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Silkworm diseases and management: A review

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Abstract
Sericulture, a vital agro based industry faces significant challenges from various silkworm diseases leading to substantial economic losses globally. This review summarises what is currently known about the main diseases that affect silkworms, such as bacterial, fungal, viral, and protozoan infections. It describes their symptoms, pathological mechanisms, etiological agents, and diagnostic approaches, which range from sophisticated molecular techniques to microscopic analysis and visual inspection. Comprehensive management strategies are also covered in the document with a focus on disease resistant breeds, strict disinfection, and nutritional management as preventive measures. The use of probiotics and herbal remedies, as well as therapeutic interventions such as antiviral, antibacterial, and antifungal treatments, are also covered. Finally, the review addresses the impact of climate change, particularly temperature and humidity fluctuations, on disease prevalence and severity, underscoring the need for robust and adaptable management strategies to ensure the industry's economic viability and ecological sustainability.

Keywords: Silkworm, diseases, Management

1. Introduction

India is the world's second largest producer and consumer of silk, making sericulture the process of rearing silkworms for the production of silk a major agro based industry. Despite its economic importance, the industry faces substantial challenges due to various silkworm diseases, which can lead to significant crop loss and financial detriment for farmers (Chopade *et al*., 2021) [7]. These diseases that are primarily caused by microorganisms like bacteria, fungi, viruses, and microsporidia frequently cause significant financial losses because there are no effective treatments and general preventative measures are insufficient (Sivaprasad *et al*., 2021) [43]. Therefore, creating efficient management plans and guaranteeing sustainable silk production require a thorough grasp of the aetiology, epidemiology, and pathogenesis of these diseases (Sisodia *et al*., 2019) [42]. At the national level, diseases related to silkworm rearing cause 15% to 20% of crop losses annually with some regions suffering even greater losses (Dey, 2016) [10]. As an illustration of the regional variability and severity of the disease impact on silk production, West Bengal reports losses ranging from 35.7% to 44.7% (Dey, 2020). About 70% of these losses each year are attributable to viral diseases, although bacterial and fungal infections also play a major role in the decreased cocoon yield (Sharma *et al*., 2020) [41]. High larval lethality and substantial financial losses are caused by nuclear polyhedrosis, a major viral disease in sericulture (Cappellozza *et al*., 2022) [5]. These pathogens' diverse and frequently severe effects underscore the urgent need for cutting-edge therapeutic and diagnostic approaches to safeguard silkworm populations (Dey, 2016) [10]. Moreover, flacherie, grasserie, muscardine, and pebrine diseases are frequently recognised as significant causes of silkworm mortality; in certain sericulture operations, flacherie alone is responsible for 70% of losses, and the total loss of cocoon crops is a noteworthy 30-40% (Sisodia *et al*., 2019) [42]. Approximately 33% of all silkworm diseases are caused by grasserie, which can cause sericulturists to suffer large financial losses (Chopade *et al*., 2021) [7]. *Bombyx mori* nucleo polyhedrovirus infection, a type of grasseries, is responsible for more than 50% of silk cocoon crop losses in India; in some areas, such as the Kashmir valley, losses range from 28 to 32% (Gani *et al*., 2018) [14].

1.1 Viral Diseases of silkworm

The rearing of silkworms is seriously threatened by viral diseases; the most common pathogens are the cytoplasmic polyhedrosis virus, infectious flacherie virus, densonucleosis virus, and *Bombyx mori* nucleopolyhedrovirus (Sivaprasad *et al*., 2021) [43]. The most significant of these is the *Bombyx mori* nucleopolyhedrovirus, which causes grasseries disease and is responsible for more than half of India's cocoon crop losses (Gani *et al*., 2018) [14]. *Bombyx mori* is extremely vulnerable to viral infections, likely as a result of centuries of domestication and mass rearing. The course of infection is greatly influenced by rearing, nutrition, and environmental factors (Sharma *et al*., 2020) [41]. Since these viral infections are so common, they can cause enzootic conditions, which can then develop into epizootic outbreaks due to overcrowding, poor feeding, or unfavourable weather conditions. This can lead to a high mortality rate for silkworms and substantial financial losses for sericulturists (Dey, 2020). These viral diseases have a widespread impact because traditional diagnostic techniques like microscopy and culturing frequently lack the sensitivity and speed necessary for early detection (Deepika *et al*., 2024) [9].

1.2 Grasserie

The symptoms of Grasserie, a viral disease caused by Borrelina bombycis, are primarily seen in the last stages of larval development. Affected silkworms have a lethargic manner and an oily skin (Kuge *et al*., 2021) [2]. Infected larvae develop enlarged and delicate integument that finally bursts to release a milky-white hemolymph that is packed with polyhedral inclusion bodies (Chopade *et al*., 2021) [7]. About 33% of all silkworm diseases are caused by this condition, which is common in all farms that raise silk and is primarily brought on by the Nuclear Polyhedrosis Virus (Chopade *et al*., 2021) [7].

1.3 Cytoplasmic Polyhedrosis

Cytoplasmic polyhedrosis, often caused by the *Bombyx mori* Cytoplasmic Polyhedrosis Virus, manifests as a distinct viral disease characterized by reduced larval growth, poor appetite, and the formation of characteristic cytoplasmic polyhedra within the midgut epithelial cells. This viral infection primarily targets the digestive system, leading to impaired nutrient absorption and subsequent weakening of the silkworm, often culminating in significant mortality rates in affected batches. The severity of cytoplasmic polyhedrosis is influenced by environmental stressors, nutritional deficiencies, and the silkworm strain's genetic susceptibility, complicating disease management strategies.

