

# INTEGRATED MANAGEMENT OF MULBERRY DISEASES FOR DIMINISHING DETERIORATION IN QUALITY PRODUCTION OF MULBERRY

## Abstract

Silk is Nature's gift to mankind and a commercial fiber of animal origin other than wool. Being an eco-friendly, biodegradable and self-sustaining material; silk has assumed special relevance in present age. Promotion of sericulture can help in ecosystem development as well as high economic returns. Sericulture is practiced in India and India is the 5th largest producer of silk in the World. It has been identified as employment oriented industry. All the sections of sericulture industry, viz. mulberry cultivation, silkworm seed production, silkworm rearing, reeling and weaving of silk and collection of byproducts and its processing provide a large scale employment, thereby a source of livelihood for the rural and tribal people. Sericulture industry is rated as the second largest employer in India. Owing to this peculiar nature, the Indian planners have identified sericulture as one of the best-suited occupations for ideal growth and development of rural India. Mulberry sericulture has been traditional occupation in Karnataka, Tamil Nadu, A.P. and Kashmir. North-eastern part of India is the only region in the world where all four varieties of silk are produced.

Silkworm diseases and mulberry insect pests and diseases are the major biotic factors responsible for the decrease in silk production in general. Mulberry (*Morus* spp.) the sole food plant of silkworm, *Bombyx mori* L. is a perennial crop with diverse genetic base.

**Keywords:** Mulberry, Deterioration, Diseases.

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## I. INTRODUCTION

The making of silk has a lengthy history. In 2640 B.C., Xilingji (Hsi-ling-chi), the third emperor of China, Huangdi (Hoang-Ti), discovered silk. Later, sericulture spread across all of China, and silk rose in value. Since at least 5,000 years ago, sericulture, or the raising of silkworms for the manufacture of raw silk, has been practiced in China. From there, it moved to Korea, Japan, India, and later the West. The wild silk moth *Bombyx mandarina*, whose range extends from the northern part of India to northern Korea, China, Japan, and the far eastern areas of Russia, was used to domesticate the silkworm. Contrary to its Japanese or Korean ancestry, the tamed silkworm is of Chinese origin. The lucrative trading route known historically as the Silk Road or Silk Route, named after its most valuable commodity, was eventually established due to demand for this exotic fabric. A Chinese princess allegedly wed an Indian prince, according to another legend. In her extravagant headdress, she carried mulberry cocoons or silkworm eggs. As a result of her disclosure of the silkworm-raising secret, India began to produce more silk. In the seventh century AD, sericulture as a practice extended from the Mediterranean region to Africa, Spain, and Sicily. Modern equipment, enhanced methods, and extensive research helped Japan's sericulture business develop in the later part of the 19th century. The world's top silk producers right now are Japan, China, Korea, Italy, the Soviet Union, France, Brazil, and India.

The only other commercial fiber of animal-based origin besides wool is silk, which is a gift from nature to humanity. Silk has special significance in the modern era since it is a material that is environmentally benign, biodegradable, and self-sustaining. Promotion of sericulture can result in both substantial financial benefits and the development of ecosystems. India engages in sericulture and ranks as the world's fifth-largest producer of silk. It has been classified as an industry that promotes employment. The cultivation of mulberries, the generation of silkworm seeds, the rearing of silkworms, the reeling and weaving of silk, the collecting of byproducts, and their processing are all aspects of the sericulture industry that generate a significant amount of work and, consequently, a source of income for rural and tribal people. The sericulture sector is considered to be India's second-largest employer. Sericulture has been deemed one of the best jobs for the optimal expansion and development of rural India by Indian planners due to this particular nature. In Karnataka, Tamil Nadu, Andhra Pradesh, and Kashmir, mulberry sericulture has been a traditional occupation. The only place in the world where all four types of silk are produced is in India's northeast.

