PLANT SCIENCE TODAY
Vol x(x): xx–xx
https://doi.org/10.14719/pst.7300

eISSN 2348-1900

REVIEW ARTICLE

Exploring the influence of plant extracts on silkworm growth and health: A review

Dipankar Brahma[1], K A Murugesh[1*], R Shanmugam[2], K Senguttuvan[3], S Marimuthu[4] & P Radha[5]

[1]Department of Sericulture, Forestry College and Research Institute, Tamil Nadu Agricultural University, Mettupalayam 641 301, Tamil Nadu, India
[2]Indian Council of Agricultural Research-Krishi Vigyan Kendra, Ooty, Mettupalayam 641 301, Tamil Nadu, India
[3]Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore 641 003, Tamil Nadu, India
[4]Centre for Agricultural Nanotechnology, Tamil Nadu Agricultural University, Coimbatore 641 003, Tamil Nadu, India
[5]Department of Forest Biology and Tree Improvement, Forestry College and Research Institute, Tamil Nadu Agricultural University, Mettupalayam 641 301, Tamil Nadu, India

*Correspondence email - murugeshka2002@yahoo.co.in

Received: 20 January 2025; Accepted: 18 April 2025; Available online: Version 1.0: 05 August 2025

Cite this article: Dipankar B, Murugesh KA, Shanmugam R, Senguttuvan K, Marimuthu S, Radha P. Exploring the influence of plant extracts on silkworm growth and health: A review . Plant Science Today (Early Access). https:/doi.org/10.14719/pst.7300

Abstract

The quality and productivity of cocoon production remain a major concern for the Indian sericulture industry. Enhancing the nutritional quality of mulberry leaves can lead to improved efficiency in cocoon and seed production. Among the various approaches being considered, enhancing the nutritional quality of mulberry leaves by fortifying and improving the economic traits and silk productivity seems to be a promising strategy. In this situation, using plant extracts during silkworm rearing emerged as a viable option to achieve this goal. The bioactive compounds present in plant extract have been shown to have positive effects on silkworms by enhancing food intake, increasing biomass and thereby improving cocoon yield. Although much research has been done in this area, the strategies proposed for its application are often insufficient to address current productivity challenges. This review aims to collect and analyse available data and information on the application of plant extracts to improve the economic characteristics of the silkworm (*Bombyx mori* L). By integrating these results, this review aims to provide information to help develop more effective strategies to improve cocoon production and quality for commercial silkworm rearing in the future.

Keywords: *Bombyx mori*; cocoon yield; fortification; mulberry; plant extracts; silk

Introduction

Sericulture is a cottage industry of socio-economic importance, particularly in developing countries like India. It is a diverse industry with great potential for sustainable development and economic growth. The properties of silk, like breathability, temperature regulation, hypo allergenicity and durability, make it an ideal material for clothing, bedding, medical and industrial applications. Its natural lustre and softness enhance its appeal in luxury fashion and home textiles, making it important in both traditional and emerging sectors. Interestingly, although China and India are the world's leading silk producers, China accounts for 85 % of global silk production and India for 15 % (1). This difference is mainly due to the lack of automation in the sericulture process in India (2). In 2023, India's total raw silk production was 38913 metric tonnes, out of which mulberry silk contributed about 77 %, Eri silk (18 %), Tasar silk (5 %) and Muga silk (1 %) (3). Despite being the world's second-largest producer, India faces an annual production deficit of around 6000 metric tonnes (4). As the demand for silk increases in India, it becomes increasingly necessary to improve the growth and health of silkworms to increase the yield and quality of silk.

Silk is obtained from the *Bombyx mori* L. silkworm, which is traditionally a monophagous insect as they prefer to feed only on mulberry leaves (family Moraceae, genus *Morus*) (Fig. 1). Mulberry leaves are rich in essential nutritional stimulants such as attracting, biting and swallowing factors, which attract silkworm larvae and form the basis of productivity in sericulture (5). Besides providing appropriate environmental conditions during rearing, it is also crucial to provide the larvae with sufficient nutrition for successful overall growth, development and cocoon production (6). The quantity and quality of silk produced depends heavily on the larvae's ability to feed on mulberry leaves and convert them into body weight and ultimately silk proteins. Well-fed, healthy silkworm development has a direct impact on important economic traits such as cocoon weight, shell weight, filament length and silk productivity. Therefore, improving the nutritional quality of mulberry leaves has direct effects on larval health, cocoon production and overall economic characteristics of silkworms. Strategies to improve the nutritional quality of mulberry leaves have been implemented, including fortification with botanicals.

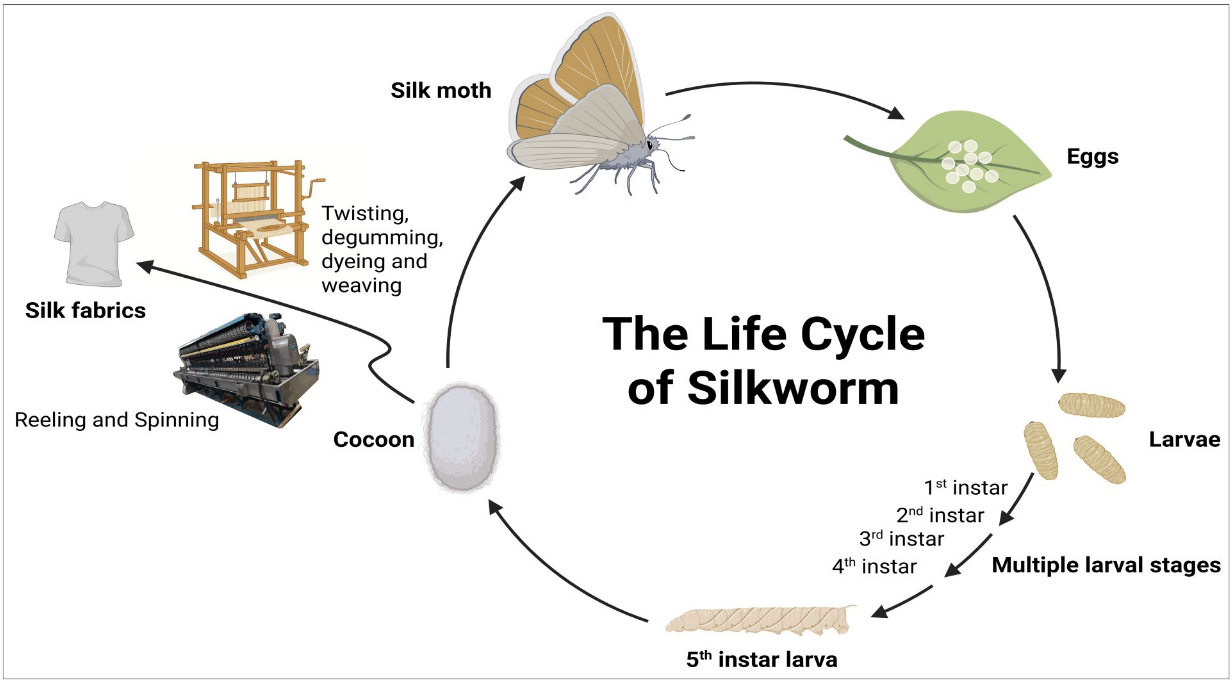

Fig. 1. Graphical representation of the life cycle of the silkworm.

Many plants are reported to contain bioactive compounds that not only improve their nutritional profile but also exhibit antifungal, antibacterial and antiviral properties, providing the dual benefit of increased productivity and resistance to pathogens (7-9). Some studies have also focused on the use of phytoecdysteroids, which have positive effects on larval spinning behaviour and silk production (10). In addition, some studies on phytojuvenoids have shown that they can interfere with the endocrine system of insects and mimic the activity of insect juvenile hormone (JH). This can disrupt development, especially during the larval stage, which is advantageous because the larvae consume more food and delay spinning, which increases the weight of the cocoon and shell (11). Therefore, using plant extracts/botanicals in sericulture is essential to boost cocoon and silk yield and is a practical and sustainable choice.

This review explores how bioactive plant compounds can improve the growth, development, disease resistance and pest management in the silkworm (*B. mori*). This consideration is important economically because silkworm health directly impacts the quality and quantity of silk production (12). The goal of the review is to bring together what we currently know about how various plant extracts affect silkworm physiology and silk production. By doing this, we hope to pinpoint effective natural methods, explore how they work and suggest future research paths that could have a greater impact on silk production.