1.4 Nuclear Polyhedrosis

Bombyx mori nucleo poly hedro virus, the most important viral pathogen in sericulture, is the cause of Nuclear Polyhedrosis Disease, also called Grasserie. It is a highly destructive viral disease that causes significant economic losses, which can surpass 50% in tropical regions such as India (Sharma *et al*., 2020) [41] (Kumar *et al*., 2022) [27]. This virus, also known as *Borrelina bombycis*, is a member of the Baculoviridae family and is distinguished by its double stranded DNA genome and rod shaped virion (Sharma *et al*., 2020) [41]. According to Dong *et al*. (2019) [11], the *Bombyx mori* nucleopolyhedrovirus has a large, circular, supercoiled DNA genome that is roughly 128,413 nucleotides long and encodes 141 open reading frames. The occlusion body, the main infectious unit, is made up of a proteinaceous structure that encloses virions, which are essential for horizontal host transmission (Gani *et al*., 2018) [14]. Nuclear polyhedrosis virus infects various tissues and replicates within the nucleus, forming inclusion bodies called polyhedra, which occlude virus particles (Sharma *et al*., 2020) [41]. Infected larvae often exhibit a swollen, shiny appearance, and their hemolymph turns milky as the disease progresses, leading to death typically in the later instars (Dey, 2016) [10].

1.5 Flacherie

Flacherie, a significant viral disease in silkworms, is primarily caused by the *Bombyx mori* Infectious Flacherie Virus, a single-stranded RNA virus belonging to the family Picornaviridae, characterized by its globular morphology with a diameter of approximately 30 nm (Sharma *et al*., 2020) [41]. Furthermore, by infecting the midgut epithelium and proliferating inside the nuclei of columnar cells, the Densonucleosis virus a spherical particle with single stranded DNA that measures 22-24 nm in diameter contributes to the flacherie complex (Sharma *et al*., 2020) [41]. These infections cause cellular disruption and hypertrophic nuclei, which in turn impair nutrient absorption and digestion (Ito *et al*., 2018) [19]. When these viruses work together, the larvae show signs like sluggishness, vomiting, diarrhoea, and decreased appetite, which eventually results in flaccid bodies and death (Sharma *et al*., 2020) [41]. Temperature, humidity, and the amount and virulence of the infectious agents all affect how the disease develops. Exposure usually happens in the third and fourth instars, and the disease starts in the fifth instar, especially during the summer and fall rearing seasons (Sharma *et al*., 2020) [41]. Lethargy, loss of appetite, and a distinctive flaccidity are all symptoms of flacherie, a complex syndrome that is frequently made worse by co-infections with bacteria like Streptococci, Staphylococci, Bacillus species, and Serratia marcescens. Some larvae also develop translucent cephalothoracic regions and vomit gut juice (Chopade *et al*., 2021) [7].

2. Bacterial Diseases of silkworm

Bacterial infections are another major contributor to silkworm mortality, with species like *Streptococcus faecalis*, *Streptococcus liquefaciens*, and *Staphylococcus sciuri* commonly implicated in bacterial flacherie, leading to significant economic losses, particularly during the final stages of silkworm rearing (Saad *et al*., 2019) [39]. These bacterial pathogens, which are frequently spread by contaminated mulberry leaves, can result in a variety of symptoms, including septicaemia and digestive disorders, which can ultimately kill the larva (Some *et al*., 2019) [44]. Since these bacterial diseases have a significant negative influence on silkworm productivity and health, prompt and precise detection techniques are crucial for efficient management (Sivaprasad *et al*., 2021) [43]. For example, flacherie, a bacterial disease that causes silkworm larvae to lose their appetite, become lethargic, and grow more slowly, is known to be primarily caused by *Streptococcus* and *Staphylococcus* species (Sisodia *et al*., 2019) [42]. Furthermore, high temperatures and humidity aggravate some bacterial flacherie manifestations, particularly those brought on by "streptococci" and "bacillus" bacteria, which cause severe weakness and death in infected silkworms (Kuge *et al*., 2021) [2]. In fact, flacherie, a prevalent disease in silkworms, can be caused by bacterial or viral infections alone, or by a combination of both, leading to significant crop losses, with some reports indicating up to 33.88% in India (Sharma *et al*., 2020) [41].

2.1 Bacterial Septicemia
This bacterial infection, which is frequently brought on by opportunistic pathogens, causes a brownish discolouration and liquefaction of internal tissues. It causes widespread systemic inflammation and rapid mortality in silkworm populations. Poor hygiene and rearing conditions frequently make these septicaemic conditions worse, which makes it possible for bacteria like Serratia marcescens, *Staphylococcus species,* and *Streptococcus faecalis* to multiply and cause a considerable amount of morbidity and mortality (Gani *et al*., 2018) [14] (Chopade *et al*., 2021) [7]. Treatment becomes even more difficult when bacteria develop resistance to common antibiotics which calls for ongoing research into new antimicrobial techniques and enhanced biosecurity measures (Dey, 2016) [10]. Bacterial septicemia's systemic nature and quick onset further highlight how important it is to detect the disease early and maintain strict sanitation procedures to prevent its spread in sericulture operations.

3. Fungal Diseases of silkworm
Fungal diseases, notably muscardine caused by entomopathogenic fungi such as *Beauveria bassiana*, also pose a considerable threat to silkworm populations, manifesting as mummification of the larvae (Dey, 2016) [10]. These infections cause the diseased larva to lose appetite, become stiff, and eventually be covered in a pale yellow, powdery material before dying and resembling a yellow stick (Sisodia *et al*., 2019) [42]. In addition to reducing yield, the main silkworm diseases Grasserie, Muscardine, and Flacherie cause harvesters to suffer significant financial losses (Chopade *et al*., 2021) [7]. Additionally, by lowering the quality and availability of their main food source, other fungi, such as those that cause leaf rust and leaf spot infections in mulberry plants, have an indirect impact on silkworm health (Nahiduzzaman *et al*., 2023) [35]. Mulberry leaf diseases like brown spot, powdery mildew, and sooty leaf spot reduce the nutritional value of mulberry leaves and have an indirect effect on silkworm growth, making them more vulnerable to other diseases (Zhang *et al*., 2024) [48]. These fungal diseases on mulberry can induce up to 60% crop loss and reduce the nutritive value of leaves, thereby impeding cocoon yield and silk production (Dey, 2020).

