

SERICULTURE AS A SUSTAINABLE AGROECOSYSTEM: BIOLOGY OF BOMBYX MORI, ECONOMIC VALUE, ENVIRONMENTAL SERVICES OF MULBERRY, AND CLIMATE CHANGE IMPACTS

Saba Noor¹, Fakhra Anwar², Shahid Mahmood³, Laiba Liaqat⁴, Amina Afzal⁵, Ayesha Rani⁶, Eman Fatima⁷

^{1, *2, *3, 4,5,6,7}Department of Zoology, University of Gujrat, Gujrat 50700, Pakistan

²fakhra.anwar@uog.edu.pk, ³shahid.mahmood@uog.edu.pk

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Corresponding Author: *

Fakhra Anwar

Shahid Mahmood

Abstract

The silkworm, *Bombyx mori*, is an insect that is widely known for producing natural silk fibers used in the textile industry. It is considered an economically important insect because the silk obtained from it is used to make clothing, carpets, and decorative fabrics. Unlike many other insects, the silkworm is a completely domesticated species and cannot survive in the wild without human care and protection. Egg, larva, pupa, and adult moth are the stages which involves in the life cycle of silkworm. This type of development is called complete metamorphosis. In which stages, the larval stage is the most important because silk production occurs during this period. The art of breeding and managing silkworms for the production of silk is called sericulture. This practice began in ancient China thousands of years ago and later spread to many other parts of the world. Studying the biology of silkworms helps researchers understand their growth, sericulture or economic importance.

Introduction

The silkworm is actually the larval stage of a silk-producing moth scientifically known as *Bombyx mori*. It is one of the most valuable insects in the textile industry because it produces natural silk fiber that is used in fabric production (Triplehorn & Johnson, 2005). Silk is produced by special silk glands present in the body of the larva. These glands release a protein called fibroin. When this protein comes into contact with air, it hardens and forms a long continuous thread. The silkworm uses this thread to build a protective structure around its body called a cocoon (Chapman,

1998). Silk is highly valued because of its strength, smooth texture, and elasticity. These properties make it one of the most desirable natural fibers in the textile industry (Ganga & Chetty, 2013). Silkworms are completely domesticated insects and depend on humans for food, care, and protection. Their main food source is mulberry leaves, it gives the nutrients needed for their growth and silk production (Ganga & Chetty, 2013).

The mulberry silkworm is scientifically known as *Bombyx mori* and belongs to the kingdom Animalia. Organisms in this kingdom are

multicellular and obtain energy from organic food sources. Silkworms belong to the phylum Arthropoda. Silkworm is the animals which have segmented bodies, jointed appendages, and a hard outer covering made from chitin protein called an exoskeleton. They are placed in the class Insecta, which consists of head, thorax, and abdomen. Insects also have six legs and a pair of antennae (Triplehorn & Johnson, 2005).

The life cycle of silkworm has four stages: egg, larva, pupa, and adult moth. During these stages the organism changes its body structure and functions as it develops into an adult insect (Chapman, 1998). Every stage is very important in life cycle of silkworm but the most active and important stage is larval stage because the insect feeds continuously and produces silk. The pupal stage is mainly a transformation stage where the internal structure of the insect changes (Ganga & Chetty, 2013). It is the first stage. The female moth lays eggs after mating. A single female moth can lay approximately 300 to 500 eggs at one time (Sharma & Kumar, 2011). These eggs are small and oval in shape. At first they appear yellow in color but later turn gray or black as the embryo develops inside the egg. Under suitable conditions like proper temperature and humidity, the eggs usually hatch within 10 to 14 days. Environmental conditions greatly influence the successful development and hatching of eggs (Sharma & Kumar, 2011).

After hatching, the larva emerges from the egg and begins feeding immediately on mulberry leaves. This stage is commonly known as the silkworm stage and is the most important stage for silk production (Ganga & Chetty, 2013). Mulberry leaves provide support the rapid growth of the larva (Ganga & Chetty, 2013). During this stage the silkworm grows rapidly and sheds its outer skin several times through a process called molting. The stages between each molting period are known as instars (Chapman, 1998). The larval stage usually lasts 20 to 30 days, depending on environmental conditions and the availability of food. At the end of this stage, the silkworm stops feeding and prepares to spin a cocoon (Krishnaswami, 1978).