Mechanisms of plant extracts in enhancing silkworm physiology

Nutritional fortification of mulberry leaves

Mulberry leaves play a very important role in the life cycle of *B. mori* silkworms, as they greatly affect the quality and quantity of silk produced (13). The silkworms require a balanced diet rich in proteins and essential amino acids for growth and proper development, as silk is primarily composed of protein-based fibroin and sericin. Although mulberry leaves are rich in protein content (7.93 % to 23.99 %) and crucial amino acids (glycine, alanine, serine and tyrosine), the agroclimatic environment can affect the number of proteins and amino acids contained in mulberry leaves, which limits the overall growth of silkworm larvae (14). The Supplementation of mulberry leaves with amino acids (alanine) has been shown to improve silkworm biological and commercial traits such as cocoon weight, shell ratio and fibroin content. On adding amino acids such as alanine, glycine and serine to the mulberry leaves, the fibroin content and cocoon weight were found to be increased by around 2.4 g, which indicates improvement in the silk filament length and silk quality (15). A study on protein supplementation has also been done with egg albumen, which has been shown to improve cocoon quality and increase silk production (16).

Although these supplementation strategies, that is, by adding specific amino acids and proteins, have been shown to be effective in increasing the silk production, researchers are also beginning to explore the potential of plant extracts as a supplemental approach. These natural products are rich in bioactive phytochemicals such as alkaloids, terpenoids and phenolic compounds and provide numerous nutritional benefits that can further improve the health and productivity of silkworms (17). Using plant extracts, the content of the nutrients can be increased, which improves the overall health of the silkworm larvae and ultimately the silkworm production. Fortifying mulberry leaves with *Psoralea coryleifolia* and *Phyllanthus niruri* extracts has significantly improved the larval weight, cocoon yield (18.79 g/10), shell ratio (19.80 %) and filament length (910.95 m), attributing these gains to enhanced nutrient intake and metabolic efficiency (18). Amino acid enrichment to the silkworm larvae was successfully studied using Lentil seed extract (8 mg/ml), which increased the larval weight (59.11 g/10), cocoon yield (22.12 kg/10,000 larvae) and filament length (1210.66 m) in silk protein synthesis (19). Medicinal plants such as *Withania somnifera* (3 %) and *Ocimum sanctum* (3 %) were found to increase the raw silk percentage (17.91 %) and filament length (1241 m), likely by stimulating antioxidant activity and silk gland protein synthesis (20).

Sesbania grandiflora leaf powder (2 %) fortified mulberry diets provided to the silkworm have led to increase in silk gland protein content and cocoon parameters (21). It has also been reported that 2.5 % *Aloe vera* and 2 % *Echinacea purpurea* are optimal for boosting silkworm larval growth, increasing antioxidant enzyme activity (peroxidase, phenol oxidase) and improving silk traits (22, 23). These studies suggest that phytochemicals which are present in several plant extracts help enhance disease resistance and metabolic vigor in the silkworm. Collectively, these studies have shown that nutritional supplements depend on their concentration, with 2-3 % or 8 mg/mL doses yielding the best results. Therefore, by integrating these fortifying agents, we can fill the nutritional gaps and take advantage of bioactive compounds present in plant extracts to improve the yield of the cocoon and silk quality. Future research should focus on isolating active principles, standardizing application protocols and developing cost-effective formulations for sustainable use in sericulture.

Metabolic and biochemical modulation

Bioactive compounds like polyphenols, flavonoids and terpenoids, which are present in the plant extract and their interaction can influence the metabolism in the silkworm body. These bioactive compounds can optimize the silkworm's physiological processes, including their nutrient utilization and detoxification pathways, to enhance silk production. Studies have shown that peppermint oil, which is rich in menthol and menthone, along with other antimicrobial agents such as dexatrol, can act as disinfectants and lower infection rates in silkworms by breaking down the bacterial cell membranes. At the same time, these bioactive compounds can help reduce oxidative stress markers, such as malondialdehyde (MDA) and protein carbonyl content (PCC), in silkworm larval haemolymph by neutralizing harmful reactive oxygen species (ROS) and strengthening the antioxidant defense systems in the silkworm's body. Moreover, they can influence enzyme activity, particularly by increasing aspartate transaminase (AST) and alanine transaminase (ALT), which are essential for processing amino acids and building proteins. This boost in enzyme activity leads to better overall health for the larvae, nutrient conversion efficiency and silk gland functionality, ultimately boosting silk yield (24).

The extracts from *Rhodiola rosea* were reported to increase the lifespan of silkworms and improve the stress tolerance by influencing the insulin/IGF-1 signaling pathway. This seems to be linked to a boost in the activity of antioxidant enzymes like glutathione S-transferase (GST) and catalase, along with changes in the levels of glutathione and malondialdehyde (25). Enrichment of mulberry leaves with extract of *aloe vera* and *Moringa oleifera* in the silkworm diets was reported to increase larval growth by enhancing certain enzyme activities, which are crucial for digestion. As a result, it improved the silkworm larval weight, quality of cocoons and even their antioxidant defences (22). *Morus alba*, Basil (*O. basilicum*) and black cumin seed (*Nigella sativa*) extracts were found to increase the protein content in haemolymph and transaminase enzyme activity in the bacterial and fungal-infected silkworm larvae, thereby promoting larval development and silk production (26).

The tormentic acid present in the *Sarcopoterium spinosum* extract was found to influence the composition of intestinal microbiota in silkworm larvae. Even though it does not significantly make changes to the bacterial diversity, it only increases the number of beneficial bacteria such as *Intestinibacter* and *Flavonifractor*. This microbial modulation indicates that it could promote gut health and reduce gastrointestinal stress in the silkworm larvae (27). The essential oil from the fruit of the *Taxodium distichum* tree has been found to boost silk production. It does this by increasing the activity of antioxidant enzymes and lowering the activity of acetylcholinesterase in the silkworm larvae. The main component in this oil, α-Pinene, helps keep the nervous system of the treated larvae healthy and enhances the length and weight of the silk filament (28). The antioxidant properties of *Bacopa monnieri* and *Lactuca sativa* extract are rich in polyphenols and flavonoids. By checking lipid peroxidation and fluorescence, the oxidative stress was measured and the results indicated better regulation of metabolic processes in silkworms, ultimately affecting their enzyme activity and overall metabolic health (29). All these biochemical approaches have made us understand the importance of bioactive compounds present in the plant extract, which are crucial in maintaining silkworm metabolism, a healthy balance of oxidative states and improving the processes that lead to better silk production. Therefore, plant extract can help increase the productivity in sericulture sustainably.

Influence of botanical supplements on larval growth and development

The silkworm (*B. mori* L.) is a monophagous insect, which is reared commercially solely on mulberry leaves for its diet. Environmental and management factors can cause fluctuations in the quality of mulberry leaves, which may not meet the minimum requirements of silkworms for proper development and growth. Therefore, enriching mulberry leaves with plant extracts represents an environmentally friendly and sustainable way to improve the growth, development and economic characteristics of the silkworm larvae (Table 1) (Fig. 2). Enrichment of mulberry leaves with plants such as *Lens culinaris* seed extract (8 mg/mL) has been proven to enhance larval weight (5.911 g), cocoon weight (2.4 g), shell weight (0.52 g) and filament length (1210.66 m), which may be due to increase content of proteins and amino acids in the lentil seeds (19). Silkworms fed with mulberry leaves enriched with plant extracts from medicinal plants like *Ocimum sanctum*, *Azadirachta indica* and *Vitex negunda* showed an increase in the silk ratio and filament length at the 2.5 % concentration (30).