3.1 Muscardine
Muscardine, a fungal disease, is caused by entomopathogenic fungi such as *Beauveria bassiana, Metarhizium anisopliae*, and *Paecilomyces farinosus*, which penetrate the silkworm cuticle, proliferate within the hemocoel, and ultimately mummify the host (Deepika *et al*., 2024) [9]. Depending on the causative agent, infected larvae become rigid and covered in a powdery fungal growth that can be white, green, or yellow. Because of the high mortality rates, sericulture suffers significant financial losses. These fungi's hyphae quickly consume internal tissues, causing mummification and the generation of mycotoxins that further impair host viability (Chopade *et al*., 2021) [7]. In 1834, Agostino Bassi proved that B. bassiana was the cause of the white muscardine disease of silkworm, which caused significant losses for the European silk industry (Kepler *et al*., 2017) [22]. Due to the ease with which fungal spores can germinate and infect silkworms, the disease is especially common in environments with low temperatures and high humidity (Kuge *et al*., 2021) [2].

3.2 Aspergillosis
Aspergillosis, caused by fungi of the genus Aspergillus, predominantly *Aspergillus flavus*, is another opportunistic fungal disease that can infect silkworms, often manifesting as a yellow or green muscardine (Kuge *et al*., 2021) [2]. This infection leads to the mummification of the larval body, exhibiting symptoms similar to other muscardine diseases, but distinguishable by the characteristic coloration of the fungal growth (Chopade *et al*., 2021) [7]. The environmental spores of *Aspergillus flavus* can contaminate mulberry leaves, which can then infect silkworms through cuticular penetration or oral ingestion, resulting in systemic infection and respiratory mycosis (Krawczyk and Łochynska, 2020) [24]. A. flavus releases aflatoxins during the course of the disease, further impairing the silkworm's immune system and digestive physiology and increasing its pathogenicity. Infected larvae's defence mechanisms are further compromised by the decreased immune-peptide expression and inhibited melanization caused by such mycotoxin production (Kaczmarek and Bogus, 2021) [21]. The quality of mulberry leaves may also be impacted by these fungi, which could have an indirect effect on silkworm productivity and health (Dey, 2016) [10].

4. Protozoan Diseases of silkworm
Pebrine, caused by the microsporidian *Nosema bombycis*, is a chronic and highly destructive protozoan disease in silkworms, leading to significant economic losses in sericulture worldwide (Suraporn and Terenius, 2021) [47]. This insidious disease, often transmitted transovarially, impacts all developmental stages of the silkworm, leading to reduced appetite, delayed molting, and the appearance of characteristic black spots on the larval integument (Chopade *et al*., 2021) [7]. While the incidence of Pebrine is less frequent, its devastating impact, especially under suboptimal rearing conditions, necessitates stringent preventative measures and early detection (Dey, 2016) [10]. The disease can take many different forms, ranging from extremely virulent infections that result in significant losses to persistent infections that enable infected silkworms to live into their pupal and adult stages, which causes *N. bombycis* to be vertically transmitted to the eggs (Suraporn and Terenius, 2021) [47] [47]. As a sign of low viability and decreased hatching success, infected eggs frequently show poor adhesion to the egg plate and may appear pale yellow (Kuge *et al*., 2021) [2]. (Chopade *et al*., 2021) [7]. Furthermore, sluggishness, uneven growth, and a propensity to vomit liquid are common symptoms of infected larvae, which can eventually result in death in later larval stages or even in pupae.

4.1 Nosema Disease
This devastating disease, commonly known as pebrine, is caused by the obligate intracellular protozoan parasite, *Nosema bombycis*, which belongs to the family Nosematidae (Chopade *et al*., 2021) [7]. This microsporidian pathogen primarily targets the midgut epithelial cells, ovaries, and malpighian tubules of the silkworm, leading to chronic infection and transovarial transmission (Kaczmarek and Bogus, 2021) [21]. The life cycle of *Nosema bombycis* involves an infectious spore stage that germinates upon contact with the larval gut, releasing a polar tube that injects sporoplasm into host cells, where it proliferates and spreads systemically throughout the silkworm (Carton, 2022) [6].

This systemic dissemination leads to severe cellular damage, ultimately impairing nutrient absorption and energy metabolism in the host (Li *et al*., 2018).

4.2 Pebrine

The microsporidian *Nosema bombycis* achieves host cell invasion by extruding a polar tube that penetrates the host membrane and injects sporoplasm into the cytoplasm, effectively bypassing the host's defense mechanisms (Li *et al*., 2018) [31]. Pebrine is distinct from other silkworm diseases in that it can spread both horizontally, through the consumption of contaminated mulberry leaves, and vertically, from infected parent moths to their offspring via eggs, making eradication particularly difficult. The symptoms of pebrine include poor growth, loss of appetite, irregular moulting, and the appearance of black spots or wrinkles on the larval integument, which are signs of severe tissue damage (Kuge *et al*., 2021) [2]. Infected silkworms have milky hemolymph and underdeveloped silk glands, and the disease often progresses slowly but unavoidably to larval death and decreased cocoon production (Dey, 2020). This protozoan infection has a significant impact on the silkworm life cycle, resulting in decreased fertility, decreased cocoon quality, and significant economic losses in sericulture.

Disease Symptoms and Diagnosis

Accurate and timely diagnosis of silkworm diseases is paramount for effective management and control strategies, encompassing both traditional observational methods and advanced molecular techniques (Gu *et al*., 2024). For instance, the presence of *Nosema bombycis* spores, characterized by their shiny, oval shape, can be confirmed microscopically in the hemolymph or gut tissues of infected larvae (Chopade *et al*., 2021) [7]. Furthermore, early detection of *Nosema bombycis* at the egg stage is crucial for preventing widespread disease transmission and is facilitated by methods such as Pasteur's adult female microscopy, despite its limitations regarding accuracy and environmental factors.