After reaching full growth, the silkworm begins spinning silk around its body to form a cocoon. This process normally takes about 2 to 3 days during the pupal stage, major internal changes occur as larval tissues break down and antennae begin to develop (Sharma & Kumar, 2011). This stage usually lasts about 10 to 14 days before the adult moth emerges. After completing development, the adult moth emerges from the cocoon. Although the moth has wings, it cannot fly efficiently because it has been domesticated for a long time. The main function of the adult moth is reproduction. Adult moths do not feed because they do not have functional mouthparts (Chapman, 1998). After mating, the female moth lays eggs to begin the next generation. The adult moth usually lives for about 5 to 10 days, completing the life cycle of the silkworm (Ganga & Chetty, 2013).

Sericulture is the practice of raising silkworms in order to obtain silk. The origin of this activity can be traced back to ancient China about 3000 BC. From China, the knowledge of silk production slowly spread to other Asian countries such as India, Japan, and Korea (Sharma & Kumar, 2011). Historical accounts mention that the Chinese kept the method of producing silk secret for a long time so that they could maintain control over the valuable silk trade (Sharma & Kumar, 2011).

The species *Bombyx mori* is a fully domesticated silkworm and cannot survive on its own in natural conditions. It depends on humans for food, care, and suitable environmental conditions needed for its growth and development (Ganga & Chetty, 2013). Today, sericulture is considered an important economic activity in many countries because it provides income and employment to a large number of people. The silk obtained from silkworm cocoons is widely used in the textile industry because of its natural shine, strength, and smooth texture (Sharma & Kumar, 2011).

Role of Silkworm

The silkworm, scientifically known as *Bombyx mori*, plays an important role in the food chain, especially in agro-ecosystems where mulberry cultivation is practiced. Although it is widely recognized for silk production, ecologically it

functions as a vital link between plants and higher-level consumers (Goldsmith et al., 2005)

Many different animals prey on silkworms in natural or semi-natural environments. Insects, prey insects like ants and beetles, and small reptiles like lizards can all eat the eggs and larvae of silkworms. Through these interactions between predators and prey, energy found in mulberry leaves is transmitted to secondary consumers. Silkworms support ecological balance by maintaining the flow of energy and nutrients between trophic levels (Sharma & Kumar, 2011). Silkworms also aid in the recycling of nutrients within ecosystems. When they feed, they produce waste, or frass, which decomposes in the ground. The soil becomes more fertile and capable of supporting microorganisms as a result of the organic matter this breakdown adds. Healthy soil promotes the growth of mulberry trees and other plants, strengthening the ecosystem cycle overall. (Goldsmith et al., 2005)

The silkworm, scientifically named *Bombyx mori*, is a herbivorous insect that mostly eats the leaves of mulberry species, such as *Morus alba*, the white mulberry. Because it eats green plants directly, it is classified as a primary consumer in the food chain. (Sharma & Kumar, 2011). Mulberry plants function as producers by converting solar energy into chemical energy through photosynthesis. As the silkworm larvae eat the leaves, the stored plant energy is converted into animal biomass. This process allows energy to go from producers to higher trophic levels. As a result, silkworms play a crucial role in maintaining the energy flow within the ecosystem by acting as a conduit between plants and the animals that eat those (Sharma & Kumar, 2011).

In their native environment, a variety of animals feed on silkworms. Insects such as sparrows may consume the larvae when they come into contact with plants. Predatory insects like ants attack silkworm eggs and young caterpillars, and parasitic wasps may lay their eggs inside the larvae. When silkworms are available, small reptiles like lizards will also eat them. Through these predator-prey relationships, silkworms supply energy to secondary and tertiary consumers. This predation controls population size and preserves ecological

balance in the food web (Sharma & Kumar, 2011). Silkworms contribute to biodiversity both directly and indirectly. They supply food for populations of birds, insects, and reptiles. Frass, their waste product, decomposes in the soil and adds organic matter, improving soil fertility and supporting microorganisms. In addition to serving as breeding grounds for silkworms, mulberry plantations serve as habitats for pollinators and small mammals. These interactions promote species diversity and environmental stability in agricultural environments (Sharma & Kumar, 2011).