The effectiveness of plant extracts depends on the specific concentration of bioactive compounds used. Different plant extracts can have various effects on silkworms' physiology depending on how potent they are and how they work in the silkworm's body. The active ingredients present in the *Parthenium hysterophorus*, *Phyllanthus niruri* and *Psoralea corylifolia* extracts helped improve the larval weight, silk gland development and cocoon yield, when used at higher concentrations of 10 % (7). Bioactive compounds like parthenin from *P. hysterophorus*, or phyllanthin and hypophyllanthin from *P. niruri* have growth-boosting and antioxidant qualities that help the silkworms absorb better nutrients and reduce the oxidative stress during their metabolism. *P. corylifolia*, commonly known as Babchi, is a traditional medicinal plant from the legume family (Fabaceae). This plant contains more

Table 1. List of plant extracts and their effect on the economic parameters of the silkworm

S. No.	Botanicals	Family	Parts used	Effective Concentration (Quantity)	Larval Weight (g)	Cocoon Weight (g)	Shell Weight (g)	Shell Ratio (%)	Filament length (m)	Reference
1	*Matricaria chamomila*	Asteraceae	Flowers	3%	3.080	1.294	0.240	18.547	-	
2	*Foeniculum vulgare*	Apiacea	Seeds	5%	3.017	1.271	0.247	19.433	-	(67)
3	*Thymus vulgaria*	Lamiaceae	Seeds	5%	3.242	1.323	0.257	19.425	-	
4	*Oroxylum indicum*	Bignoniaceae	Stem bark	1:1 (with distilled water)	-	1.951	0.400	20.502	989.00	(68)
5	*Parthenium hysterophrus*	Asteraceae	Leaf	10%	2.582	1.713	0.326	19.030	879.36	
6	*Phyllanthus niruri*	Phyllanthaceae	Leaf	10%	2.664	1.749	0.343	19.611	883.96	(7)
7	*Psoralea coryleifolia*	Leguminosae	Leaf	10%	2.688	1.842	0.370	20.086	905.99	
8	*Ganoderma lucidum*	Fabaceae	Whole mushroom	0.2%	-	1.901	0.309	16.250	918.72	(33)
9	*Morinda citrifolia*	Rubiaceae	Fruit	0.3%	-	1.786	0.289	16.180	886.35	
10	*Sida acuta*	Malvaceae.	Leaves	2.0%	2.559	1.599	0.298	18.636	898.00	(69)
11	*Coix aquatica*	Poaceae	Leaves	2.0%	-	2.178	0.510	23.415	901.00	(38)
12	*Ocimum basilicum* L. and *Vigna unguiculata*	Lamiaceae and Fabaceae	Leaves	1:15 w/w (For every 1 parts of the botanical powder, 15 parts of mulberry leaves are used by weight.)	4.076	1.453	0.351	24.156	-	(39)
13	*Aloe vera*	Asphodelaceae	Leaves	2.5%	3.952	1.946	0.446	22.918	-	(22)
14	*Moringa oleifera*	Moringaceae	Leaves	2%	3.740	1.912	0.428	22.384	-	
15	*Echinacea purpurea*	Asteraceae	Leaves	0.5%	3.038	1.430	0.310	21.678	-	(34)
16	*Clove oil*	Myrtaceae	Leaves	10%	3.800	1.290	0.230	17.829	842.30	(37)
17	*Ocimum sanctum*	Lamiaceae	Leaves	2.5%	3.277	1.330	0.260	19.548	435.10	
18	*Azadirachta indica*	Meliaceae	Leaves	2.5%	3.392	1.450	0.250	17.241	433.70	(30)
19	*Vitex negunda*	Lamiaceae	Leaves	2.5%	3.311	1.680	0.240	14.285	332.80	
20	*Tinospora cordifolia*	Menispermaceae	Leaves	3%	1.615	1.414	0.258	18.246	-	(70)
21	*Lens culinaris*	Fabaceae	Seed	8 mg/ml of distilled water	5.911	2.400	0.520	21.666	1210.66	(19)
22	*Taxodium distichum*	Cupressaceae	fruits	1%	4.657	1.432	0.296	20.68	1058.24	(28)
23	*Lepidium sativum*	Brassicaceae	Seed	0.25%	-	1.571	0.367	23.36	-	(35)

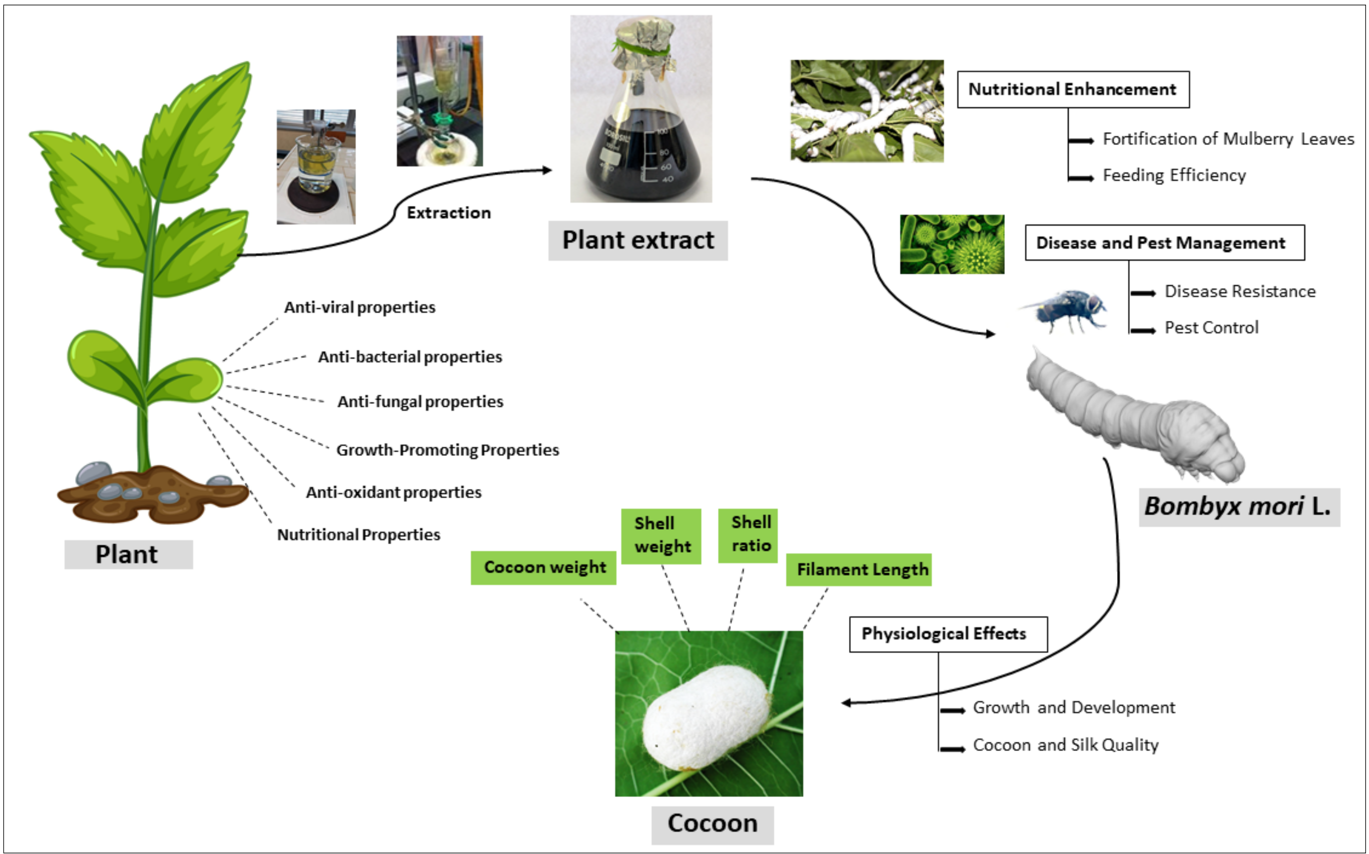

Fig. 2. Graphical representation of influence of plant extract on silkworm.

than 163 different chemical compounds, including coumarins and flavonoids (31). Compounds like psoralen encourage the silk protein production at a higher level by activating certain genes like fib-H when used at a higher concentration but compounds like bakuchiol, at a low concentration of 1.25 ppm when applied to 48 hr old fifth instar silkworm larvae, significantly increased the cocoon weight and silk filament length. Bakuchiol increases the protein metabolism by mimicking juvenile hormone effect, thereby extending the larval duration and delaying the pupation process, which impacts their growth and development for better silk production (32). *Ganoderma lucidum* extract at a low concentration of 0.2 % was reported to boost the immune system and help silkworms handle stress without overwhelming their metabolism because of its highly potent immunomodulatory polysaccharides, like β-glucans and triterpenoids (33). *Echinacea purpurea* extract with a similar concentration of 0.25 % contains alkylamides and cichoric acid that help promote phagocytosis and fight off microbes in silkworms and similarly, *Lepidium sativum* extract contains glucosinolates, such as glucotropaeolin, that break down into bioactive isothiocyanates. These compounds help increase detoxification enzymes, leading to better survival rates for the larvae, even at just 0.25 % (34, 35).