The main biotic factors causing the general decline in silk output are silkworm diseases and insect pests and diseases of mulberries. *Bombyx mori* L.'s primary food source, the mulberry (*Morus* spp.), is a perennial crop with a wide genetic base. Worldwide, large agricultural losses are caused by plant diseases, which are regarded as a key biotic constraint (Rasool *et al.*, 2022). Mulberry has become more susceptible to many plant diseases as a result of intense high yielding variety cultivation under a variety of agroclimatic settings (Philip *et al.*, 1994; Teotia and Sen, 1994; Sukumar and Padma, 1999). To improve the quantity and caliber of cocoons, mulberry leaves must be free of disease. The production of silk cocoons is also impacted by weather conditions that encourage disease outbreaks, which cause losses of 15 to 20% in mulberry crops. In India, mulberry trees are susceptible to the following diseases

## II. FUNGAL DISEASES

- 1. Powdery Mildew – *Phyllactiniacorylea*:** The fungus is a member of the Ascomycete order Erysiphales and family Erysiphaceae. Ramakrishna and Sudan made the first official report of the illness in 1954. It occurs during the wet and winter season (July-March), and is more common in hilly locations than plain ones. According to Sullia and Padma (1987), feeding mildew-affected leaves to silkworms has a negative impact on their growth and development, which leads to a low production of cocoons and silk. According to Munshiet *al.* (1994), the peak season for powdery mildew occurrence in Kashmir Valley is from August to November. In addition to reducing nutritional value, mildew causes a loss of about 12% (Teotia and Sen, 1994; Qadri et al., 1998). Although there are differences in the diseases among the mulberry cultivars grown in Kashmir, none have been found to be fully free from them.
  - **Symptoms:** On the lower surface of the leaves, white powdery patches are initially visible before they eventually cover the entire leaf surface. later change color from black to brown. Infected leaves deteriorate and drop off. Low temperatures (24–26°C) and high humidity (>70%) encourage the spread of the disease.



Source: Irfan et al., 2011

- **Pathogen and Disease Cycle:** The pathogen *P. corylea* is an ectoparasite that enters the cells of the epidermis through the stomata to take up nutrients (Kuno *et al.*, 1980). Both asexual and sexual reproduction are mechanisms used by the fungus. While sexual reproduction occurs later and under unfavorable climatic conditions, asexual reproduction occurs in the early phases. Conidia are the reproductive organs used in asexual reproduction. The mycelium, which resembles an appressorium in shape and is unbranched hyaline, produces a mycelial mat and adheres to the surface of the leaf utilizing globed adhesive structures. Hyaline, single-celled conidia with dimensions of 20 x 70 µ are terminally carried on septate conidiophores. Through wind currents, the disease is disseminated by the freed conidia. The fusion of antheridium and ascogonium results in the development of fruiting bodies termed cleistothecia, which are used for sexual reproduction. Numerous colorless needle-shaped appendages with inflated, ball-like basal parts cover the cleistothecia. Five to fifty asci are found inside

the cleistothecium. Each ascus has two ascospores when it matures under favorable conditions and is freed by splitting cleistothecia. Ascospores that have germinated create hyphae and transmit the illness by developing conidia. Ectophytic mycelium is produced by the fungus. Through haustoria injected into the mesophyll tissues, it receives nutrients from the host. Conidiophores are erect, long, and hyaline structures that clip off conidia with an oval form at their tips. Cleistothecia are asci-bearing, flat, sphere-shaped, papillate structures.