Visual Symptoms

When silkworms are visually inspected, early diagnostic indicators can be found such as black spots on the integument which are a sign of pebrine, or behavioural changes in the larva such as delayed moulting or decreased appetite (Chopade *et al*., 2021) [7]. Furthermore, five days after infection, infected larvae may stop feeding and move slowly (Suraporn and Terenius, 2021) [47]. When flacherie occurs, the larvae become flaccid, grow irregularly, and may release a yellowish, foul smelling gut fluid. They frequently present with softened faeces and rectal protrusion (Sharma *et al*., 2020) [41]. Nuclear polyhedrosis virus-affected larvae become lethargic and show a distinctive enlargement of the intersegmental areas, they frequently hang head down from rearing trays (Sharma *et al*., 2020) [41]. The skin of such larvae also turns shiny before molting and easily ruptures, oozing a turbid, milky white hemolymph (Chopade *et al*., 2021) [7].

Microscopic Examination

A basic method for identifying different pathogens is still direct microscopic analysis of tissue smears or hemolymph samples, which can reveal distinctive features like the hexagonal or pentagonal occlusion bodies suggestive of nucleopolyhedrovirus infections (Gani *et al*., 2018) [14]. This technique is also essential for observing the ovoid spores of *Nosema bombycis*, which are found in the midgut, silk glands, and ovaries and are pathognomonic for pebrine disease (Gu *et al*., 2024). The distinctive filamentous structures of fungi linked to muscardine diseases or bacterial colonies in cases of bacterial septicaemia can be seen by further microscopic examination. Beyond simple visualization, specialized staining techniques, such as Giemsa or lactophenol cotton blue, enhance the contrast and visibility of these microbial agents, facilitating more precise identification and differentiation of various pathogens within host tissues. For instance, microscopic detection of *Nosema bombycis* spores in fecal pellets or infected larvae is a primary method for diagnosing pebrine, although experienced technicians are required due to the method's time-consuming nature and subjectivity (Kuge *et al*., 2021 and Zhang *et al*., 2023) [49].

Molecular Diagnostic Techniques

Polymerase chain reaction and enzyme-linked immunosorbent assay are two molecular diagnostic methods that provide greater sensitivity and specificity for the early and precise identification of silkworm pathogens, including latent infections. These techniques offer a crucial advantage in disease management since they make it possible to identify particular pathogen DNA or RNA sequences and antibody responses, respectively, frequently before outward symptoms appear (Zhang *et al*., 2023) [49]. The limitations of conventional, laborious diagnostic techniques have also been addressed by recent developments that have introduced intelligent detection methods using machine learning algorithms like YOLOv8 for real time and batch detection of microparticle viruses in silkworms (Zhang *et al*., 2023) [49]. These cutting edge molecular tools and computational approaches significantly improve the capacity for rapid and precise disease identification, enabling more effective intervention strategies to mitigate economic losses in sericulture (Elgendy *et al*., 2024) [12].

Disease Management Strategies

To reduce pathogen spread and economic impact, effective disease management in silkworm rearing requires a multifaceted approach that integrates strict prophylactic measures, reliable detection methodologies, and responsive intervention strategies (Sivaprasad *et al*., 2021) [43]. Strict hygiene and disinfection procedures are essential to this type of management in order to eradicate or drastically lower pathogen loads in rearing environments (Gani *et al*., 2018) [14]. Using chemical disinfectants like formalin or bleaching powder, as well as environmental controls to maintain the ideal humidity and temperature, this entails thoroughly cleaning and sterilising rearing houses, equipment, and appliances. The potential of particular therapeutic interventions, such as chemotherapy and thermotherapy, to slow the progression of the disease in infected silkworms has been investigated in addition to environmental controls (Sisodia *et al*., 2019) [42].

Preventive Measures

The most effective defence against silkworm diseases is still prevention, which emphasises careful environmental management, nutritional optimisation, and genetic resistance (Dey, 2020). A "prevention first" approach is essential, with a focus on thorough disinfection to reduce the risk of disease transmission and increasing silkworm vigour to increase disease resistance (Gani *et al*., 2018) [14]. In order to lower the pathogen load and stop horizontal transmission, this involves choosing disease-free layings from mother moths that have been carefully screened for pathogens like Nosema bombycis using microscopic inspection and upholding strict hygiene throughout the rearing process (Chopade *et al*., 2021) [7].

Disinfection and Hygiene

Rigorous disinfection protocols are paramount for reducing the pathogen load in the environment and preventing disease transmission, especially given that environmental factors significantly influence disease dissemination (Pandey *et al*., 2024) [36]. In addition to the preventative advantages of a clean rearing environment, routine screening and health status monitoring of silkworms are essential for early disease detection (Elgendy *et al*., 2024) [12]. These precautions also include the thorough cleaning of rearing equipment, which frequently entails the application of substances like 0.5% formalin or 2% bleaching powder, which efficiently deactivate a wide range of pathogens, including bacterial, fungal, and viral agents. The proper application of these disinfectants, which guarantees the right contact time and concentration to achieve optimal pathogen inactivation, further increases their efficacy. Furthermore, specialized disinfection practices, such as treating eggs with 2% formalin, are vital for eliminating vertically transmitted pathogens like pebrine spores (Chopade *et al*., 2021) [7]. Implementing robust biosecurity practices and good farm management are also essential foundational steps to prevent disease outbreaks in the first place (Elgendy *et al*., 2024) [12].