The difference might arise from the presence of bioactive compounds, their structure and their different mechanism of action from various plant sources on silkworm physiology. Studies have also found that the effects of essential oils on silkworm economic parameters showed mixed results. In one study use of plant extract as a natural oil as additive in silkworm food was explored. Among the jojoba oil, citronella oil, lemon grass oil and a mix of sunflower and soybean oils, citronella oil, when combined with mulberry leaves, led to the highest larval weight gain, while lemon grass oil resulted in the lowest. Interestingly, jojoba oil helped reduce the mortality rates among the larvae and the combination of sunflower and soybean oil extended the duration of the larval stage (36). While another study found that 10 % clove oil significantly increased larval weight, although the effect on shell ratio and filament length was negligible. This might suggest that differences in plant biochemical properties could be responsible for this effect (37). The application of phytoecdysteroids extracted from *Coix aquatica* at different stages of the fifth instar showed varying results, from reducing the larval duration to increasing the cocoon shell ratio by 23.415 %. Phytoecdysteroids were shown to be effective in causing silkworms to spin uniformly without compromising the quality of their cocoons (38). The recent study explores the impact of four plant powder mixes on silkworm larvae weight, silk gland weight, cocoon parameters and moth fecundity of certain local and imported hybrids. From the results, it is very clearly seen that the application of mulberry leaves treated with a mixture of *Ocimum basilicum* L. and *Vigna unguiculata* (M2) to local silkworm hybrids significantly increased the weight of larvae by 8.93 % and that of silk glands by 37.45 %. The weight of the cocoon shell increased by 39.84 % and the number of eggs increased by 28.93 % (39). This enriches nutrient quality in the mulberry leaves, which ultimately affects the important economic parameters and the amount of silk produced. This shows that some mixtures of plant extracts or compounds might have a synergistic effect, but how this works remains unclear and needs further research. Future studies should focus on exploring ways in which plant extracts may be combined to obtain the most benefit rather than focusing on individual herbal extracts.

Disease management strategies

Anti-viral activity

Researchers are studying and exploring plant extracts for their antimicrobial properties against viruses, bacteria and fungi to improve silkworm growth. (Table 2). *Bombyx mori* Nucleopolyhedrovirus (*Bm*NPV) or Grasserie disease has been one of the greatest tragedies for the sericulture business, causing serious economic losses. This disease is most evident in the 4th and 5th instar stages of larvae, making early detection challenging (40). Bael, or *Aegle marmelos*, is a tree species indigenous to the Indian subcontinent and parts of Southeast Asia (41). It has been identified as capable of providing antiviral protection to the silkworms against *Bm*NPV. The hexane extract of *A. marmelos* leaves has been shown to provide more than 95 % larval survivability at a concentration of 1000 µg. It has been reported that larvicidal substances contained in *A. marmelos*, especially marmelide, reduce the virus-induced multiplication in larvae, making them more resistant to viral diseases (42).

Methanolic extracts of *Phyllanthus amarus*, *Lantana camara*, as well as marine seaweeds such as *Sargassum wightii* have been found to possess a promising antiviral activity against *Bm*NPV. The methanolic extracts of *P. amarus* at a concentration of 1000 µg increased the survival rate up to 89 % in *Bm*NPV infected larvae, which suggests a high degree of antiviral activity. It is assumed that these extracts can achieve their effects because of the presence of important bioactive components, such as phenolics and flavonoids, which affect the process of viral replication. Similar effects were noticed with the methanolic extract of *S. wightii*, which resulted in enhanced cocoon weight and silk parameters (43). Interestingly, research on hexane extracts from a medicinal plant such as *Psoralea corylifolia* and *Plectranthus amboinicus,* which are used traditionally for various medicinal purposes, was administered to the silkworm larvae at a concentration of 1000 ppm. The combination of these specific plants increases the alkaline phosphatase content in the white Tamil Nadu (TN) variety to 5.25 µg/100 µL and 5.23 µg/100 µL, respectively, improving the amylase activity, thereby promoting digestion and reducing infection (44). The ethanolic extracts from plants like *Eupatorium odoratum* and *Hyptis suaveolens* have shown strong antiviral activity against the silkworm larvae. When tested at concentrations of 3000, 5000 and 8000 ppm, the study found that the highest concentration increased neurosecretory cell activity and reduced the infection rates by 40 %. The bioactive compounds in these plants, such as terpenoids and flavonoids, play a significant role in promoting hormone release, which aids in recovery and fights off the *Bm*NPV infection (45).

Anti-bacterial activity

Bacterial diseases in silkworms, including flacherie and septicemia, lead to a decrease in silk production and result in economic losses in commercial silkworm rearing. Several bacterial pathogens, such as *Bacillus*, *Streptococcus*, *Staphylococcus*, *Pseudomonas*, *Klebsiella granulomatis* and *Klebsiella pneumoniae* have been identified as some of the pathogens that can cause bacterial disease, such as flacherie in silkworms (46, 47). Certain plant extracts have proven to have antibacterial properties and are used in the production of environmentally friendly bed disinfectants to combat bacterial pathogens. The incorporation of alkaloids and polyphenols present in *Tridax trilobata* demonstrated a considerable antibacterial activity against pathogens responsible for Flacherie and Sappe diseases in silkworms. Phytochemical-functionalized AgNPs, prepared through the flower extracts of *T. trilobata*, show improved anti-biofilm properties, with pathogen activity reduced significantly for bacterial strains such as *Bacillus subtilis*, *Staphylococcus aureus*, *Escherichia coli* and *Salmonella typhi*. It significantly enhances larval feeding efficiency, thus improving survival rate, body weight and cocoon yield, although the effect is concentration dependent at 10-50 µg/mL (48). Aqueous extract of garlic was reported to be effective against *Pseudomonas* spp. particularly pathogenic strain AC-3, which is a major bacterium responsible for flacherie disease in the muga silkworms (*Antheraea assamensis*). The bioactive compound allicin and its related compounds, which form disulfide bonds with bacterial enzymes, disrupt the bacteria's membrane and affects its metabolic functions, thereby preventing the flacherie disease and potentially enhancing larval health and reducing mortality (49).

A significant antibacterial activity against *Bacillus cereus*, *Escherichia coli* and *Staphylococcus aureus*, pathogens of silkworms, were demonstrated by propolis extract and cinnamon oil. The ethanolic extracts of propolis (EEP) and cinnamon oil controlled bacterial flacherie and enhanced the biological parameters of silkworms such as larval weight, cocoon weight and silk weight. Among the EEP tested concentrations, 100 µL EEP was more effective in controlling gram-positive bacteria than gram-negative bacteria due to differences in the permeability of Gram's cell wall. Propolis also improved the larval development and increased the cocoon weight with EEP at 7–14 µL/mL being the best concentration to inhibit bacterial growth and enhance silk yield (50). Bioactive extracts from the *Phyllanthus niruri* plant, including alkaloids and phenols, significantly enhance immune response from flacherie caused by *Escherichia coli,* including an increase in haemocyte activity, as well as the activities of the enzymes such as phenoloxidase and esterase which strengthened larval defense systems. Significant enhancement in the economic parameters, including the weight of cocoon, weight of cocoon shell and the shell ratio, was also observed after treatment with *P. niruri,* with optimum results achieved with the application of 5 µL (51).

