strategy makes it possible to identify new sites where silk farming may be extended in a planned manner.

Up to now, silk production remains a significant contributor in many countries' economies. However, efforts are still underway towards finding means of increasing silk yield, improving quality and enhancing production efficiency too. Having been there for ages but still productive; sericulture is not only an invaluable cultural heritage but also a scientific research field (Sun *et al.,* 2012; Chakraborty *et al.,* 2022; Liu *et al.,* 2019).

2. Effects of Climate Change on Sericulture

Temperature Fluctuations and Silkworm Development

Silkworms' (*Bombyx mori* L.) growth and development can be influenced by temperature fluctuations.

Silkworm growth is directly proportional to temperature i.e. if temperatures are not varied then they can't develop well (Rahmathulla V.K., 2012).

The ideal temperature for rearing silkworms should range between 25-26 degrees Celsius. Any variation below (20-21oC) or above (28-29oC) this range negatively impacts the growth and development of the insects (Zhang Y., 2018).

Heat shocks have been found to cause death rate rise, speed up larval stages, reduce larval weight as well as intake and utilization of silkworm food leading to low efficiency with failure in cocoon formation pupae and imagoes also may not form.

The feeding temperature for young worms is 26-28°C with relative humidity of about 80-85% while that of those which have reached adult stage is maintained at 23-24°C with relative humidity being about 70-75% (Zhang Y., 2018).

Abnormalities in wide-range deviations from normality may suppress silk gland activity due to inhibited synthesis process besides producing less fluid protein component used for fibers formation (Bekkamov *et al.,* Samatova M.M.,2023)

Different temperatures can affect various biological and commercial features like heat shock proteins expression on silkworms Rahmathulla V.K.(2012)

Early stages(chawki stage) exposure to high temperatures can inhibit subsequent phases growth towards post-cocoon parameters(Rahmathulla V.K.,2012)

Mostly, it has been observed that silkworm lines do best when larvae are kept at a constant temperature of 25 ±1 °C under a relative humidity level of between 70%-80%. Majority shows decreased performance if subjected to temperature or humidity fluctuation for three hours (Hussain *et al.,*2011).

Silkworm growth, cocoon production as well as amount and quality of eggs laid by female *Bombyx mori* can be affected by climate factors mostly temperature and humidity (Hussain *et al.,*2011)

Temperature influence in silkworm development may cause various changes ranging from survival rate, productivity to cocoon quality. When worms are not provided with optimal conditions of temperatures which may also have lower qualities up to 14%, cocoon yield per box can decrease by 15-30 kilograms (Bekkamov *et al.,* 2023; Samatova M.M.,2023).

Increased Frequency of Extreme Weather Events

Climate change heightens extreme weather occurrences such as droughts, heat waves and heavy rains which affect silkworm rearing and cocoon production significantly (Rahmathulla, 2012). Temperature controls silkworm physiology as well as cocoon production. The most desirable range of temperature for the growth of silkworm is between 22-27°C (Rahmathulla, 2012). Temperatures below 20°C or above 30°Careunfavourable for the health of the silkworm leading to diseases especially in early instars (Rahmathulla, 2012). Later larval instars experience increased growth due to high temperature but have shorter periods while low temperatures retard growth with elongation of larval period (Gowda and Reddy, 2007). Silkworms are highly affected by extremely hot weathers. Protein synthesis patterns get disrupted during heat stress responses whereas DNA, RNA and lipids among other biological molecules are damaged in them due to high levels of heat (Sureshkumar *et al.,*2002). Heat shock proteins express themselves through heat shock response system which is being used currently in breeding thermotolerant varieties of silkworms (Basavaraja *et al.,* 2005; Nagaraju, 2002).

Humidity also affects rearing performance where it should be maintained at a relative humidity of between 75% -85% (Singh and Saratchandra, 2012). High humidity together with high temperature creates favorable environment for different kinds of diseases attacking the silkworms. In one study there was positive relationship observed between humidity level variation and viral bacterial fungal infections occurrence on the worms (Sharma et al.,2020). Flooding caused by heavy rainfall can destroy mulberry plantations which serve as food for these worms while lack of enough moisture during drought periods adversely affects both quality and quantity of mulberry leaves; being nutritional requirement for growth and cocooning process of silkworms (Rahmathulla *et al.,* 2004). Silkworm rearing seasons are influenced by changes in weather patterns associated with climate change. In Assam India, summer season is projected to extend due to global warming hence reducing chances for rearing eri silkworms (Lalitha *et al.,* 2018). Silkworm egg production now only thrives under specific climatic conditions as a result of this climatic shift (Lalitha et al., 2018).