Nutritional Management

A balanced diet directly affects the silkworms' physiological vigour and defensive abilities, making proper nutritional management essential to enhancing their immunity and resilience against infectious diseases. To improve larval growth and fortify their innate defences against infections, these entails supplying premium mulberry leaves that are enhanced with vital nutrients (Dey, 2020). The nutritional makeup of mulberry leaves can also be altered to provide immunomodulators or preventative agents, which will increase the silkworm's resistance to common illnesses. For example, maintaining ideal nutrient availability can boost the silkworm's constitutive and inducible immune responses, increasing their capacity to successfully fight off invasive pathogens (Dey, 2016) [10]. On the other hand, malnutrition or starvation weakens the immune system and generally makes silkworms more vulnerable to pathogen attack (Dey, 2020).

Use of Disease Resistant Breeds

Due to their innate genetic characteristics that provide increased tolerance or immunity to particular pathogens, disease resistant silkworm strains are an essential long term strategy for sustainable sericulture (Dey, 2016) [10]. By utilising natural genetic endowments, this method reduces the need for chemical interventions and provides a more ecologically friendly means of disease control. For example, in nations like China and India, silkworm varieties resistant to the *Bombyx mori* densovirus have been found and used, greatly lessening the impact of this viral disease (Dey, 2020). By adding genes that strengthen the silkworm's immune system or directly obstruct pathogen replication, genetic engineering efforts are being made to increase resistance against other common diseases, like pebrine (Suraporn and Terenius, 2021) [47]. This strategy is considered one of the most economical and effective ways to prevent diseases like grasserie, by exploiting the inherent resistance within silkworm populations (Gani *et al*., 2018) [14].

Therapeutic Measures

In order to mitigate established infections within silkworm populations, therapeutic measures include direct interventions. Once a disease outbreak is identified, antimicrobial agents or other preventive treatments are frequently administered. Synthetic chemicals and natural products, such as plant extracts with antibacterial, antiviral, or antifungal qualities against common silkworm pathogens, can be used in these interventions (Sisodia *et al*., 2019) [42]. The effectiveness of these treatments can vary, though, and their use frequently needs to be carefully considered to prevent drug resistance or adverse effects on silkworm health. By lowering the pH of the midgut and possibly modifying the silkworm's immune system or preventing pathogen adhesion, the use of lactic acid bacteria, such as *Lactobacillus casei*, has demonstrated promise in lowering pebrine mortality. (Suraporn and Terenius, 2021) [47]. Moreover, certain synthetic and natural diet preservatives, such as ethyl paraben and medium-chain fatty acids, have demonstrated significant antibacterial activity against prevalent silkworm pathogens, suggesting their potential in therapeutic applications (Lei *et al*., 2024) [29].

Antiviral Treatments

Highly sensitive and specific detection of viral pathogens like BmNPV is made possible by the ongoing development of sophisticated diagnostic techniques, such as lateral flow assays and antibody based biosensors. This is essential for prompt intervention to stop widespread outbreaks (Gani *et al*., 2018) [14]. Targeted antiviral strategies are necessary because genomic mutations and rearrangements can result in differential pathogenicity, according to genomic approaches that take into account different BmNPV strains (Cappellozza *et al*., 2022) [5]. Although it is still difficult to completely eradicate the viral genome using such techniques, recent developments in genetic engineering, such as CRISPR/Cas9 systems, offer encouraging paths for creating silkworm lines with increased antiviral resistance by focussing on important viral genes (Dong *et al*., 2019) [11]. Beyond genetic modification, the use of naturally derived antiviral compounds and peptides is also being explored, aiming to inhibit viral replication or assembly within infected silkworms.

Antibacterial Treatments

Antibiotics and other bactericidal agents are frequently used to treat bacterial infections, but it's important to use them sparingly to avoid antibiotic resistance. For instance, rifampicin and streptomycin taken orally have been shown to be effective in treating gattine disease, a common bacterial illness that affects silkworms (Dey, 2020). Alternative strategies, like probiotic interventions, are necessary because the careless use of synthetic antibiotics can negatively impact silkworms' beneficial gut microbiome

(Subramanian *et al*., 2009) [46]. For example, it has been demonstrated that supplementing with Lactobacillus casei significantly lowers mortality in *Bombyx mori* larvae challenged by *Nosema bombycis*. This effect may be due to improved nutrient absorption and pathogen competitive exclusion (Suraporn and Terenius, 2021) [47]. The judicious application of antimicrobial agents must also consider their pharmacokinetic properties within the silkworm system, which have been shown to be fundamentally similar to those in mammals (Hamamoto *et al*., 2019) [17].

Antifungal Treatments

Sericulture is seriously threatened by fungal infections, especially muscardine diseases brought on by entomopathogenic fungi like *Beauveria bassiana*, which calls for particular antifungal treatments. Chemical fungicides may provide short term respite, but their use can harm non target organisms and cause environmental issues, highlighting the need for more sustainable management techniques (Dey, 2016) [10]. Therefore, as environmentally friendly substitutes, biological control agents such as particular fungal antagonists or bacterial endophytes that generate antifungal compounds are being researched. A strong long term solution is also offered by the creation of resistant silkworm strains via genetic modification or selective breeding initiatives that strengthen their innate antifungal defences (Matsumoto *et al*., 2020). Furthermore, plant derived extracts and essential oils are increasingly recognized for their antifungal properties, offering a promising avenue for ecofriendly management of fungal diseases in silkworms (Mohsin *et al*., 2024). Probiotic applications, specifically using *Streptomyces noursei* or *Enterococcus hirae* SX2, have also demonstrated significant antifungal activity, inhibiting the germination of entomopathogen conidia and improving silkworm growth and survival (Subramanian *et al*., 2009 and Cappellozza *et al*., 2022) [5].