- **Mode of Spread and Survival:** Conidia or ascospores are the two ways the fungus spreads.
  - **Management:** Widen the space between plants so that the garden will receive enough sunlight and airflow. cultivating resistant cultivars like China White, MR1, and MR2. Bavistin (0.2%) or Karathane (0.2%) spraying is useful for disease control. If the condition is severe, two sprays spaced 15 days apart are needed. Yellow lady bird beetles, *Illeiscincta* Fab, and *I. indica* Timb have been identified as natural enemies that prey on *P. corylea* conidia and mycelia. On leaves that are eaten by beetles, the fungus *P. corylea* is unable to reproduce (Kumar and Chowdary, 2001). According to *Cladosporium* spp, a fungus, *P. corylea* conidiophores and conidia are hyper parasitic (Rao and Sullia, 1981).
2. **Leaf Spot- *Cercospora Moricola*:** Patel *et al.* (1949) from India first described the *Cercospora moricola* Cooke-caused Leaf Spot disease. The fungus is a member of the class Deuteromycetes, order Moniliales. The disease is highly prevalent from June to December, during the rainy season, and continues into January and February (Siddaramaiah *et al.*, 1978). According to the season and variety, it decreases leaf yield by 10% to 20% (Sharma *et al.*, 2009). According to a survey done by Kausar (2003) in 1999, the Kashmir Valley has the highest incidence (66.47%) and intensity (50.03%) of the leaf spot disease. With a mean incidence of 41% and an intensity of 24% throughout the Kashmir Valley, the district of Srinagar had the lowest illness incidence (17.17%) and intensity (7.91%). None of the 34 genotypes of mulberry were resistant to disease. In contrast, Botetul, Takawase, and Serpentina were shown to be quite vulnerable. Varieties including Obawase, KNG, Brantul, and Senmestsu were classified as resistant to the illness. However, it was shown that the majority of commercial varieties, including Goshocerami, Kokuso-20, 21 and 27 Kanva-2, Limoncina, etc., were only mildly susceptible.
- **Symptoms:** In the beginning, brownish circular or irregular leaf spots expand, coalesce, and eventually form shot holes. Leaf damage that is severe causes them to turn yellow and drop off early. A dense mass of intertwined, cushion-like hyphae that produce conidia on conidiophores is produced by the fungus *C. moricola*. Conidia are 70 x 30 in size, 3-7 celled hyaline, and tapering. Conidia begin to grow and produce hyphae, which then invade host cells and cause the mycelium to form. Conidia are the main means by which the disease is transmitted (Sukumar and Ramalingam, 1981). It takes 10 to 15 days after the initial vaccination for symptoms to appear.



**Source:** Mulberry disease calendar for sericulture areas of India

- **Management:** Follow broader plantation spacing (90 cm x 90 cm) or paired row planting technique [(90 + 150) 60 cm] for cultural control.
- **Chemical Control:** According to Siddaramaiah *et al.* (1978), the systemic fungicide Bavistin 50 WP @ 0.1% concentration can be used to treat the leaf spot disease. About 200–250 grams of bavistin are needed for a mulberry garden that is one acre in size. If the illness is extremely severe, two sprays should be administered at intervals of 15 days. It is best to spray during the colder parts of the day. After one week of spraying, there is no lingering bavistin toxicity, and leaves can be securely used for silkworm rearing. Brown spot disease has been successfully treated with *Trichoderma harzianum* (Th-1) and *Trichoderma pseudokoningii* (Tp) (Sharma and Gupta, 2000). Leaf extracts of *Eucalyptus spp.* and *Calotropis gigantia* also found to be effective (Sarvamangala *et al.*, 1993).

### 3. Leaf spot (*Myrothecium roridum*)

- **Symptoms:** Initially, the surface of the leaf shows dark, uneven necrotic patches. Spots grow, spread out, and unite to form larger, uneven holes.



**Source:** Mulberry disease calendar for sericulture areas of India

- **Control:** Use paired row planting systems [(90 + 150) 60 cm] or greater plantation spacing (90 cm x 90 cm).
- **Chemical Regulation:** Spray 2 g/lit. of 0.1% Carbendazim 50% WP (Bavistin). After 10 days, a second spray may be applied if the disease is more severe. Furthermore, it was discovered that administering 0.2% of Foltaf80W had a 10-day safe window of effectiveness against *Myrothecium roridum* (Govindaia *et al.*, 1988 a).
- **Resistant Varieties:** The leaf spot disease is less likely to affect types with thick cuticles and epidermis. Varieties including Kalia Kutahian and Bilidevalaya were discovered to be immune, whilst Kanva-2, S-54, MR-2, C- 7gg, Jodhpur, Paraguay, RFS-135, RFS-175 and Almora local were resilient to this disease having less than 5% disease incidence. According to Govindaiah *et al.* (1989b), EB x Kosen and Mandaiaya have been demonstrated to be vulnerable.