Antifungal and some antimicrobial activity

Diseases caused by fungi are regarded as a serious threat to the *B. mori* during the silkworm rearing process. Among two of the principal pathogens *Aspergillus* and *Beauveria bassiana, B. bassiana* is the most dangerous and causes the muscardine disease, which negatively affects larval development and the quality of cocoons (52, 53). A study evaluating the antifungal effectiveness of *Ficus carica*, *Datura stramonium* and *Vitis vinifera* showed that *F. carica* was the most effective, achieving a maximum larval survival rate of 79.9 % (54). The methanolic extract of *Curcuma longa* rhizome showed its antifungal activity when applied as a 10 % foliar spray to the muga silkworm, *Antheraea assamensis* Helfer larvae infected with *B. bassiana*. The treatment significantly improved the cocoon parameters such as weight of cocoon, weight of cocoon shell, filament length and raw silk content and improved the tensile

Table 2. List of plant extracts and their effect on disease management

S. No.	Botanicals	Type of extract	Effective Concentration	Pathogen Targeted	Mode of Action	Effect Observed	Reference
1	*Aegle marmelos*	n-hexane extract	1000 µg	*Bm*NPV	Interferes with viral replication	>95% larval survival, increased cocoon weight	(42)
2	*Phyllanthus amarus*	Methanolic extract	1000 µg	*Bm*NPV	Antiviral, inhibits viral replication	89% survival of infected larvae	
3	*Lantana camara*	Methanolic extract	1000 µg	*Bm*NPV	Antiviral via bioactive phenolics	63% larval survival and Moderate increase in cocoon weight	(43)
4	*Sargassum wightii*	Methanolic extract	1000 µg	*Bm*NPV	Antiviral, enhances larval immune response	67% larval survival and Improved cocoon weight and shell parameters	
5	*Psoralea corylifolia*	n-hexane extract	1000 ppm	*Bm*NPV	Boosts enzyme activity, enhances digestion	Increased alkaline phosphatase and amylase activity, improved resilience	(44)
6	*Plectranthus amboinicus*	n-hexane extract	1000 ppm	*Bm*NPV	Enhances physiological and biochemical parameters	Increased lipid content and enzyme activity	
7	*Hyptis suaveolens*	Ethanolic extract	3000, 5000, 8000 ppm	*Bm*NPV	Promotes neurosecretory activity, regulates physiological processes	Normal feeding behaviour and recovery from infection	(45)
8	*Eupatorium odoratum*	Ethanolic extract	3000, 5000, 8000 ppm	*Bm*NPV	Stimulates secretion of NSC granules, aids in physiological recovery	Nearly normal body weight and cocoon production	
9	*Tridax trilobata*	crude extract	10-50 µg/mL	*Bacillus subtilis, S. aureus, E. coli, S. typhi*	Antibacterial, anti-biofilm, feeding efficiency enhancement	Improved larval survival, increased body weight and higher weight of cocoon and cocoon shell	(48)
10	*Propolis extract (EEP)*	ethanol extracts	7–14 µl/ml	*Bacillus cereus, E. coli, S. aureus*	Disrupts bacterial cell membranes and inhibits enzymes	Improved larval weight (25.53 g), cocoon weight (12.53 g) and silk production	(50)
11	Cinnamon oil	ethanol extracts	50–100 µl	*B. cereus, E. coli, S. aureus*	Inhibits bacterial growth via essential oil compounds (e.g., cinnamaldehyde)	Enhanced cocoon weight (10.47 g) and larval health	
12	*Phyllanthus niruri*		5-10 µL	*Escherichia coli*	Immune enhancement, antimicrobial activity	Increased haemocyte count, cocoon weight and shell ratio; reduced mortality	(51)
13	*Ficus carica*	Aqueous extract	20%	*Beauveria bassiana*	Antifungal activity	Maximum larval survival (84.2%)	(54)
14	*Curcuma longa*	Methanolic extract	10%	*Beauveria bassiana*	Antifungal activity; inhibition of spore germination; enhanced silk protein synthesis	Improved weight of cocoon, weight of cocoon shell, filament length, tensile strength and raw silk ratio	(55)
15	*Nigella sativa (Black Seed)*	Petroleum-ether extract	1%, 2%, 3%	*Bacillus thuringiensis* and *Beauveria bassiana*	Thymoquinone-based antimicrobial activity	Enhanced silk ratio (25.56%), reduced larval mortality (10-12%)	(56)
16	*Ocimum basilicum (Basil)*	Petroleum-ether extract	1%, 2%, 3%	*Bacillus thuringiensis* and *Beauveria bassiana*	Phenolic compounds and essential oils with antimicrobial properties	Increased larval weight (4.032g), decreased mortality (10%), improved cocoon weight (1.642g)	(56)
17	*Eugenia caryophyllaea*	Methanolic extract	1:10	*Bacillus cereus, Proteus vulgaris*	Antimicrobial activity through essential oils (acetyl eugenol, beta-caryophyllene)	Increased larval weight (38.00g/10 worms), Improved shell ratio (21.49%), Enhanced filament length (842.30m), Higher cocoon weight (1.29g) and Improved shell weight (0.23g)	(37)
18	*Adhatoda vasica*	aqueous extract and methanolic extract	1:3	*BmNPV* and *S. sciuri*	Antimicrobial action via secondary metabolites (e.g., alkaloids, flavonoids)	Enhanced cocoon weight (1.89 g, 1.78 g) and shell ratio (17.47%)	(57)
19	*Phyllanthus niruri*	Aqueous and methanolic extracts	1:3	*BmNPV* and *S. sciuri*	Antimicrobial and antiviral action via secondary metabolites	Improved cocoon weight (1.94 g, 1.81 g) and shell ratio (17.65%)	
20	*Sesbania grandiflora*	n-hexane, chloroform and ethyl acetate extract	0.4 - 6.2 mg/mL	methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant *Enterococcus* (VRE)	Inhibition of bacterial growth	Enhanced larval growth and survival	(9)

properties of the silk fibers. These benefits are attributed because of the presence of bioactive compounds of *C. Longa*, like curcumin and tormelon, that inhibits the germination of the fungal spores and strengthen the defense mechanisms of the larvae (55).

According to some of the study revealed, the petroleum ether extracts of *O. basilicum* (basil) and *Nigella sativa* (black cumin) had antibacterial and antifungal properties against *Bacillus thuringiensis* and *Beauveria bassiana*. Treatment of artificially infected *B. mori* silkworm larvae with *O. basilicum* leaves and *N. sativa* seed extract significantly increased the larval weight and reduced the larval mortality. These extracts also increased the weight of the pupa and the cocoon. The maximum filament length of silk was recorded at a concentration of 3 % (56). The Clove oil contains the bioactive compounds acetyl eugenol, beta-caryophyllene and triterpenoids, therefore, it stimulates protein synthesis and nutrient bioavailability. The β-sitosterol and terpenes found in clove oil attract the silkworms, which ultimately increases the metabolic rates and controls the microbial pathogens (37). *Adhatoda vasica* and *Phyllanthus niruri* leaves were reported to have strong antimicrobial properties and their extracts have shown impressive results on fourth and fifth instar silkworm larvae when inoculated with *Bm*NPV and *S. sciuri*. The extracts gave better result of cocoon weight, shell weight, pupal weight and shell ratio in the PM×CSR2 silkworm compared to the control (57).

Effect of plant extract on pest management

Plant extracts are derived from various plant sources and are considered safer for pest control because of their natural origin. It is effective against a wide range of pests and has low toxicity to non-target organisms such as beneficial insects and soil microorganisms (58). The threat of Uzi fly, especially *Exorista sorbillans* and *Exorista bombycis*, is enormous and causes significant losses in sericulture (59, 60). The impact is an economic loss which includes mortalities from 8 % to 80 % in sericultural states like Karnataka, experiencing up to 80 % infestation and Tamil Nadu and Andhra Pradesh, ranging from 30-40 % (61). Conventional insecticides are ineffective and harmful to silkworms; effective management strategies are therefore essential. Some botanicals proved to be useful in controlling this pest by inhibiting metamorphosis and reproduction, which cause death when applied.

The impact of plant oils was assessed on Uzi fly at different concentrations: 0.2, 0.4 and 0.8 %. The results showed that at 0.8 % per cent concentration of the neem oil extract significantly reduced the egg laying capacity, hatchability and maggot recovery, while karanj oil significantly reduced maggot mortality. Spraying plant oil from neem and karanj also significantly reduced the pupation rate, adult emergence, adult longevity and fecundity (62). In another study, the efficacy of the plant essential oils and solvent extracts regarding adulticidal activity was highlighted, with essential oils showing a higher activity than the other extract forms such as petroleum ether extract, chloroform extract, butanol extract and aqueous extract. Based on the Gas Chromatography Mass Spectrometry (GC-MS) analysis, the major compounds responsible for the biological activity were identified as thymol and carvacrol, which inhibit the acetylcholinesterase of the pest and disrupt its nervous system. Thymol, the main component of this oil, along with other compounds such as γ-terpinene and O-cymene, contribute to its powerful insecticidal properties. The rapid action of this oil, resulting in high pest mortality, suggests its potential as a sustainable and environmentally friendly alternative to chemical insecticides to protect the silkworms from *E. sorbillans* infestation (63).