Extreme weather also affects post-cocoon parameters. Poor reelability can be caused during cocoon spinning under high temperatures, which may lead to reduced raw silk recovery as well as variation in the denier of raw silk fibers produced (Mathur et al., 2000). Cocoons should contain less than 20% water content if they are to be of good quality and reelability (Gowda and Reddy, 2007).

To mitigate these impacts, investigators propose the development of breed types resilient to climate change effects on sericulture practice, adjustment in rearing schedules, improvement in mulberry cultivation techniques and better controls over environmental conditions within rearing houses among others (Rahmathulla, 2012). Assessing vulnerability levels then formulating appropriate adaptation strategies for sericulture across different agro ecological zones will greatly contribute towards sustainable silk production given increasingfrequency/intensity/range of climate extremes worldwide(Kumar and Parikh,1998).

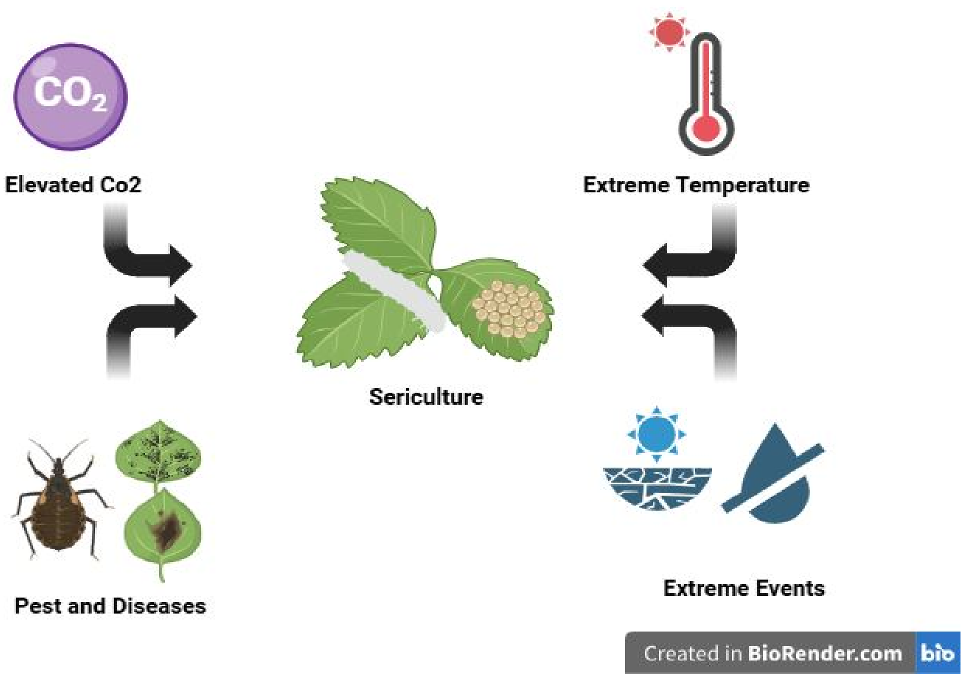

Fig. 1. Various Factors Affecting on Sericulture (Created in BioRender.com)

3. Impact of Climate Change on Silkworm Host Plants

Changes in Precipitation Patterns and Mulberry Cultivation

According to Shaista Mehraj et al., (2023) climate change does impact on the physiological processes of mulberry plants like dormancy, bud break and sprouting behavior. This means that shifts in these aspects may occur due to global warming. They found out that sprouting days for mulberries have been enhanced by about 10 days because of this phenomenon. Western Himalaya region which is important for growing mulberries is experiencing mixed changes in precipitation patterns; some areas are receiving more Indian summer monsoon (ISM) rainfall while others are experiencing less rain fall events, this was according to Saini *et al.,* (2023). Models also indicate higher variability in rainfall with increased number of extreme events and longer dry spells during ISM over the region.

Kambale *et al.,* (2023) were looking at crop water requirements trends for mulberry under different climate change scenarios. They found out that across all studied areas for various climate change scenarios there was an increasing trend in crop evapo-transpiration (ETc) of mulberry meaning that there is a relationship between water requirements and climate variability among these crops. Seidavi *et al.,* (2017) predicts global warming will decrease leaves yield but increase silk breakage while reducing raw silk production as well as silk content which implies direct effects at plant level besides other factors affecting it including insect pest shifts.