#### 4. Leaf Spot (*Pseudocercospora Ramori*)

- **Symptoms:** On the lower surface of the leaves, small to medium-sized velvety black dots can be seen. Under the leaves, a few spots converge and spread. Leaves that have been severely affected turn yellow and prematurely defoliate.



**Source:** Mulberry disease calendar for sericulture areas of India

- **Control:** Spray 2 g/lit. of 0.1% Carbendazim 50% WP (Bavistin). After 10 days, a second spray may be applied if the disease is more severe.
5. **Root Rot- *Fusarium Oxysporum*, *Macrophomina Phaseolina*:** All regions of the country where mulberries are grown are affected by the disease, but to variable degrees. According to Philip *et al.* (1994), the prevalence of *F. solani*-caused mulberry root rot in southern India ranged from 3 to 55%. During the years 2001–2002, the prevalence of root rot disease in Kashmir Valley was 16.85% (Anonymous, 2002). Due to the root rot disease, the majority of seedlings raised for grafting economically significant cultivars as well as saplings put in fields in rearing zones fail. Regardless of age or system, abrupt drying of older plantations happens frequently.

- **Symptoms:** Affected plants experience sudden wilting, wilting of the leaves, and complete drying up. Plants that are affected can be removed with ease. Primary and secondary roots are rotting, and rotten roots turn black and have a lot of black sclerotia. bark of a root decays.



**Source:** Diseases and nematodes of mulberry

- **Management:** Removing and burning the sick plant's roots and stump. Applying neem cake @ 1 tonne/ha in four divided dosages. *Bacillus subtilis* antagonist @ 25 g/plant. Application of carbendazim with a 10 ml/1% dosage per plant soak the soil. *Trichoderma harzianum*, *T. viride*, and *Chaetomium indicum* applied to the soil at a rate of 2% were very successful in suppressing the root rot disease (Munshiet *al.*, 2009).

## 6. Stem Canker- *Lasiodiplodia (Botryodiplodia) Theobromae*

- **Symptoms**
  - **Nursery:** Inability of cuttings to sprout as well as the sudden withering and mortality of seedlings. stem and bud discoloration and drying above the earth. Below the soil's surface, the bark on the stem is rotting and flaking. Under infected bark, there are black mycelial threads visible, and the infected stem portion's bark has black eruptions on it. A 40–45% loss is brought on by this condition.
  - **Grown-Up Plants:** Bark discolouration in a grayish brown hue near the stem's cut ends. Plant mortality, late sprouting, mortality of buds and sprouts, black lesions on the affected area of the bark, and delayed sprouting. A few days following the plants' pruning, the aforementioned signs can be seen.
- **Management:** Avoid planting during the cold months. It is advised to pre-treat cuttings for 12 hours with carbendazim at a concentration of 4g/litre. After pruning, carbendazim @ 4g/litre should be sprayed or applied as a thin layer to the sliced surfaces of the stems (Sengupta *et al.*, 1991). It is advised to use biocontrol formulations containing 2 g/m<sup>2</sup> of *Trichoderma pseudokoningii*.

7. **Leaf Rust:** Ramakrishna first reported the *Cerotelium fici* (Cast.) to cause leaf rust disease in India in 1952. The pathogen is a member of the basidiomycete class and the Uredinales order and family. It is a frequent illness that manifests in the winter months (November to February). The disease is more likely to affect mature leaves. When rust is present, leaves will rapidly and prematurely defoliate, which will reduce the number of leaves available for late-age raising.
- **Symptoms:** Older leaves develop tiny, erratic reddish to rusty brown markings on their lower surface. On the adjacent upper surface of the leaves, there are black specks. The leaves prematurely turn yellow and wither.