Challenges and limitations

Although plant extracts are administered to the silkworm, showing better results in boosting the economic traits and tackling the pests and diseases, there lies several factors that make it difficult to effectively use them on a larger scale (56). Even though there are plenty of studies showing the benefits of plant extracts, the methods for using them aren't clearly defined or standardized. This inconsistency makes it hard to get reliable results and makes it difficult for commercial silkworm rearing. Another challenge is that many plant extracts may degrade quickly and lack ready-to-use formulations (64). This instability and inconvenience can limit their practical application at the field level during commercial rearing. Improving the shelf-life of these plant extracts with the right additives could help boost their effectiveness (65).

While most plant extracts have beneficial effects on silkworms, others can have a negative effect on silkworms like Neem, chrysanthemum and *Cudrania tricuspidata* extracts, with neem having the most immediate and serious impact, especially on young instar silkworm larvae (66). Therefore, the importance of carefully choosing the plant extracts is crucial, along with identifying the active components present in the selected plants and standardizing them to ensure that the desired effects on silkworms are consistent. Lastly, calculating a thorough cost-benefit analysis for using plant extracts commercially is key to figuring out whether they're economically viable for sericulture.

Future perspectives and research directions

To enhance the quality and yield of silkworm cocoon, future strategies should focus on a few important areas. Future studies could be done to identify plants that have beneficial compounds like alkaloids, glycosides, sterols, ecdysones and phenolics, which could be used commercially. It's also crucial to choose plant extracts that are not harmful to silkworms. Certain challenges, such as photo-degradability and lack of ready-to-use formulations for the plant extracts, should be taken care of for proper silkworm growth and development. The shelf-life of plant extract can be improved by using the right additives for their better effectiveness. The study should also explore combining the plant extracts with effective chemicals for better disease management and enhanced cocoon quality. Disinfectants made of plant extracts can also be explored for commercial use. Large-scale field trials can be conducted to finalize the effective formulations and assess their cost-effectiveness. By focusing on these areas, Plant extracts can be used sustainably to improve the quality and yield of silkworm cocoon.

Conclusion

The results of this review demonstrate how plant extracts can improve silkworm productivity, growth and disease control. Mulberry leaves are enriched with plant bioactive chemicals and can significantly improve the cocoon production and silk quality. Furthermore, incorporating plant-based technologies promotes the sustainability of sericulture by reducing reliance on chemical additives or disinfectants. To maximize the use of plant extracts in sericulture practices, future research should focus on standardizing extract concentrations and elucidating the biochemical processes underlying these benefits.

Acknowledgements

The authors gratefully acknowledge the support of the Department of Sericulture, Forest College and Research Institute and Central Silk Board. Special thanks to the technical staff for their invaluable assistance.

Authors' contributions

DB conceptualized the study, collected the literature as well as rigorously reviewed the articles and contributed to the first draft of the manuscript. KAM contributed to literature collection and manuscript review. RS assisted with literature review and drafting specific sections of the manuscript. KS contributed to results interpretation. SM assisted with the collection of literature related to nanotechnology-based research articles and interpretation. PR contributed to alignment of sequence, drafting of manuscript and helped to prepare figures and tables and contributed to manuscript revision. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: The authors do not have any conflict of interest to declare.

Ethical issues: None

References

1. Fibre2Fashion. The upward journey of South India's silk. Fibre2Fashion [Internet]; 2015 [cited 2024 Dec 26]. Available from: https://www.fibre2fashion.com/industry-article/7503/the-upward-journey-of-south-indias-silk
2. Jyothi S, Mamatha DM, Raju PJ, Sultana S, Seetharamulu J. A study on the sericulture farm automation system using the Internet of Things (IoT). In: Jyothi S, Mamatha DM, Zhang YD, Raju KS, editors. Proceedings of the 2nd International Conference on Computational and Bio Engineering. Lecture Notes in Networks and Systems. Singapore: Springer 2021;15. https://doi.org/10.1007/978-981-16-1941-0_40
3. Central Silk Board, Ministry of Textiles. Annual report. Bengaluru: Government of India; 2023 [cited 2024 Dec 26]. Available from: https://csb.gov.in/wp-content/uploads/2024/05/1-AR-2022-23-Final-Low.pdf
4. Bukhari R, Kour H. Background, current scenario and future challenges of the Indian silk industry. Int J Curr Microbiol Appl Sci. 2019;8(5):2448–63. https://doi.org/10.20546/ijcmas.2019.805.289
5. Neog K, Unni B, Ahmed G. Studies on the influence of host plants and effect of chemical stimulants on the feeding behaviour in the Muga silkworm, *Antheraea assamensis*. J Insect Sci. 2011;11 (133):1–16. https://doi.org/10.1673/031.011.13301
6. Gupta SK, Dubey RK. Environmental factors and rearing techniques affecting the rearing of silkworm and cocoon production of *Bombyx mori* Linn. Acta Entomol Zool. 2021;2(2):62–67. https://doi.org/10.33545/27080013.2021.v2.i2a.46
7. Gobena WS, Bhaskar RN. Fortification of mulberry leaves with medicinal botanical plant extracts effect on silkworm, *Bombyx mori* L. (PM× CSR2) (Lepidoptera: Bombycidae) larval growth and cocoon traits. J Biol Sci. 2015;15(4):199–206. https://doi.org/10.3923/jbs.2015.199.206
8. Devi VP, Bai RM. Antifungal effect of *Ocimum sanctum* L. against white muscardine disease of silkworm, *Bombyx mori* L. J Biopest. 2014;7(2):205–09. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84920283663&partnerID=40&md5=3eef2ab24a79f6801701dfd140c289d0
9. Anantaworasakul P, Hamamoto H, Sekimizu K, Okonogi S. *In vitro* antibacterial activity and *in vivo* therapeutic effect of *Sesbania grandiflora* in bacterial infected silkworms. Pharm Biol. 2017;55 (1):1256–62. https://doi.org/10.1080/13880209.2017.1297467
10. Kumar KPK, Singh GP, Sinha AK, Madhusudha KN, Prasad BC. Antiviral action of certain medicinal plants against *Am*CPV and their effect on cellular and biochemical changes in Tasar silkworm, *Antheraea mylitta* D. Res J Med Plant. 2011;6(1):92–99. https://doi.org/10.3923/rjmp.2012.92.99
11. Shivakumar GR, Raman KVA, Magadum SB, Datta RK, Hussain SS, Banerji A, Chowdhary SK. Effect of phytoecdysteroids on the spinning, cocoon and reeling parameters of the silkworm, *Bombyx mori* L. Allelopathy J. 1996;3(1):71–76. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-1342313374&partnerID=40&md5=cf7b431b99bb80b529cff85f81a6ba7d
12. Nair SK, Nair JS, Vijayan VA. Phyto-juvenile hormone for augmentation in cocoon yield in silkworm, *Bombyx mori* L. J Biopest. 2010;3(1):212–26. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-79951746167&partnerID=40&md5=5e793be9f6f666bb7fa0ddd6cb051fff
13. Mahanta DK, Komal J, Samal I, Bhoi TK, Dubey VK, Pradhan K, et al. Nutritional aspects and dietary benefits of “Silkworms”: Current scenario and future outlook. Front Nutr. 2023;10:1121508. https://doi.org/10.3389/fnut.2023.1121508
14. Ruth L, Ghatak S, Subbarayan S, Choudhury BN, Gurusubramanian G, Kumar NS, Bin T. Influence of micronutrients on the food consumption rate and silk production of *Bombyx mori* (Lepidoptera: Bombycidae) reared on mulberry plants grown in a mountainous agro-ecological condition. Front Physiol. 2019;10:878. https://doi.org/10.3389/fphys.2019.00878
15. Matei A, Tanase DB, Diaconescu C, Constantinescu M, Dolis M. Contributions to the study of the leaf protein value in different mulberry varieties. Archiva Zootechnica. 2006;9:153–57.
16. Muzamil A, Tahir HM, Ali A, Bhatti MF, Munir F, Ijaz F, et al. Effect of amino acid fortified mulberry leaves on economic and biological traits of *Bombyx mori* L. Heliyon. 2023;9(10):e21053. https://doi.org/10.1016/j.heliyon.2023.e21053
17. Islam T, Khan IL, Ganie NA, Sahaf KA, Jan N, Gora MM. Impact of egg albumen (egg white) fortified mulberry leaf on rearing and some cocoon parameters of silkworm, *Bombyx mori* L. (CSR6 × CSR26) × (CSR2 × CSR27) double hybrid. Int J Chem Stud. 2020;8 (4):267–71. https://doi.org/10.22271/chemi.2020.v8.i4e.10034
18. Yang L, Yang C, Li C, Zhao Q, Liu L, Fang X, Chen XY. Recent advances in biosynthesis of bioactive compounds in traditional Chinese medicinal plants. Science Bulletin. 2016;61(1):3–17. https://doi.org/10.1007/s11434-015-0929-2
19. Islam T, Qadir J, Bashir I. Impact of lentil seed (*Lens culinaris*) fortified mulberry leaves on silk productivity of *Bombyx mori* L. Biol Forum Int J. 2023;15(3):851–54.
20. Hajam OA, Rufaie ZH, Khan IL, Mir SA, Gul S, Buhroo ZI, Baqual MF. Influence of plant extract fortified mulberry leaf on some reeling

