



Infectious Disease (Fungal, Bacterial, Viral, and Nematodal) of Mulberry Plant and Its Control Measure: A Review

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Sericulture is an allied agricultural activity. It is concerned with the production of silk (and its byproducts). The silks produced in sericulture can be widely categorized as Mulberry silks and Non-Mulberry silks (also called Vanya silk meaning wild silks). Mulberry silk is most widely produced and it plays an essential role in the economic growth of the industry. Mulberry silk is obtained by rearing mulberry silkworms (*Bombyx mori* L). During rearing, they are fed mulberry leaves which are obtained from the mulberry plants; the primary food plant of the silkworm. The mulberry plant is perennial in nature. It belongs to the Moraceae family and the genus *Morus* with a wide variety of species, viz. *Morus alba*, *Morus nigra*, *Morus serrata*, etc. Mulberry plants are widely distributed all around the world in Tropical, Subtropical, and Temperate regions. It finds its early roots in Southeast Asia. The Mulberry plant falls prey to many diseases caused by various organisms like bacteria, viruses, fungi, and nematodes. The occurrence and severity of the diseases vary with season, varieties, agro-climatic zones, and the cultural practices that are undertaken. These diseases affect the mulberry leaves, stems, and different parts of the plant.

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Affected plants stop the growth and reduced leaf yield. As well as, these leaves are not suitable for silkworm feeding. This review mainly focuses on infectious diseases (fungal, bacterial, viral, and nematode) of mulberry plants and their management.

Keywords: Mulberry silkworm; disease; Bombyx mori; symptoms; Morus indica; sericulture; causal organism; leaves.

1. INTRODUCTION

Sericulture is one of the important branches of agriculture science. This agro-based industry producing different types of raw silk, such as mulberry, muga, tassar and eri. Among these, mulberry silk has high demand in the agriculture market. This mulberry silk is produced by the mulberry silkworm (*Bombyx mori* L) [1]. The host plants of *Bombyx mori* L is *Morus alba*, *Morus nigra*, *Morus rubra*, *Morus indica*, *Morus laevigata*, *Morus serrata* etc [2]. Mulberry plants having about 68 species and the majority of the species is occurring in Asia [3]. On the basis of geographical location and environmental condition, all the varieties of mulberry plants are distributed in different parts of India as well as the world [4,5]. Mulberry is derived from the Latin word *Morus*. It belongs to order urticales and the family Moraceae [3]. One healthy plant is very much required for the rearing of silkworms and as well as to get the good quality of the silk from the cocoon. Mulberry cultivation is the not only rearing of silkworms but also the production of silk. During mulberry cultivation many diseases attacked the mulberry plant, all diseases are caused by fungi, viruses, bacteria, and nematodes [2]. These diseases may be soil-born or air-born. The mulberry diseases are divided into different categories on the basis of mode of transmission, prevalence, plants part affected, periodicity, and parasitic in nature. The causes decrease of leaf production and losses of nutritive content of the leaf. Affected leaves are not suitable for silkworm feeding purposes and it can harm silkworm growth and development. Mulberry disease may be infectious or non-infectious [6]. Infectious diseases are categorized into fungal (Powdery Mildew, Cercospora Leaf Spot, Pseudocercospora Leaf Spot, Fusarium Leaf Spot, Black Leaf Spot, leaf spot, leaf rust, Cerotelium leaf rust, Anthracnose Disease), bacterial (leaf blight, bacterial rot disease), viral (Mulberry leaf mosaic disease, mulberry yellow net vein, dwarf disease, mulberry ring post) and nematode. All diseases having different symptoms and different factors for the development of the disease [7].

2. FUNGAL DISEASE

2.1 Powdery Mildew

Powdery Mildew is one of the major leaf diseases of the mulberry plant. This disease is caused by *Phyllactinia corylea*, which belongs to the division Ascomycota [8]. It is affecting during the rainy and post rainy seasons. The disease incidence is more from August to December. It spreads so fast through the distribution of the fungal spores with the help of wind. In one farm, they affected more than 70 to 80% of the leaf within one week, and leaf yield loss about 35 to 40% [6]. This fungus affected only mature leaves. Affected leaves reduced 30% of the protein content and these leaves are not suitable for silkworm rearing. After feeding of the infested leaves, silkworm becomes weak and affect with various diseases [9].

Symptoms: In the beginning stages, white powdery spots are appearing on the upper surface of the leaves. In later stages, the whole leaf cover with them, and gradually these spots turn yellowish-brown and then black in color [10]. The texture of the affected leaves hardens compare to the previous time and then leaves dry, leathery, and fall off [9].