The worst effect is on pest's dynamics. Climate change affects insect pest scenario in mulberry growing areas as observed by Seidavi *et al.,* (2017). Pests like Bihar hairy caterpillar, pink mealybug, thrips, leaf webber among others are being reported frequently nowadays than before this time around every year when they should appear once only if at all while mites too have become common place during last few years. Also root knot disease powdery mildew leaf rust and leaf spot which were rare in previous times are now common place diseases affecting mulberry trees in most parts of the world. Higher CO2 concentrations may improve water use efficiency and PSII function in mulberry seedling leaves during drought stress but according to Liu *et al.,* (2019) this benefit does not come without costs because elevated levels can be offset by other effects of climate change such as high temperatures, increased tropospheric ozone concentrations and altered precipitation.

Changes in Host Plant Distribution and Abundance

The consequences of climate change on the dispersion and number of silkworm host plants are complex and multi-faceted in terms of their implications for sericulture. This includes both their physiology and geographical range which is affected by climate change therefore affecting such aspects as rearing silk production among others. According to Srivastava *et al.,*1997; Gowda and Reddy, 2007 elevated atmospheric CO2 levels together with increased temperatures can significantly alter growth patterns as well nutritional values for mulberry plants (*Morus spp.*) which serve as the main hosts for domesticated silk moth *Bombyx mori*. These environmental modifications may result into more biomass but less quality nutrition i.e., decreased nitrogen content higher carbon-nitrogen ratios starch levels total soluble sugars polyphenols etcetera (Rahmathulla *et al.,* 2004; Gururaj *et al.,* 1999).

One cannot overstate the direct effect that modified nutritional composition of mulberry leaves has on the life cycle stages of silkworms and silk production. Lower nutrient values could mean that silkworms need to consume more leaves thereby prolonging their developmental time and causing changes in cocoon quality (Mathur *et al.,* 2000; Pillai and Krishnaswami, 1987).

Worldwide locations suitable for growing mulberries will be altered by climate change. There might be areas where current temperature or precipitation conditions become unfavourable for mulberry cultivation while other parts of the world become more suitable than they currently are (Kumar & Parikh, 1998). Such shift in appropriate regions can greatly influence upon geography as well as economics of sericulture industry.

Climate change affects silk production at all stages of sericulture according to Sanghi *et al.,*(1998) and Sinha *et al.,* (2000) including host plant physiological responses post-cocoon technologies too. Climate change will increase frequency of occurrence of extreme weather events such as floods and droughts which have great impact on mulberry growing and silkworm rearing. Similarly, eri silkworm *Samia ricini* also faces challenges brought by climate change due to its ability to feed on different host plants. Areas where silkworms are reared traditionally experience problems with maintaining host plants because they are impacted upon by changes in temperatures as well as rainfall patterns (Qadri *et al.,* 2010; Singh and Benchamin, 2002).

Impact on Silkworm Food Quality and Quantity

The sericulture industry is worried about how climate change will affect the quality and quantity of food for silkworms, since both the mulberry plants and silkworms are affected (Rahmathulla *et al.,* 2012; Kumar *et al.,* 2018). Different weather patterns such as temperature changes impact not only mulberry leaf yield but also nutritional composition hence affecting directly on nutrition and development of the silkworms (Gowda *et al.,* 2007; Rahmathulla *et al.,* 2004; Gani and Gosh 2018). When metamorphosing, large variations in temperatures interfere with larval metabolic processes thereby decreasing silk gland activity leading to lesser production of silk in general(Myler, 2000). Beyond physiological response of host plants of silkworms, climate change also affects rearing methods used during the process as well as post-cocoon technology employed while producing raw silk (Kumar *et al.,* 1998; Sanghi *et al.,* 1998).

Climate variability is projected to cause significant crop losses, ranging from 10% to 40% of agricultural crops (Kumar et al., 1998; Sanghi *et al.,* 1998). Although there are few data on sericulture in particular, it can be assumed that the industry will face similar challenges which might result in decreased net revenue and productivity (Kumar *et al.,* 1998; Sanghi *et al.,* 1998; Chen *et al.,* 2016). To counterbalance climate change impacts on silkworm food quantity as well as quality researchers have been attempting developing new varieties or hybrids that can cope with changing environmental conditions better (Rahmathulla *et al.,* 2012; Wang *et al.,* 2019). This involves creating strains of silkmoths that can withstand higher temperatures and nutrient fluctuation (Rahmathulla *et al.,* 2012).