Inferences with Mulberry Trees

The ecological relationship between silkworms and mulberry bushes is a clear example of herbivory. The larvae of silkworms depend almost entirely on mulberry leaves for growth and the production of silk. Carefully regulated culture ensures that the plants will continue to grow and regenerate even though heavy feeding may result in lower leaf biomass. This robust association demonstrates the close relationship between producers and primary consumers in the ecosystem. Mulberry plant availability and health have a direct impact on silkworm development and survival. (Goldsmith et al., 2005).

Sericulture, the practice of rearing the tame silkworm *Bombyx mori* for silk making, is a significant agro-based action that attaches farming with insect making systems. The success of giant silkworm rearing be contingent mostly on the agriculture of mulberry (*Morus* spp.), which aids as the chief food source for giant silkworm larvae (Ashrith et al., 2025). Mulberry tree leaves offer indispensable nutrients that inspiration larval growing, cocoon development, and satin crop. The mixing of mulberry tree agriculture with giant silkworm childhood forms a supportable farming organization in which plant making chains pest expansion and satin making (Bora et al., 2025). Fresh trainings have revealed that cultivating the nourishing eminence of mulberry tree leaves knowingly augments larval growing, covering bulk, and satin efficiency in *Bombyx mori* (Khursheed et al., 2025).

Sericulture theaters a noteworthy role in rustic farming thrifths, mainly in emergent nations where it is trained as a additional rural movement. The course of silk making contains some stages, counting mulberry tree agriculture, giant silkworm childhood, covering gathering, and silk whirling (Hemavathi et al., 2024).. Each period requires agronomic incomes and toil, so creating employ occasions in country societies. Since giant silkworm grubs feed wholly on mulberry tree leaves, the development of sericulture heartens the agriculture of mulberry tree homesteads and advances farming efficiency (Shafique et al., 2025). Study has specified that enhanced mulberry tree agronomy practices and the use of biological nutrients can augment leaf superiority, which finally surges covering yield, strand length, and overall silk making (Hemavathi et al., 2024; Khursheed et al., 2025).

Environmental Benefits

Mulberry tree cultivation linked with giant silkworm childhood offers some conservational rewards. Mulberry tree plants have stout and widespread root organizations that help soothe loam and avoid soil devastation. Nonstop mulberry tree homesteads provide lasting undergrowth cover, which advances soil assembly and preserves soil richness through the putrefaction of dropped shrubberies (Ranjitha Bai et al., 2024). Mulberry trees also pay to conservational guard by engrossing carbon dioxide from the ether and backup carbon appropriation. In calculation, mulberry tree floras have been testified to backing in biological renovation and may help in the redress of dirty soils by engrossing certain weighty alloys (Manzoor & Qayoom, 2024).

The growing and expansion of giant silkworm are powerfully prejudiced by conservational situations such as infection, moistness, and periodic temperature disparities. Ideal environmental situations are indispensable for strong larval expansion and first-class covering making. However, temperature modification and vacillations in disease or shower decorations may harmfully move both mulberry tree agriculture and giant silkworm makeup (Sangma et al., 2025).

Variations in conservational situations can reduce mulberry tree leaf superiority and create strain for giant silkworm larvae, finally touching cocoon produce and silk eminence. Therefore, preserving appropriate conservational running and up-and-coming climate-resilient giant silkworm breeds are imperative tactics for sustaining the sericulture business (Ashrith et al., 2025).