Control measure: Planting some mildew-resistant varieties such as MR₁ and MR₂. During plantation time, follow wider spacing (90cm×90cm) and paired row planting system [(90+150) ×60cm] to decrease the humidity [11]. Spraying of .05% Morestan, 0.1% Karathane to the entire leaves of field. Removal of disease-affected leaves and burn them. Harvesting of leaves at the proper time to decrease the disease incidence [5].

2.2 Fungal Leaf Blight

It is one type of air-borne disease. The causal organism of the fungal blight is *Alternaria alternata* and *Fusarium pallidoroseum* [12]. The disease incidence is more in summer and during rainy seasons. The favorable temperature is 25

to 30°C and humidity is 50 to 60% for the growth of the disease. It is transmitted through fungal spores by water droplets, wind. The crop loss is 10 to 12% [6].

Symptoms: Early-stage leaves become brownish in color and in advanced stage blackish in color. Generally, it is started from the tips portions of the leaf. In the end, the entire leaf becomes brown in color and falls off [3].

Control measure: Spraying of 0.2 % Dithane M-45 (Mancozeb 75 % WP) on the leaves. During plantation time, follow wider spacing (90cm×90cm) and paired row planting system [(90+150) ×60cm] to decrease the humidity and prevention of the disease [13].

2.3 Cercospora Leaf Spot

It is one of the major leaf diseases of the mulberry plant. The causal organism of the disease is *Cercospora moricola* (Division: Deuteromycota) [14]. This disease is airborne. During the rainy season, the disease incidence is more from June to November. Normally it is started after 35 to 40 days of pruning. This disease is spread through flash dispersal of the conidiospores by raindrops, wind. The affected 80% of the leaf of the whole farm within 7 to 8 days [2]. The spores cannot live temperature below 20°C and above 30°C. The favorable humidity is 75 to 80% for the growth of the disease. The crop loss is about 10 to 12% [6].

Symptoms: The appearance of a small circular or irregular white color spot with a yellow halo and then leaves falling off [14].

Control measure: Removal of disease-affected leaves and burn them. Cleaning of the mulberry garden to remove the weeds and unnecessary plants. Spraying of Bavistin 0.05%, Difolatan 0.2%, and Benlate at the rate of 5 ml per plant twice or thrice a 15 days interval [15].

2.4 Pseudocercospora Leaf Spot

It is one of the major leaf diseases of the mulberry plant. It is caused by *Pseudocercospora mori* (division: Deuteromycota) [6]. The disease incidence is more from June-August to December. This disease has brown to dark mycelia colonies on the upper surface of the leaves. The conidiophores are broken out through stomata [16]. The affected 60 to 70% of the leaf of the

farm once it is affected by one plant. Some varieties such as C₇₆₃, C₁₇₂₆, S₁₆₃₅, Tr₄, Tr₁₀ having resistance against this disease [2].

Symptoms: On the upper surface of the leaves, hyphal mats are formed. The color of the hyphal mat was grey to brown and appeared deep brown color spots on the lower surface of the leaves. Later, the lower surface of the leaf become yellowish in color and slowly it covers upward also. Finally, the defoliation of the leaf [2].

Control measure: Spraying of Carbendazin 0.1% solution to the leaves at the first stage of infection. Removal of disease-affected leaves and burn them [17].

2.5 Fusarium Leaf Spot

It is one of the leaf diseases of the mulberry plant. The causal organism of the disease is *Fusarium solani* (Division: Deuteromycota) [7]. The affection occurs throughout the year. The disease incidence is more during the dry and hot seasons. The affection is more some varieties such as Goshorami, Ichinose, Sujanpuri, Leimoncina, Kasuga. The fungus grows into mycelium and has double-layer conidia. This disease not only affects the leaves but also affects the growth and development of the silkworm body [18].

Symptoms: Affected leaves become dry and appear burnt. Leaves turn yellow in color due to the breakdown of the chlorophyll in them. Moreover, buds are also affected and stopping apical growth [7].

Control measure: Spraying of Dithane M-45 or Bavistin at 0.25% concentration to the leaves [13].

2.6 Black Leaf Spot

It is one type of leaf disease and it is caused by *Colletotrichum gleosporioides* (Division: Deuteromycota) [6]. The peak period of the disease is from June to October, especially in the post rainy season. This disease is affecting in some varieties such as MR₂, China Peking, ACC₂₃₃, and ACC₁₅₁ [2].