Use of Probiotics

By altering the composition of the gut microbiota and boosting immune responses, probiotic supplementation especially with genera like Lactobacillus has become a promising way to support silkworm health and disease resistance (Suraporn and Terenius, 2021) [47]. Beneficial microorganisms that can generate antimicrobial compounds, competitively exclude pathogens, and enhance nutrient assimilation are administered in this manner (Subramanian *et al*., 2009) [46]. For example, by possibly enhancing the host's defences, *Lactobacillus casei* has been shown to lower mortality rates in silkworms challenged with *Nosema bombycis*, a pebrine causing agent (Suraporn & Terenius, 2021) [47]. Likewise, certain *Streptomyces noursei* cultures that were initially isolated from native silkworm breeds have demonstrated effectiveness in colonising the silkworm gut and enhancing a number of biological parameters, including pupation percentage, cocoon weight, shell weight, and larval body weight (Subramanian *et al*., 2009) [46].

Herbal Remedies

Due to their broad spectrum antimicrobial qualities and low environmental impact, traditional herbal remedies have drawn a lot of attention as environmentally friendly and sustainable means of managing diseases in sericulture (Saad *et al*., 2019) [39]. For instance a variety of plant extracts have antiviral, antibacterial, and antifungal properties that can greatly lower the prevalence of disease and enhance the production of silk (Saad *et al*., 2019) [39]. When silkworms are infected with Bacillus thuringiensis, it has been demonstrated that the use of botanicals, such as extracts from black seed and basil leaves, greatly increases larval weight and reduces mortality (Saad *et al*., 2019) [39]. Furthermore, by promptly applying herbal formulations to food plants, such as Jeevan Sudha, a botanical spray, bacterial infections in tasar silkworms have been effectively reduced (Pandey *et al*., 2024) [36]. These herbal interventions also contribute to enhanced biological parameters and technological traits, such as increased cocoon weight and improved silk filament length, indicating their potential to both mitigate disease and enhance productivity (Saad *et al*., 2019) [39]. Another notable example involves the use of amla extract during silkworm rearing, which has been observed to improve larval survival and silk productivity by preventing infections (Sisodia *et al*., 2019) [42]. Furthermore, certain medicinal plants are not only effective as chemotherapeutics but also serve as valuable feed additives, stimulating appetite, enhancing growth, and bolstering the immune response in various aquaculture species (Hegde *et al*., 2023) [18].

Impact of Climate Change on Silkworm Diseases

Climate change significantly influences the prevalence and severity of silkworm diseases by altering environmental parameters such as temperature, humidity, and rainfall, which directly impact pathogen viability and host susceptibility (Dey, 2020). These climatic shifts can create more favourable conditions for the proliferation of certain pathogens and stressors on silkworms, thereby increasing their vulnerability to infections (Lalitha *et al*., 2023) [28].

Effect of Temperature

Stress on silkworm larvae gets worse by elevated temperatures, especially sudden shifts from day to night, which have been repeatedly associated with a higher incidence of diseases like Grasserie and Flacherie (Dey, 2020). For example, it has been demonstrated that changes in air temperature have a direct effect on silkworm productivity and biological parameters, increasing their vulnerability to disease outbreaks (Boboyev *et al*., 2023) [3]. Furthermore, high temperatures can increase some pathogens' virulence and capacity to replicate, which exacerbates the severity of the disease (King *et al*., 2018) [23]. Relative humidity below 75% and temperatures outside of the ideal range of 24-28°C for silkworm growth, on the other hand, can cause stress and increase the susceptibility of silkworms to pathogenic infections. The silkworm's immune response may be suppressed by this environmental stress, making it less able to defend against opportunistic infections (Sharma *et al*., 2020) [41]. Additionally, excessive heat can degrade the nutritional value of mulberry leaves, which weakens silkworms and reduces their innate resistance to illness (Pandey *et al*., 2024) [36]. Additionally, these circumstances may change the microbial communities in the silkworm's gut, which may promote dysbiosis and make it more vulnerable to opportunistic infections (Bharali *et al*., 2025) [2].

Effect of Humidity

High humidity levels, especially when combined with elevated temperatures, create an ideal environment for the proliferation of fungal and bacterial pathogens, leading to an increased incidence of diseases such as muscardine and flacherie. This rise in humidity can also contribute to the spread of foodborne diseases, as it affects the survival and dissemination of pathogens (Awad *et al.*, 2024) [1]. Moreover, both temperature and humidity are critical environmental factors influencing the occurrence and severity of epizootics in silkworm populations (Sevim *et al.*, 2023) [40]. Low humidity, conversely, has been associated with the increased prevalence of Grasserie, a viral disease, demonstrating the nuanced and multifaceted impact of varying moisture levels on silkworm health (Dey and Kuge *et al.*, 2021) [25]. The interplay between these factors can create synergistic effects, where the combination of suboptimal temperature and humidity significantly amplifies disease risk beyond what either factor alone would cause, as observed in both laboratory and field settings. Moreover, humidity directly influences the physiological functions of silkworms, impacting their survival rates and overall developmental success.

Conclusion

Sericulture faces major obstacles due to silkworm diseases, which emphasises the urgent need for sustainable and integrated management approaches. To promote healthy and resilient silkworm populations, these tactics must take into account predisposing factors and make use of developments in probiotics, herbal remedies, and genetic advancements. The economic sustainability and ecological viability of sericulture will ultimately depend on a multifaceted strategy that combines traditional knowledge with contemporary scientific advancements for effective disease management (Raichvarg, 2022) [38] (Sivaprasad *et al.*, 2021) [43]. Every element of the disease triangle should be addressed by such an integrated approach, which incorporates both preventative and curative tactics: the environment by improving rearing conditions, the pathogen by lowering its load, and the host by modifying host defences. Furthermore, studying the microbiota of silkworms may reveal new microbial-based treatments and provide fresh perspectives on the connection between diet, host health, and disease resistance (Raichvarg, 2022) [38]. Their importance in host metabolism and disease susceptibility is highlighted by the ability of beneficial microorganisms in the silkworm gut to break down different polysaccharides, generate vital enzymes, and even affect pesticide resistance (ElKraly *et al.*, 2023) [13]. By better understanding these microbial interactions, new approaches to improving silkworm health and resistance to pathogens may be developed, which could help reduce crop losses from diseases, which in some areas can reach 44.7%. Furthermore, sericulture has been transformed by the use of molecular techniques for pathogen identification, which offer a major advantage over conventional methods by enabling the quick and precise detection of disease-causing agents. (Deepika *et al.*, 2024) [9]. This advancement enables timely interventions and targeted management strategies, minimizing the spread and impact of various silkworm diseases.