For increased silkworm (*Bombyx mori* L.) crop production and silk yield, managing climatic factors is important. In the rearing of silkworms for cocoon production, temperature, humidity, air movement, gases and light are key factors (Singh *et al.,* 2016). Sericulture can be protected from adverse effects of climate change by employing right environmental control strategies (Kumar *et al.,* 2015).

In conclusion, climate change impact on quantity and quality of food for silkworms is a multi-faceted problem that requires continuous research work coupled with suitable response measures. If the sericulture industry wants to sustain silk manufacturing in view of changing environments, then they must address problems related to mulberry leaves' growth; conditions under which worms are brought up as well as post-cocoon processing methods among others (Rahmathulla *et al.,* 2012).

Effects on Silkworm-Host Plant Interactions

The subject of climate change's effect on interactions between silkworms and the plants they feed on is an intricate and multifaceted one that can impact many areas of sericulture. Situated within this context, moriglobal warming, particularly in terms of increased carbon dioxide emissions and temperature, may play havoc with both mulberry trees as well as silkworms themselves thus altering their relationship thereby affecting silk production in this process. Mulberries which happen to be the primary host plant for *Bombyx mori* L., could experience higher photosynthetic rates coupled with increased biomass production under raised levels of CO2 due to elevated temperatures (Rahmathulla *et al.,* 2012). However environmental changes also transform foliar chemistry leading to reduced nitrogen contents alongside higher C:N ratios among other modifications such as enhanced amounts starches or total soluble sugars or even polyphenols found within leaves of mulberry trees (Bhattacharyya et al., 2019). These changes affect the quality of nutrition derived from leaves hence it can greatly influence growth rates consumption levels digestibility patterns observed among silkworm larvae unlike before according Bhattacharyya *et al.,* (2019)

Silkworms might have to consume more mulberry leaves due to the decrease in nutritional quality induced by elevated temperatures and CO2 (Bhattacharyya *et al.,* 2019; Ghosh *et al.,* 2019; Mandal *et al.,* 2019). This increased feeding behavior, which is similar to many other Lepidopteran species, can prolong silkworm's developmental stages (Bhattacharyya *et al.,* 2019; Ghosh *et al.,* 2019; Mandal *et al.,* 2019).

Another thing that climate change may do is shift when silkworms emerge and mulberry leaves are available, since both of these events are necessary for successful silk production (Gowda and Reddy, 2007; Rahmathulla *et al.,* 2004). Mulberry leaf grows and matures in response to temperature and precipitation patterns so there could be a mismatch between them and silkworm development stages. (Gowda and Reddy, 2007; Rahmathulla *et al.,* 2004).

Climate change affects raw silk production through the response of mulberry plants and silkworm rearing as well as post-cocoon technologies awareness of this fact was emphasized by Kumar and Parikh, 1998; Sanghi *et al.,*1998. Temperature, humidity, air circulation are among environmental conditions that largely influence silkworm physiology and cocoon quality. When there are extreme weather events such as droughts or floods it can negatively affect both mulberry cultivation and silkworm rearing hence reducing overall sericulture productivity (Kumar and Parikh, 1998; Sanghi *et al.,*1998). According to researchers' findings climate variability leads to substantial loss in agriculture which includes sericulture. It is estimated that a rise of average global temperature above two degrees Celsius will cause not only between ten to forty percent crop failure but also significant revenue decline in farming sector with limited specific figures for this industry (Kumar and Parikh, 1998; Sanghi *et al.,* 1998).

4. Adaptation and Mitigation Strategies for Sericulture

Breeding Climate-Resistant Silkworm Varieties

Breeding climate-resilient silkworms has become vital in sericulture; especially in tropical and subtropical regions with harsh conditions for rearing. The main aim of producing such types is to find breeds of silkworms that can endure high levels of heat coupled with humidity as they produce silk both in good quality and quantity (Ramesha *et al.,* 2009; Kumar *et al.,* 2002). Thermo-tolerance is one of the major objectives when breeding climate-resistant silkworms since many important qualitative characters like viability and cocoon traits drop dramatically beyond 28°C (Ueda and Lizuka, 1962; Pillai and Krishnaswami, 1987; Kato *et* al.,1989). In view of this problem, some scholars have been looking for those kinds which can survive higher temperatures among them being bivoltine (Shirota, 1992; Tazima and Ohnuma, 1995; Kumar *et al.,* 2001). Twenty-four bivoltine silkworm germplasm resources were subjected to evaluation for thermal stress tolerance at RH% ± over three generations (Kumar *et al.,* 2002; Koundinya *et al.,* 2003). The research indicated significant variation among these resources based on nine genetic parameters associated with survival rate at high temperature during pupation stage (Kumar *et al.,* 2002).