**Source:** Mulberry disease calendar for sericulture areas of India

- **Disease Cycle:** *C. fici* is an obligatory micro-cyclic rust fungus. It primarily takes the forms of mycelium, uredia, and uredospores. Oval to spherical uninucleate uredospores are formed singly on uredophores in uredia. Uredospores germinate, generate hyphae, and enter the leaves through stomata in favorable conditions (22–24 oC and high humidity). In order to suck nutrients out of the host cells, the hyphae develop intercellularly within the host tissue. Uredospores quickly transmit the disease by water droplets and wind currents (Sengupta *et al.*, 1991).
  - **Management:** The disease can be reduced most effectively by using leaves promptly, especially during the winter months, and by allowing for greater spacing. spraying 500–625 g/ha of carbendazim. Use either 0.02 Triadimefon 25WP (Bayleton) @8g/10 litres of water or 0.2% Copper Oxychloride 50WP (Blitox) [4 g/litre of water]. No variety has been discovered to be totally immune (resistant) to this illness. A few cultivars, including AB x Phill, K2 x Kosen, ACC-115, and Almora local, were discovered to be only weakly resistant, with disease incidence of less than 20%. *Adhatoda zeylanica* and *Azadirachta indica* leaf extracts have been shown to be beneficial against rust illnesses. Rust was also successfully combatted by *Trichoderma harzianum* and *T. pseudokoningii* (VijayaKumari, 2014).
8. **Red Rust:** In addition to the typical leaf rust brought on by *C. fici*, red mulberry rust brought on by *Aecidium mori* (Baracl.) Diet has also been recorded in various regions of India. It is common in subtropical nations including China, Japan, the USSR, Korea, and others. It is a mild illness that is sporadically observed in northern India (Sengupta *et al.*, 1991). Young buds, leaves, petioles, and shoots are impacted by *Aecidium mori*. The



damaged buds swell up and coil abnormally, and they develop several faintly protruding yellow dots. On both surfaces of the damaged leaves, numerous little protruding dots are spherical and glossy yellow in color. Infected shoots and petioles can transmit the fungus via their vascular bundles. Mid-ribs and the afflicted veins develop abnormalities and coil up. Through aeciospores, the disease is transmitted by wind and water movement. Spraying the area with fungicides like Bavistin 50 WP, Foltaf 80W, or 0.5% concentration of sulfur dust will help manage the disease.

**9. Twig Blight:** According to Govindaia *et al.* (1988b), *Fusarium pallidoroseum* (Cooke) Sacc. is the fungus that is behind the twig blight disease. The pathogen is a member of the Moniliales order in the Deuteromycetes class (Najar *et al.*, 2011). In general, this disease was seen all year round, but the wet and post-rainy season (June-October) saw a higher occurrence. In addition to the aforementioned *Fusarium* species, reports of *F. roseum*, *F. moniliformis*, *F. etiseti*, *F. oxysporum*, and *F. accuminatum* on mulberry have also been made (Saito *et al.*, 1978; Shirata *et al.*, 1980; and Govindaia *et al.*, 1987).

- **Symptoms:** The sick plants have a bushy look with abundant growth of axillary branches, marginal browning or blackening of the leaves at first, and then full burning, causing severe defoliation. Affected branches feature dark longitudinal lesions that eventually cause the branches to split and dry out (Sengupta *et al.*, 1991).
- **Control Measures:** Foltaf 80W and DithaneM-45 have been found to be efficient against the twig blight among the several fungicides tested. The fungicides can be applied as a foliar spray in a lower concentration (0.2%) and as a soil drenching in a greater concentration (0.5%) because the disease is soil and air borne.

**10. Sooty Mold-*Capnodium*, *Cladosporium*, *Aureobasidium*, *Antennariella*, *Limacinula* and *Scorias*:** A black, non-parasitic, superficial fungal growth known as sooty mold grows on plant surfaces. The interaction between sap-feeding insects and non-parasitic fungi is what causes the sooty mold. Sooty mold is a major issue in both temperate and tropical regions of the world (Nelson, 2008). Plants turn dark and typically get sticky. The implicated fungi are saprophytic, which means they stay on the surface rather than invading the plant tissues. Although the mold doesn't produce nutrients on the plant, it is difficult to eradicate and limits the amount of light that reaches the leaves, which slows down photosynthesis. Plants and leaves get dark and frequently become sticky. The implicated fungi are saprophytic, which means they stay on the surface rather than invading the plant tissues. Although the mold is not feeding on the plant, it is difficult to remove and limits the amount of light that reaches the leaves, which slows down photosynthesis (Irfan *et al.*, 2012).