References

1. Awad DAB, Masoud HA, Hamad A. Climate changes and food-borne pathogens: the impact on human health and mitigation strategy. Climatic Change. 2024;177(6).
2. Bharali B, Basumatary P, Bora U. Microbiome dynamics in *Samia cynthia ricini*: impact of growth stage and dietary variations. Appl Microbiol. 2025;5(2):40-51.
3. Boboyev Y, Bekkamov C, Nurmanova S, Aminbayeva N. Impact of change in air temperature on the biological parameters of larvae and productivity of silkworm cocoons. BIO Web Conf. 2023;65:1020-30.
4. Campos-Herrera R, Carpentero E, Puelles M, Ojer JLR, Blanco-Pérez R. Entomopathogenic nematode compatibility with vineyard fungicides. J Nematol. 2023;55(1):1-10.
5. Cappellozza S, Casartelli M, Sandrelli F, Saviane A, Tettamanti G. Silkworm and silk: traditional and innovative applications. Insects. 2022;13(11):1016-28.
6. Carton Y. Louis Pasteur face à la maladie du ver à soie (1865-1870): du chimiste au biologiste. C R Chim. 2022;25:315-22.
7. Chopade PS, Raghavendra CG, S MK, RN B. Assessment of diseases in *Bombyx mori* silkworm - a survey. Glob Transit Proc. 2021;2(1):133-9.
8. Das D, Paul P, Mandal P. Prolonging mulberry leaf longevity with silver-doped copper oxide nanoparticles: a postharvest approach. Discov Plants. 2025;2(1):1-10.
9. Deepika I, Ramesh KV, Kumar I, Singh A, Debnath R, Dubey H, *et al*. Molecular diagnostics in sericulture: a paradigm shift towards disease diagnosis in silkworms. Entomol Exp Appl. 2024;172(5):372-85.
10. Dey S. Biology and feeding efficacy of *Brumoides suturalis* (Fabricius) (Coccinellidae: Coleoptera), a native predator of whitefly, *Aleuroclava pentatuberculata* (Sundarraj and David), a mulberry pest: in search of an effective biocontrol agent for sericulture in West Bengal. 2016. [Unpublished or missing publication source].
11. Dong Z, Qi Q, Hu Z, Chen P, Huang L, Zhang X, *et al*. Construction of a one-vector multiplex CRISPR/Cas9 editing system to inhibit nucleopolyhedrovirus replication in silkworms. Virol Sin. 2019;34(4):444-54.
12. Elgendy MY, Ali SE, Dayem AA, Khalil RH, Moustafa MM, Abdelsalam M. Alternative therapies recently applied in controlling farmed fish diseases: mechanisms, challenges, and prospects. Aquac Int. 2024;32(7):9017-34.
13. ElKraly OA, Awad M, El-Saadany HM, Hassanein SE, Elrahman TA, Elnagdy SM. Impact of gut microbiota composition on black cutworm, *Agrotis ipsilon* (Hufnagel) metabolic indices and pesticide degradation. Anim Microbiome. 2023;5(1):1-12.
14. Gani M, Chouhan S, Babulal, Gupta RK, Khan G, Narukullapati BK, *et al*. *Bombyx mori* nucleopolyhedrovirus (BmBPV): its impact on silkworm rearing and management strategies. J Biol Control. 2018;31(4):189-96.
15. Gray MJ, Ossiboff RJ, Berger L, Bletz MC, Carter ED, DeMarchi JA, *et al*. One Health approach to globalizing, accelerating, and focusing amphibian and reptile disease research—reflections and opinions from the first global amphibian and reptile disease conference. Emerg Infect Dis. 2023;29(10):1-8.
16. Gu H, Cao Z, Yang Y, Chen K, Lü P. Detection and control of pébrine disease in the silkworm (*Bombyx mori*). 2024. [Unpublished or missing journal name].
17. Hamamoto H, Horie R, Sekimizu K. Pharmacokinetics of anti-infectious reagents in silkworms. Sci Rep. 2019;9(1):1-7.