Thermotolerance is selected for in bivoltine silkworms when the pupation rate exceeds 70% (Kumar *et al.,*2002). Some germplasms have been discovered to be temperature tolerant at a percentage of greater than 70% during this selection process (Kumar *et al.,* 2002; Koundinya *et al.,* 2003). Varieties bred should also be suitable for rearing during spring and autumn. Key technologies, principles, and methods that enable the selection and breeding of silkworm races adaptable to different seasons were identified by researchers (He and Oshiki, 1984; He *et al.,* 1991). Such attempts aim at producing stronger breeds of silkworms capable of surviving under various environmental conditions throughout the year. Besides thermotolerance, researchers are attempting to develop disease resistant silkworm hybrids which can tolerate high temperatures too. This will create more resilient strains that can withstand both pathogenic challenges and environmental stresses (Suresh Kumar et al., 2005; Basavaraja *et al.,*2005).

New chances have been created to breed climate resistant silkworm varieties by molecular breeding techniques advanced of late. Molecular marker-assisted breeding has been used to develop silkworm hybrids with resistance to specific pathogens like Bidensovirus (BmDNV2), and thermotolerance as well (Rao *et al.,* 2006; Sudhakara Rao *et al.,*2002). In other words, it is necessary to breed climate-resistant silkworm strains through a combination of traditional methods and modern biotechnology approaches. The aim is therefore to select those races that can withstand severe environmental conditions while still performing well in terms of productivity and quality of silk over years under various climatic zones (Suresh Kumar *et al.,* 2004; Basavaraja *et al.,* 2005).

Improving Mulberry Cultivation Practices

One of the most significant effects of climate change on mulberry growing is that it starts early, which is a phenological shift (Zhang *et al.,* 2021). Such a change calls for adjustments in conventional means of farming so as to foster favorable development amid transforming environmental circumstances. The utilization of water-saving techniques for irrigation has become vital in improving mulberry cultivation under climatic variations. Drip irrigation and micro-sprinkler systems save water, maintain or enhance leaf yield and quality in mulberries

(Ghosh *et al.,* 2022; Wang *et al.,* 2023; Patel *et al.,* 2022). These methods do not only help in saving water but also support general sustainability during mulberry growing (Singh *et al.,* 2022; Rao *et al.,* 2023).

To combat climate change, it is important to adopt soil management practices for robustness of mulberry. Different investigations have proved organic amendments such as vermicompost and farmyard manure enhance soil health, increase water retention capacities as well as availability of nutrients for mulberries (Singh *et al.,* 2023; Rao *et al.,* 2022; Li *et al.,* 2022; Gupta *et al.,* 2021). These not only stimulate plant growth but also sequestrate carbon in the earth thereby reducing global warming impact (Zhang *et al.,* 2022; Kumar *et al.,* 2023). Carbon absorption by the trees is a significant breakthrough towards combating climate change since it shows that they can be used as valuable resources too. Carbon gets stored both above and below ground biomass within such tree species therefore creating opportunities to store large amounts of it during their growth stages (Chen *et al.,* 2023; Sharma *et al.,* 2022). Changing cultivation methods which enhance natural carbon sequestration would contribute greatly towards mitigating climate changes according to Kumar and others (Kumar *et al.,* 2022).

Genetic improvement through breeding programs is also an important strategy for adaptation under variable climatic conditions. The current focus is on developing drought tolerant varieties able survive high temperatures disease resistance among others heat resistant types too are being bred (Sharma *et al.,* 2022).

Climate change has altered dynamics of pests and pathogens thus making integrated pest management more relevant than ever before. In order to keep pest population below economic threshold levels while at the same time minimizing reliance on chemical pesticides there should be use biological controls like pheromone traps besides promoting beneficial insects this will help reduce them significantly (Zhang *etal.,*2018). These measures not only make farming systems tougher but also environmentally friendly in terms of resilience against diseases that attack them frequently because this happens due to changes brought about by global warming (Kumar *et al.,* 2021). The potential of mulberry-based agro-forestry systems in enhancing farm resilience to climate change has been realized. Apart from generating extra income for the farmers these systems also improve soil fertility, promote biodiversity conservation as well as carbon sequestration which is vital for mitigating against climate changes effects (Singh *et al.,* 2021). Combining it with other crops in agricultural landscapes can lead to sustainable farming practices that are more resilient to weather patterns associated with global warming (Rao *et al.,* 2021). Better coping mechanisms by farmers through adopting improved methods on one hand while increasing efforts towards reducing emissions through better land use management among others would go along way into dealing with the challenges posed by climate change among mulberry growers (Reddy *et al.,* 2020).