Effect of Climate Change

Mulberry plants belong to the family Morceau and are successfully grown under varied climates ranging from warm temperate to subtropical regions of Asia, Africa, Europe, and the United States, with the majority of species native to East and South Asia. Important species cultivated in India include *Morus alba*, *Morus indica*, *Morus bombycids*, *Morus sinensis*, and *Morus multicaulis*. Mulberry leaves are the basic food material for the silkworm, *Bombyx mori*, and nutritious leaves are the most important growth-regulating factor for this insect (Muthulakshmi et al., 2003). Being monophagous, the silkworm derives almost all essential nutrients for growth from mulberry leaves. Since the bulk of silk produced globally is directly derived from mulberry leaf protein, good quality leaves in abundant quantity are essential for successful cocoon production. The physiological growth and development of mulberry depend on climatic factors such as rainfall, temperature, relative humidity, and soil quality (Ravikumar et al., 2010).

The mulberry silkworm, *Bombyx mori*, is highly sensitive to temperature, humidity, and rainfall fluctuations. Being domesticated for centuries, its adaptability differs from wild silkworms. As a cold-blooded organism, temperature directly affects physiological activities. The optimum temperature for quality cocoon production ranges between 22–27°C, while temperatures below 20°C or above 30°C adversely affect physiology and disease susceptibility (Hibberd et al., 1996). High temperatures accelerate larval growth but shorten larval duration, whereas low temperatures prolong development. Later in stars are particularly sensitive to heat stress, influencing biochemical and physiological processes (Parry, 2018).

The golden silk producer *Antheraea Assamese*'s is semi-domesticated and reared outdoors, making it highly vulnerable to climatic fluctuations. Seasonal shifts have already been observed due to rising autumn temperatures (Sahana Ghosh et al., 2018). Similarly, *Samia ricin* is domesticated but sensitive to environmental stress, while *Antheraea mylitta* depends heavily on ambient temperature and humidity during larval and pupal stages (Sinha & Chaudhury, 1992).

In recent years, insect pests and diseases have become major limiting factors affecting mulberry leaf production due to intensive cultivation and indiscriminate fertilizer and pesticide use. Climate change and agro-ecosystem shifts have altered pest incidence, with early insect attacks linked to cloudy weather and high humidity (Samothrace et al., 2004). Major pests include the pink mealy bug *Maconellicoccus hirsutum*, leaf Webber *Diaphasia pulverulently*, and bud mites, while diseases include powdery mildew caused by *Phyllactinia corylea*, leaf rust caused by *Pteridosperm mori*, and leaf spot caused by *Cercosporin morcilla*. The pink mealy bug alone causes significant yield losses, reducing cocoon production substantially (Samothrace et al., 2004). Seasonal outbreaks of leaf Webber have been reported in Karnataka, Tamil Nadu, and Andhra Pradesh with considerable leaf yield loss. Environmental factors such as temperature, humidity, light, and nutrition strongly influence pest incidence and phenotypic expression (Ram et al., 2016). Elevated CO₂ and temperature also influence plant pathogens. Increased CO₂ can enhance fungal pathogen aggressiveness and infection rates, while dense canopy and humidity favor pathogen multiplication. Rising temperatures may increase susceptibility to rust diseases, and moderate temperatures enhance fungal growth. Climate change factors such as extreme precipitation, high CO₂, and humidity thus favor disease development (Pless et al., 2005). Silkworm larvae consume large quantity of mulberry foliage and transform plant biomass into silk protein and organic waste. Their remains enrich soil fertility by repaying nutrients to the agro-ecosystem, thereby helping soil microbial action and nutrient recycling processes (Kumaresan et al., 2011). Mulberry farming

associated with sericulture provides to vegetative cover in rural landscapes. These plantations help decrease soil erosion, increase carbon sequestration, and give micro habitats for small organisms. As a outcome, sericulture systems can encourage localized biodiversity preservation (FAO, 2019; Singh et al., 2014).

Environmental Challenges

Silkworm development is highly sensitive to temperature and humidity. Optimal environmental conditions promote healthy larval growth, proper molting, and efficient cocoon formation. However, extreme or fluctuating temperatures can disturb metabolic processes and reduce survival rates (Rahmathulla, 2012). Climate change has intensified these problems by increasing global temperatures and altering rainfall patterns. Increase in Temperature can speed up larval metabolism but may also lead to physiological stress, developmental abnormalities, and reduced silk yield. In addition, irregular weather conditions is harmful for silk worm (FAO, 2019; Singh et al., 2014). Humidity have a crucial role in rising of silkworm. Both excessively high and extremely low humidity levels can interfere with larval development. Maintaining balanced conditions is therefore essential for maintaining stable sericulture production systems (Kumaresan et al., 2011).