Symptoms: Small black or dark brown rectangular spots appear on the mature leaves. In later stages, leaves become yellow in color [6].

Control measure: Common fungicides can be used, such as Blitox, Bavistin to control the fungus. Leaves can be used for rearing after one week of spraying [17].

2.7 Leaf Rust

Leaf rust is the most dangerous leaf disease of the mulberry plant. It is caused by *Aecidium mori* (Division- Basidiomycota) [19]. The disease incidence is more in August-September and February. This virus occurs mostly in high temperature and high humidity conditions. The affected leaves are not suitable for silkworm rearing. Generally, this virus affecting more in mature leaves [20]. The favorable temperature is 23-26°C and humidity is above 70% for the development of the disease. The losses of the crop are 10 to 15%.

Symptoms: Irregular reddish to rusty brown spots, pinheads in size appear on the lower and upper surface of the leaves. Affected parts become deformed [20].

Control measure: Leaf harvest should be done at the proper time. During plantation time, follow wider spacing (90cm×90cm) and paired row planting system [(90+150) ×60cm]. Spraying of 0.2% Kavach on the leaves [21].

2.8 Cerotelium Leaf Rust

It is one of the leaf rust diseases of the mulberry plant. The causal organism of the disease is *Cerotelium ficii* (Division: Basidiomycota) [6]. It occurs mostly in the winter season. This disease is spread through water droplets and wind, which distribute the urediospores from the uredium. The leaf loss is about 10 to 30% [18].

Symptoms: Rust spots appear on the leaves in the lower part of the branch. Leaves are deformed and then, drop off [18].

Control measure: Fungicides can be used such as Kavach, Foltaf. Utilisation and timely harvesting of leaves to reduce the net loss [21].

2.9 Anthracnose Disease

It is one type of fungal disease in the mulberry plant. The causal organism is *Colletotrichium ilindemuthianum* (Division: Deuteromycota) [19]. The disease incidence is more in the post rainy season from June to October. These disease is affecting in some varieties such as MR-2, China Peking, ACC₁₅₁ and ACC₂₃₃ [2].

Symptoms: In the early stage, brown to reddish-brown in color, and circular spots appear in the leaf blade. Later circular spots become irregular and extend to the margin, then turn brown in color. The leaves become completely burnt and dry off [2].

Control measure: Spraying of Blitox at 2% concentration on the leaves. Fungicides can be used such as Captof, Bavistin [15].

3. BACTERIAL DISEASE

3.1 Bacterial Leaf Blight Disease

Leaf blight is the major bacterial disease of the mulberry plant. It is caused by *Pseudomonas mori* and *Xanthomonas mori* [22]. The disease is both air and soil-borne. The disease incidence rate is more during hot and humid conditions. Irrigation and cultivation practices in the soil are other factors for transmitting the disease. This disease mainly affects the leaves but they can be affected in young and old shoots. The crop loss is 5 to 10% [23].

Symptoms: Small, water-soaked non-uniform spots appear on the lower margin of the leaves. Later spots become larger, color changes into brown with a yellow margin. Gradually, it is spread to the upper side. Affected young leaves become wrinkled and curl outwards [22]. In advance stages, symptoms are divided into two categories such as halo and necrotic types. Halo symptoms occur in the dry season and dry area. In the upper part of the plant, yellow color halo spots are developing in the leaves. Leaves become bent or rolled and speckled distorted appearance in the leaf. In the case of necrotic type, bacteria infected the leaf veins and petioles [2]. The necrotic type mostly occurs in wet weather. Affected tips of young shoot become necrotic and distorted torn appearance in the leaf.

Control measure: Raising disease-resistant varieties like Kanva -2. Foliar spray of phyto bacteriomycin 0.05% to 0.01% solution on the leaves. The affected plant should be removed and burn it. Close spacing should be avoided [24].

3.2 Bacterial Rot Disease

It has two types, such as Bacterial rot disease I and Bacterial rot disease II. Bacterial rot disease I caused by the *Bacterium moricolum* [2].

Symptoms: Forming a whitish colony in affected twigs, is generally at the ground level. Leaves become wither and twigs break off.

Bacterial Root Disease II caused by *Bacterium mori*.

Symptoms: Affected leaf and stem are distorted, as well as tissues, rot, and growth are also affected [2].

Control measure: More fertilizing should be avoided (especially nitrogen fertilizers). The affected plant part should be removed and burn it. Follow cultural practicing like weeding, spacing, tilling, etc [24].