Integrated Pest Management Strategies

According to Rahmathulla *et al.,* (2012), Integrated Pest Management (IPM) techniques are becoming more important in sericulture due to climate change. In different farming systems like silkworm breeding, climate change has been observed to greatly impact insect pests' population dynamics and distribution (Bale *et al.,* 2002). Sericulture producing regions may experience higher incidences of pest outbreaks coupled with the introduction of new species as a result of global warming and changed precipitation patterns there (Srinivasa *et al.,* 2019). The cultural, biological and chemical controls involved in IPM strategies for sericulture also focus on coping with these challenges (Srinivasa *et al.,* 2019; Rahmathulla *et al.,* 2012).

For example, cultural practices entail keeping hygiene in rearing houses at optimum levels, using disease free eggs and adopting suitable methods of rearing (Srinivasa *et al.,* 2019; Bhat and Nataraju, 2006). By so doing they help minimize pests and diseases thereby improving overall health condition of silkworms which was also supported by the findings of Sakthivel *et al.,* (2012). Biological control methods are very instrumental in the integrated pest management strategies applied against sericulture because it involves utilization of natural enemies like predators, parasitoids as well as microbial agents against different types or categories of pests that attack these crops systems hence reducing reliance on chemicals (Srinivasa *et al.,* 2019; Bhat and Nataraju, 2005). Bacillus thuringiensis application has shown good results when used for controlling lepidopteran pests in mulberry cultivation used for rearing silkworms besides this being essential during such an attempt according to Srinivasan's work among others cited by them too such as Sakthivel's article published along with these two papers mentioned above were also part of their sources (Srinivasa *et al.,* 2019; Sakthivel *et al.,* 2012).

When necessary, chemical controls should be used sparingly and in conjunction with other IPM measures (Sharma *et al.,* 2015). Biodegradable eco-friendly pesticides need to be employed more often than not so as to shrink ecological footprint left behind by sericulture practices that involve use of chemicals but this should only happen if there is no other way of dealing with pests or diseases (Bhat and Nataraju, 2005). Monitoring combined early warning systems are crucial components for any integrated pest management strategy applied against sericulture due to climate change which may lead to emergence new pests as noted by Bale *et al.,* (2002) while developing models capable predicting outbreaks based on climate factors where Rahmathulla got involved in his study concerning mulberry cultivation among others such works were cited too including those done by Srinivasa who mentioned about different types or categories of breeding systems used in silk farming depending on what variety is being reared within a particular area.

Another thing that can be done under IPM strategies for sericulture against climate change is breeding silkworm varieties and mulberry cultivars resistant to pests and diseases which would reduce the need for using chemicals thus making them sustainable even under changing environmental conditions like global warming (Srinivasa *et al.,* 2019; Sakthivel's article along with these two papers mentioned above were also part of their sources).

Therefore, integrated control methods must focus on all aspects such as various control measures, sustainability as well adaptation to current environmental changes when planning how best address impacts brought about by global warming on silk production through IPM approaches within this sector as highlighted by Sharma & co-authors(2015) before ending my conclusion part here itself without forgetting some important points raised earlier but continuing them further until we reach an end where necessary too (Srinivasa *et al.,* 2019). Lastly, more research should be done in collaboration between policy makers and people who practice sericulture so that effective integrated pest management strategies can be developed to deal with climate change impacts on silk production (Srinivasa *et al.,* 2019).

5. Conclusion

Climate change poses large challenges to sericulture, an ever-changing field built on ancient customs and modern science. Fluctuating temperatures along with extreme weather events and less frequent rainfalls disrupt the growth cycle of silk worms and the cultivation of mulberry. To protect the industry, it is important to have adaptive measures in place such as producing varieties able to withstand different climates or improving how they are grown. The genetic makeup as well as physical reaction of these insects and their host plants need continual examination if we want sustainable silk production. Remote sensing among other innovative technologies should be used together with GIS during strategic planning so that this sector can still thrive even when faced by climatic changes that may occur in future times. Additionally, integrating traditional knowledge with new ideas will also help ensure resilience as well economic viability within sericulture under changing climatic conditions.

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