parameters of silkworm, *Bombyx mori* L. Int J Vet Sci Animal Hus. 2024; 9(3):429–33.

21. Bhuvaneswari E, Shree RSM, Thirupathaiah Y, Kumar V, Teotia RS. Impact of *Sesbania grandiflora* leaf powder fortification on growth and economic traits of bivoltine double hybrid (FC1 × FC2) silkworm, *Bombyx mori*. Indian J Seri. 2018;57(1–2):14–21. Available from: https://www.scopus.com/inward/record.uri?eid=2s2.085092603974&partnerID=40&md5=3c8a8f54966273db8cceb175aa25b534
22. Moustafa M. Improving the silk industry by studying the effect of several aqueous extracts to enhance the efficiency of silkworm *Bombyx mori* L. production. J Plant Protect Pathol. 2020;11(2):121–26. https://doi.org/10.21608/jppp.2020.85989
23. Moustafa MN. The effect of fortificated mulberry leaves with *Echinacea purpurea* on silkworm (*Bombyx mori* L.) physiology and production. Egypt Acad J Bio Sci Entomol. 2023;16(4):163–71. https://doi.org/10.21608/eajbsa.2023.332234
24. Hassan EM. Effect of dexatrol and peppermint oil as a disinfectants on some biochemical characters of infected silkworm *Bombyx mori*. J Entomol. 2014;12(1):12–20. https://doi.org/10.3923/je.2015.12.20
25. Chen C, Song J, Chen M, Li Z, Tong X, Hu H, et al. *Rhodiola rosea* extends lifespan and improves stress tolerance in silkworm, *Bombyx mori*. Biogerontol. 2015;17(2):373–81. https://doi.org/10.1007/s10522-015-9622-8
26. Helaly WM, Elyamani EM, Saad MSI. Influence of some plant extracts as antiseptics to control bacterial and fungal diseases of silkworms, *Bombyx mori* L. Zagazig J Agric Res. 2020;47(3):707–17. https://doi.org/10.21608/zjar.2020.95906
27. Bay V, Gür S, Bayraktar O. Plant-derived tormentic acid alters the gut microbiota of the silkworm (*Bombyx mori*). Sci Reports. 2022;12(1). https://doi.org/10.1038/s41598-022-17478-4
28. Sabry HM, Saad MI, El Shafiey SN. Reinforce the silkworms' nutrition using essential oil of *Taxodium distichum'* fruits: A prospective way to improve silk production. Catrina Int J Environ Sci. 2023;28(1):21–31. https://doi.org/10.21608/cat.2023.209349.1174
29. Gaikwad YB, Gaikwad SM, Bhawane GP. Effect of induced oxidative stress and herbal extracts on acid phosphatase activity in lysosomal and microsomal fractions of midgut tissue of the silkworm, *Bombyx mori*. J Insect Sci. 2010;10(113):1–9. https://doi.org/10.1673/031.010.11301
30. Gupta SK, Singh V, Pandey RP, Yadav P. Impact of certain plant extracts on different larval and cocoon characters of silkworm *Bombyx mori* linn. Zool Entomol Letters. 2022;2(2):42–45. https://doi.org/10.22271/letters.2022.v2.i2a.46
31. Koul B, Taak P, Kumar A, Kumar A, Sanyal I. Genus *Psoralea*: A review of the traditional and modern uses, phytochemistry and pharmacology. J Ethnopharmacol. 2019;232:201–26. https://doi.org/10.1016/j.jep.2018.11.036
32. Nair KS, Nair JS, Trivedy K, Vijayan VA. Influence of Bakuchiol, a JH analogue from Bemchi (*Psoralea corylifolia*) on silk production in silkworm, *Bombyx mori* L.(Bombycidae: Lepidoptera). J Appl Sci Environ Manage. 2003;7(2):31–38. https://doi.org/10.4314/jasem.v7i2.17208
33. Selin DC, Venkadesh B, Kumaran T. Impact of ganoderma and noni extract on the economic parameters of silkworm, *Bombyx mori* L. Pharma Innov. 2015;4(10):93.
34. Khezrian A, Bagheri M, Zanjani RS, Rahimabad YK, Nematollahian S, Zahmatkesh A. The effects of feed supplements and *Nosema bombycis* infection on economical traits in various silkworm breeding lines. Entomol Exp Et Appli. 2021;170(3):277–83. https://doi.org/10.1111/eea.13135
35. Alfazairy AA, Elsakhawy DA, El-Meniawi FA, Hashem M, Rawash IA. Effects of mulberry leaf enrichment with *Lepidium sativum* L. seed powder suspension on the economic parameters of *Bombyx mori* L. Sci Reports. 2024;14(1). https://doi.org/10.1038/s41598-024-67128-0
36. Elyamani EM, Moustafa MN, Abd-Elmonem MM, Farag MF. Utilization of some volatile and fixed oils in silkworm diets: a novel strategy for maximizing silk production. Egypt J Agri Res. 2025;103(1):29–39. https://doi.org/10.21608/ejar.2025.346665.1627
37. Prashanthi G, Sujatha K, Sampath A, Fatima K. Antibacterial activity of clove oil extracted from *Eugenia caryophyllaea* and its effect on the economic traits of mulberry silkworm *Bombyx mori* L. Bullet Pure Appli Sci Botany. 2022;41(2):87–93. https://doi.org/10.5958/2320-3196.2022.00010.6
38. Barge S, Pardeshi A. Influence of phytoecdysteroids isolated from *Coix aquatica* on cocoon characteristics of silkworm *Bombyx mori* L. Pharma Innov J. 2019;8(3):389–93.
39. Hassan SI, Rateb SH, Mohanny KM, Hussein MH. Efficiency of some plants powder mix as a dietary supplement for silkworm (*Bombyx mori*). SVU-Int J Agri Sci. 2020;2(2):378–83. https://doi.org/10.21608/svuijas.2020.41808.1034
40. Suraporn S, Suthikhum V, Terenius O. The mortality of *Bombyx mori* larvae challenged by BmNPV is reduced when supplemented with *Lactobacillus acidophilus* bacteria. BMC Res Notes. 2024;17(1). https://doi.org/10.1186/s13104-024-07019-9
41. Vasava D, Kher MM, Nataraj M, Silva TAJ. Bael tree (*Aegle marmelos* (L.) Corrêa): importance, biology, propagation and future perspectives. Trees. 2018;32:1165–98. https://doi.org/10.1007/s00468-018-1754-4
42. Somu C, Karuppiah H, Sundaram J. Antiviral activity of seselin from *Aegle marmelos* against nuclear polyhedrosis virus infection in the larvae of silkworm, *Bombyx mori*. J Ethnopharma. 2019;245:112155. https://doi.org/10.1016/j.jep.2019.112155
43. Somu C, Paulchamy R, Moorthy SM, Sundaram J. Antiviral activity of selected medicinal plants and marine seaweeds on the grasserie infected larvae of silkworm, *Bombyx mori*. Arch Phytopathol Plant Protect. 2017;50(17–18):850–67. https://doi.org/10.1080/03235408.2017.1401700
44. Elumalai D, Thaiyalnayagi G, Poovizhiraja B. Investigation of BmNPV infection on physiological and biochemical parameters of *Bombyx mori* administrated with botanicals. J Crop Weed. 2022;18(2):248–52. https://doi.org/10.22271/09746315.2022.v18.i2.1596
45. Shivdas BS. Effect of ethanolic plant extractives on cephalic neuroendocrine system of BmNPV inoculated 5th instar larvae of *Bombyx mori* L. (Lepidoptera, Bombycidae). Entomon. 2024;49(2):235–42. https://doi.org/10.33307/entomon.v49i2.1175
46. Mohanta MK, Saha AK, Saleh DK, Hasan MA. Bioefficacy of some plant extracts against pathogenic bacteria isolated from diseased silkworm larvae. Uni J Zool. 2013;32:9–14.
47. Mohanta MK, Saha AK, Saleh DKMA, Islam MS, Mannan KSB, Fakruddin M. Characterization of *Klebsiella granulomatis* pathogenic to silkworm, *Bombyx mori* L. 3 Biotech. 2014;5(4):577–83. https://doi.org/10.1007/s13205-014-0255-4
48. Surendra DM, Chamaraja NA, Yallappa S, Bhavya DK, Joseph S, Varma RS, et al. Efficacy of phytochemical-functionalized silver nanoparticles to control flacherie and sappe silkworm diseases in *Bombyx mori* L. larvae. Plant Nano Biol. 2023;5:100048. https://doi.org/10.1016/j.plana.2023.100048
49. Choudhury A, Guha A, Yadav A, Unni B, Roy M. Causal organism of flacherie in the silkworm *Antheraea assama* Ww: Isolation, characterization and its inhibition by garlic extract. Phyto Res: PTR. 2002;16(1):S89–90. https://doi.org/10.1002/ptr.810
50. Omar S, Fathy D. Evaluation of controlling silkworm bacterial diseases using propolis extract and cinnamon oil. J Agri Chem Biotechnol. 2016;7(7):213–18. https://doi.org/10.21608/jacb.2016.40892
51. Jaisyprabha R, Quraiza MTF, Jespa JP, Prabha V. Effect of *Phyllanthus niruri* on the *Escherichia coli* infected silkworm, *Bombyx mori* L. Uttar Pradesh J Zool. 2024;45(16):8–14. https://doi.org/10.56557/upjoz/2024/v45i164282