Good mulberry leaves is one of the most important factors influencing silkworm growth. Mulberry leaves contain essential nutrients and moisture that support larval metabolism. If the nutrition of the leaves declines due to environmental stress or poor agricultural practices, silkworm development can be negatively affected. Regions (Ram et al., 2016

Environmental pollution has become another important concern in modern sericulture. Industrial emissions, pesticide residues, and heavy metals can contaminate soil and mulberry plants. When silkworms consume contaminated leaves, toxic substances may accumulate in their bodies and disrupt physiological functions. (Parry, 2018). Exposure to pollutants may weaken the immune system of silkworms, making them more vulnerable to infectious diseases. In severe cases,

pollution can lead to increased larval mortality and poor cocoon quality, which ultimately affects the economic output of silk production systems. (Pless et al., 2005).

Silkworms are effected by several diseases caused by protozoa, viruses, bacteria, and fungi. These diseases spread rapidly under unfavorable environmental conditions economic losses in sericulture operations. Research has shown that diseases occur frequently in commercial sericulture farms. (Hemavathi et al., 2024; Khursheed et al., 2025). These diseases affect and can lead to abnormal larval growth, reduced cocoon formation, and increased mortality. Environmental factors such as temperature fluctuations, poor hygiene, and contaminated food often increase the likelihood of disease outbreaks. (Sharma & Kumar, 2011).

Pebrine is one of the most harmful disease. It is caused by the protozoan parasite *Nosema bombycis* and can infect both larvae and adult moths. This disease spreads through contaminated eggs and infected rearing environments. Symptoms of Pebrine include irregular larval growth, dark spots on the body, weakness, and failure to spin healthy cocoons. Because disease can persist across generations if proper control measures are not implemented. (Ganga and Chetty, 2013). Grasserie is a viral disease caused by *Bombyx mori* nucleopolyhedrovirus and primarily affects late larval stages. Infected larvae develop swollen bodies filled with fluid, and their skin becomes fragile and shiny. Eventually, the larvae rupture and release viral particles into the surrounding environment, which can infect other silkworms. Poor ventilation, overcrowding, and high humidity levels often accelerate the spread of this disease. (Scoble, 1995).

Flacherie is mainly associated with bacterial infections that affect the digestive system of silkworm larvae. One of the commonly involved bacteria is *Serratia marcescens*. Infected larvae lose appetite, become weak, and develop a soft or flaccid body. Environmental stress such as high temperature, poor nutrition, and contaminated food can increase the occurrence of this disease in silkworm rearing houses. (Manzoor & Qayoom, 2024). Muscardine is a fungal disease commonly

observed in humid environments. It is caused by the entomopathogenic fungus *Beauveria bassiana*. After death, infected larvae become hard and are covered with white fungal spores. These spores can easily spread through the air or contaminated equipment, infecting other silkworms in the rearing facility. (Triplehorn and Johnson, 2005).

Conservation and Management Strategies

Maintaining proper sanitation in silkworm rearing houses is essential for preventing disease outbreaks. Removal of infected or dead larvae is also necessary to prevent contamination. (Goldsmith et al., 2005; Yokoyama, 2003). One of the most effective preventive measures in sericulture is the use of certified illness-free eggs. Microscopic examination of moths and eggs helps detect infections such as Pebrine before the eggs are distributed to farmers. Maintaining optimal temperature, humidity, and ventilation conditions can significantly reduce environmental stress on silkworms. Controlled environmental systems help create stable conditions that support healthy larval growth and reduce the spread of pathogens. (Fukuda, 1960). Healthy mulberry plantations are essential for sustainable silkworm rearing. Proper irrigation, soil management, and the use of nutrient-rich mulberry varieties improve leaf quality and enhance silkworm growth and cocoon production. (Chapman, 1998)

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