4. VIRAL DISEASE

4.1 Mulberry Leaf Mosaic Virus

It is one of the major viral diseases of the mulberry plant. The virus is spread through insects vectors like aphids or grafting [3].

Symptoms: Mosaic, green and dark patches appear on the leaves. Development of the plant high is decreased and as well as reduced leaf size. Dwarfed and chlorotic lesions appear on the leaves [25].

4.2 Mulberry Yellow Net Vein Virus

It is one type of viral disease of the mulberry plant. It is transmitted through grafting [26].

Symptoms: Affected leaves of the vein turn in yellow in color and net vein appearance. Growth and development of the plant are reduced and leaves become twined & distorted [4].

4.3 Mulberry Ring Post

It is another type of viral disease of the mulberry plant. It is spread through grafting and nematodes.

Symptoms: Show filiform and ring post symptoms. This virus infects quickly and covered all the newly emerged leaves of the plant [19].

4.4 Dwarf Disease

The dwarf disease is one type of viral disease of the mulberry plant. The causal organism of the disease is mycoplasma.

Symptoms: Leaves become irregularly arranged and yellow in color [2].

Control Measures for Viral Diseases: Removal of affected plant parts and burns them. Old crops should be removed from the field before plantation. Farm implement should be clean and disinfectant with trisodium phosphate (3 to 10%) [27]. Planting materials should be virus-free (cutting, grafting). Spraying of insecticides such as 0.01% Deethoate, Methyl Parathion to the plants. Nematicides can be used (Carborifuran at 30 kg/ha/yr four times). Raising virus-resistant varieties and thermotherapy can be followed (exposure of planting materials to sunshine) [28].

5. NEMATODAL DISEASE

It is one of the major diseases of the mulberry plant. The causative organism is nematodes [29]. They have different types of species such as *Meloidogyne incognita*, *Hemicriconemoidales communis*, *Haplolaimus indicus*, *Rotylenchus reniformis*, *Xiphinema basini*, *Meloidogyne javanica*, etc. Among these, *Meloidogyne incognita* is the most common species in India. The disease incidence is more in the summer season. It occurs throughout the year and they prefer sandy soils. These diseases are transmitted through farm implements and contaminated soil. The favorable temperature is 20 to 30°C and pH 4-8 for growth of the disease [30]. The larvae are soil penetrate the roots near the root caps and shifted to the other parts of the roots. The nematode larvae are secreted by the proteolytic enzyme inside the root and that releases the growth hormone from the precursor of the plant [31]. The hormones are responding from the root tissue by cortical and stellar cells, which generate the formation of giant cells & large cavities in the cortex. Each gall has 4 to 5 giant cells. The galls apply pressure on the vascular tissues and affect the root function. The loss of the crop is 15% [32].

Symptoms: Stunted plant growth and reduced leaf yield. It has underground symptoms like the formation of galls on the roots. Young galls are whitish-yellow in color. Old gall is pale brown in color and big in size. In the root surface, root nodules are appeared [33].

Control measures: Cultural practices should be following; it includes ploughing and mulching the soil, application of organic manure and compost to the plot. Oil cakes (1500 kg/ha/yr) can be used to control the nematode affection [34]. Soil

fumigants can be used such as D-D (Dichloropropane and Dichloropropene) mixture, Methyl bromide to control the nematode population. Applying of Timet (3kg/ha/yr), Furadon 3G (6kg/ha/yr) to the plantation plot [35].

6. CONCLUSION

The mulberry silkworm (*Bombyx mori* L) holds a prestigious state in the silkworm industry. These silkworms naturally produce silks that are pure white in color. The demand for mulberry silk is ever rising in the current market. Seeds of good health and quality, healthy host plants, and good environmental conditions are the major elements that define a successful rearing cycle of the mulberry silkworm. Among all these factors, the food plants (Syn: Host plants) have a great role to play when it comes to the growth and development of the silkworm larvae. In the present research, it was unearthed that diseases of host plants possess a major difficulty for mulberry silkworm rearing due to their affinity towards the host plants. The infectious diseases (fungal, bacterial, viral, and nematode) are the major diseases that extensively threaten the host plants and are considered as major diseases of the genus, *Morus*. Therefore, it is imperative to manage the diseases effectively by using appropriate control measures. Healthy host plants are the foundation for the development of the sericulture industry. Hence, it is important to control the diseases scientifically to provide protection to the silkworm host plants and to minimize future losses.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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