52. Matsumoto Y, Sekimizu K. Silkworm as an experimental animal for research on fungal infections. Microbiol Immun. 2019;63(2):41–50. https://doi.org/10.1111/1348-0421.12668

53. Dongare SK, Gaikwad PM, Pawar SS, Khyade VB. Studies on symptomological and economic parameters of silk cocoons of *Bombyx mori* inoculated with *Beauveria bassiana* (Bals.) Vuill. International Acad J Account Fin Manage. 2018;05(01):28–34. https://doi.org/10.9756/iajafm/v5i1/1810004

54. Bhat A, Dar KA, Ganie NA, Sahaf KA, Mir SA. Efficacy of botanical extracts on the management of muscardine disease of silkworm, *Bombyx mori* L. caused by *Beauveria bassiana*, (Bals) Vuill. J Entomol Res. 2021;45(3):430–35. https://doi.org/10.5958/0974-4576.2021.00067.0

55. Saharia S, Kalita S, Kalita D, Ojah A, Bardoloi S. Assessment of the effect of methanolic herbal extract on cocoon parameters and tensile properties of silk fiber spun by *Beauveria bassiana* infected Muga silkworm, *Antheraea assamensis* Helfer. Asian J Bio Life Sci. 2023;12(2):395–401. https://doi.org/10.5530/ajbls.2023.12.52

56. Saad MSI, Elyamani EMY, Helaly WMM. Controlling of bacterial and fungal diseases that contaminating mulberry silkworm, *Bombyx mori* by using some plant extracts. Bulletin Nat Res Centre. 2019;43(1). https://doi.org/10.1186/s42269-019-0218-3

57. Anitharani KV, Bhaskar RN, Gowda M, Chandrashekhar S, Peter A. Effect of medicinal plants on cocoon parameters of PM×CSR2 inoculated with BmNPV and *Staphylococcus sciuri*. Pest Manage Horti Ecosyst. 2022;28(2):81–86. https://doi.org/10.5958/0974-4541.2022.00043.1

58. Bora D, Khanikor B, Gogoi H. Plant based pesticides: Green environment with special reference to silkworms. In: Soundararajan RP, Editor. Pesticides - Advances in Chemical and Botanical Pesticides. InTech; 2012 https://doi.org/10.5772/47832

59. Sut R, Naan TR, Dutta RB, Kashyap B, Saikia M, Gogoi I, Saikia H. The Uzi fly challenge: Biological insights and threats to Muga silkworms. Ann Res Rev Bio. 2024;39(9):1–10. https://doi.org/10.9734/arrb/2024/v39i92113

60. Bari F, Kumar R, Lavannya V. Study of Uzi fly, *Exorista bombycis* (Louis) infestation during rearing of mulberry silkworm in different seasons in Karnataka. Indian J Entomol. 2023:142–44. https://doi.org/10.55446/IJE.2023.1178

61. Sathe TV, Desai AS. Economical and distributional status of Uzi fly, *Exorista sorbillans* Wied. (Diptera: Tachinidae) in sericulture in India. Indian J Appl Res. 2014;4(8):10–13. https://doi.org/10.15373/2249555X/August2014/3.

62. Naan T, Sut R, Kashyap B, Dutta RB, Saikia M, Gogoi I, Saikia H. Effectiveness of plant oils for bio-intensive control of Uzi fly infestation in mulberry silkworm (*Bombyx mori*): A comparative study. J Adv Bio Biotechnol. 2024;27(9):1025–37. https://doi.org/10.9734/jabb/2024/v27i91373

63. Khanikor B, Bora D. *Ocimum gratissimum* Linn. (Lamiaceae) essential oil for the management of *Exorista sorbillans* Wiedemann (Diptera: Tachinidae) menace of silkworm in seri ecosystem. J Asia-Pacific Entomol. 2022;25(3):101960. https://doi.org/10.1016/j.aspen.2022.101960

64. Alamgir ANM. Herbal drugs: Their collection, preservation and preparation; evaluation, quality control and standardisation of herbal drugs. In: Therapeutic Use of Medicinal Plants and Their Extracts: Volume 1. Progress in Drug Research, vol 73. Cham: Springer; 2017. p. 453–95 https://doi.org/10.1007/978-3-319-63862-1_10

65. Nishad J. Stability of plant extracts. In: Mir SA, Manickavasagan A, Shah MA, editors. Plant Extracts: Applications in the Food Industry. Academic Press; 2022. p. 89–126 https://doi.org/10.1016/B978-0-12-822475-5.00007-7

66. Rattanapan A, Sujayanont P. Impact of neem seed extract on mortality, esterase and glutathione-s-transferase activities in Thai polyvoltine hybrid silkworm, *Bombyx mori* L. Insects. 2024;15(8):591. https://doi.org/10.3390/insects15080591

67. Mahmoud M. Effect of certain evaluated plant crude extracts on the productivity of silkworm (*Bombyx mori* L.). J Adv Agri Res. 2014;1;19(1):50–59.https://doi.org/10.21608/jalexu.2014.160304

68. Talari S, Akula S, Kuntamalla S, Nanna RS. Effect of stem bark extracts of *Oroxylum Indicum*; an ethnomedicinal forest tree on silk production of *Bombyx mori*. Int J Pharma Sci Res. 2014;5(2):568. https://doi.org/10.13040/ijpsr.0975-8232.5(2).568-71

69. Barge SB, Pardeshi AB. Influence of dietary supplementation of *Sida acuta* plant extract on the mulberry silkworm, *Bombyx mori* L. Int J Zool Stud. 2018;3(2):199–202.

70. Kumari S, Hassan SMM. Effect of giloy on the commercial parameters of the *Bombyx mori*. Acta Entomol Zool. 2023;4(1):55–58. https://doi.org/10.33545/27080013.2023.v4.i1a.97

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting

Copyright: © The Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited (https://creativecommons.org/licenses/by/4.0/)

Publisher information: Plant Science Today is published by HORIZON e-Publishing Group with support from Empirion Publishers Private Limited, Thiruvananthapuram, India.