18. Hegde A, Kabra S, Basawa R, Khile DA, Abbu RUF, Thomas NA, *et al*. Bacterial diseases in marine fish species: current trends and future prospects in disease management. World J Microbiol Biotechnol. 2023;39(11):1-16.
19. Ito K, Kidokoro K, Katsuma S, Sezutsu H, Uchino K, Kobayashi I, *et al*. A single amino acid substitution in the Bombyx-specific mucin-like membrane protein causes resistance to *Bombyx mori* densovirus. Sci Rep. 2018;8(1):1-10.
20. J KJ, K KP, J CE, M NB. Performance of *Bombyx mori* and *Samia cynthia ricini* silkworms under controlled environmental conditions in Uasin Gishu County. J Entomol Zool Stud. 2022;10(6):1-6.
21. Kaczmarek A, Boguś MI. Fungi of entomopathogenic potential in Chytridiomycota and Blastocladiomycota, and in fungal allies of the Oomycota and Microsporidia. IMA Fungus. 2021;12(1):1-20.
22. Kepler RM, Luangsa-ard JJ, Hywel-Jones NL, Quandt CA, Sung G, Rehner SA, *et al*. A phylogenetically-based nomenclature for Cordycipitaceae (Hypocreales). IMA Fungus. 2017;8(2):335-53.
23. King WL, Jenkins C, Seymour JR, Labbate M. Oyster disease in a changing environment: decrypting the link between pathogen, microbiome and environment. Mar Environ Res. 2018;143:124-32.
24. Krawczyk K, Łochyńska M. Identification and characterization of *Pseudomonas syringae* pv. *mori* affecting white mulberry (*Morus alba*) in Poland. Eur J Plant Pathol. 2020;158(1):281-90.
25. Kuge S, Dhumal R, Patil V, Patil S. Important silkworm diseases and their management. 2021.
26. Kumar D, Mukhopadhyay R. Climate change and plant pathogens: understanding dynamics, risks and mitigation strategies. Plant Pathol. 2024.
27. Kumar S, Singh HN, Verma AP, Kumar V, Patel A. Age-specific life table of mulberry silkworm, *Bombyx mori* Linn. race NB4D2 × SH6 at two different temperature ranges under laboratory conditions. Int J Trop Insect Sci. 2022;42(6):3785-92.
28. Lalitha N, Hemachandran H, Nath A, Guha L, Neog K. Foliage to fiber: decoding the nutritional efficiency and assimilation of different hosts on growth, reproduction and silk production of *Samia ricini* (Donovan) (Lepidoptera: Saturniidae). Res Sq. 2023. [Preprint].
29. Lei X, Qian Z, Zhu X, Zhang N, He J, Xiao J, *et al*. Fitness effects of synthetic and natural diet preservatives on the edible insect *Bombyx mori*. NPJ Sci Food. 2024;8(1):1-10.
30. Li H, He Y, Jia L, Liu Y, Yang D, Shao S, *et al*. Effect of cocooning conditions on the structure, carbon and nitrogen isotope ratios of silks. PLoS ONE. 2023;18(9):1-13.
31. Li Z, Wang Y, Wang L, Zhou Z. Molecular and biochemical responses in the midgut of the silkworm, *Bombyx mori*, infected with *Nosema bombycis*. Parasit Vectors. 2018;11(1):1-11.
32. Matsumoto Y, Yamazaki H, Yamasaki Y, Tateyama Y, Yamada T, Sugita T. A novel silkworm infection model with fluorescence imaging using transgenic *Trichosporon asahii* expressing eGFP. Sci Rep. 2020;10(1):1-10.
33. Moharrami M, Bagheri M, Nematollahian S. Detection and characterization of *Nosema bombycis* using TEM and SEM techniques. PubMed. 2022;77(4):1473-9.
34. Mohsin M, Aleem MT, Goraya MU, Aguilar-Marcelino L, Abbas RZ, Abbas A. Editorial: Natural products and pseudo-natural products against veterinary disease-causing microorganisms. Front Vet Sci. 2024;11:1-3.
35. Nahiduzzaman M, Chowdhury MEH, Salam A, Nahid E, Ahmed F, Al-Emadi N, *et al*. Explainable deep learning model for automatic mulberry leaf disease classification. Front Plant Sci. 2023;14:1-12.
36. Pandey JP, Rani A, Gadad HS, Singh J, Jena KK, Chowdary NB. Status and strategy for management of various diseases of tropical tasar silkworm *Antheraea mylitta*. Plant Arch. 2024;24:1-10.
37. Parbin H, Chutia BC, Koushik S, Ahmed A, Hazarika G, Borah P. Detection of probiotic bacteria *Ligilactobacillus salivarius* in the midgut of eri silkworm (*Samia ricini*, Donovan) collected from Borduar, Assam. Indian J Agric Res. 2024.
38. Raichvarg D. Silkworm, science worm. C R Biol. 2022;345(3):35-41.
39. Saad M, Elyamani E, Helaly W. Controlling of bacterial and fungal diseases that contaminate mulberry silkworm, *Bombyx mori*, by using some plant extracts. Bull Natl Res Cent. 2019;43(1):1-7.
40. Sevim A, Akpınar R, Öztürk SH, Yılmaz F, Kayaboynu Ü, Sevim E, *et al*. PCR-based screening of pathogens in *Bombus terrestris* populations of Turkey. Acta Parasitol. 2023;69(1):275-84.
41. Sharma A, Sharma P, Thakur J, S M, Bali K. Viral diseases of mulberry silkworm, *Bombyx mori* L. - a review. 2020.
42. Sisodia NS, Gaherwal S, Jain R. Determination of different diseases and preventive measures of mulberry silkworm. Int J Sci Res Biol Sci. 2019;6(4):101-4.
43. Sivaprasad V, Rahul K, Makwana P. Immunodiagnosis of silkworm diseases. In: Methods in Microbiology. London: Academic Press; 2021. p. 27-42.
44. Some S, Bulut O, Biswas K, Kumar A, Roy A, Sen IK, *et al*. Effect of feed supplementation with biosynthesized silver nanoparticles using leaf extract of *Morus indica* L. V1 on *Bombyx mori* L. (Lepidoptera: Bombycidae). Sci Rep. 2019;9(1):1-14.
45. Some S, Sarkar B, Biswas K, Jana TK, Bhattacharjya D, Dam P, *et al*. Bio-molecule functionalized rapid one-pot green synthesis of silver nanoparticles and their efficacy toward the multidrug-resistant (MDR) gut bacteria of silkworms (*Bombyx mori*). RSC Adv. 2020;10(38):22742-54.
46. Subramanian S, Mohanraj P, Muthuswamy M. New paradigm in silkworm disease management using probiotic application of *Streptomyces noursei*. J Farm Sci. 2009;22(3):499-502.
47. Suraporn S, Terenius O. Supplementation of *Lactobacillus casei* reduces the mortality of *Bombyx mori* larvae challenged by *Nosema bombycis*. BMC Res Notes. 2021;14(1):1-5.
48. Zhang M, Yuan C, Liu Q, Liu H, Qiu X, Zhao M. Detection of mulberry leaf diseases in natural environments based on improved YOLOv8. 2024.
49. Zhang Y, Su J, Wang T, Xu C, Yu A. Intelligent detection method of microparticle virus in silkworm based on YOLOv8 improved algorithm. Res Sq. 2023.