**11. Stem Rot:** Stem rot brought about by *Polyporus hispidus* (Bull) Fr. and *Ganoderma applanatum* (Pers). The drying and rotting of the twigs and branches are signs of the disease.

**12. Collar Rot:** It can be brought about by *Phomamororum* Sacc. and is prevalent from July to September. The plant begins to wilt as a result of the stem near the ground decaying (Yadav and Sukumar, 1987).

**13. Stem Blight:** *Phoma exigua* Desm. incites the disease stem blight which is widespread throughout the wet season (July to October). The fragile stem splitting and wilting of the leaves are the signs.

**14. Bud Blight:** Bud blight caused by *Fusarium lateritium* f.sp. *mori* Desm.) Maet. Sato occurs in winter (February-March) and the symptoms are rotting of the buds (Sukumarand Yadav, 1988).

### III. BACTERIAL DISEASES

In Japan, Hori recognized bacterial mulberry infections as early as 1901. Recently, Sinha and Saxena in 1966 reported on it in India. As a result, numerous workers in various sections of the nation have reported them. In the majority of mulberry-growing regions, especially in South India, bacterial infections are frequently present during the wet season. High elevations have a higher prevalence of these. The bacteria can survive in a temperature range of 10 to 40 °C, with 20 to 35 °C being ideal. Newly planted mulberry trees are more vulnerable to the attack of bacterial illnesses because these circumstances are more closely related to waterlogged conditions.

**1. Bacterial Blight:** Bacterial blight caused by *Pseudomonas mori* Bayer and Lambert belongs to the order Pseudomonadales of the class Schizomycetes. In India, it is a significant disease that reduces leaf yield by 5 to 10% from June to October.

- **Symptoms:** On the lower surface of the leaf, there are several erratic water-soaked areas. Curled, decaying, and turning brownish black in color, leaves become. The bark of new shoots has a number of black longitudinal blemishes. Defoliation and yellowing are further signs.



**Source:** Mulberry disease calendar for sericulture areas of India

- **Disease Cycle:** The main source of bacterial inoculum is soil. Through irrigation, agricultural operations, mechanical traumas, and biological agents, the illness can spread secondarily. The bacterium is rod-shaped, 0.9 to 1.4 by 1.8 to 4.5 microns in size, and is endospore-free. Nutrient agar colonies are round, white, smooth, flat, and translucent. 52°C is the thermal inactivation point.

- **Management:** The affected plant needs to be pulled out and burned. The polluted soil needs to be let out in the sun to dry. Streptomycin and streptocycline, two agricultural antibiotics, can be applied as a foliar spray at a concentration of 0.1% (Krishnaprasad and Siddaramaiah, 1978). After a 10 day period of spraying, the leaves can be used for raising silkworms. Neem leaf extracts work well and are offered commercially as Azhadirachtin 0.15%. It has been discovered that bioagents like *Trichoderma harzianum* and *Pseudomonas fluorescence* are efficient (Shahnaz *et al.*, 2022).
- 2. **Bacterial Wilt:** *Pseudomonas solanacearum* Smith, which is frequently seen from April to November during the rainy season, is the disease's culprit. The plants begin to wilt and the roots begin to rot. For the control of the illness, formalin solution (1:100) or bleaching powder 0.2% might be applied.
- 3. **Leaf Scorch:** According to Kostka *et al.* (1986), the fastidious xylem inhabiting bacterium (FXIB) frequently causes leaf scorch in July. The impacted leaves exhibit tissue desiccation and marginal necrosis.
- 4. **Shoot Soft Rot:** According to Takahashi and Sato (1978), *Erwinia corotovora* var. *corotovora* (Jones) Dye. is a prevalent pathogen in Japan responsible for Shoot Soft Rot disease in Mulberry. Early spring non-sprouting and soft rot of the overwintered shoot, as well as middle or late spring soft rot of the young shoot, are typical indications of the illness.

#### IV. MOSAIC DISEASE

Mosaic and yellow net vein are the two viral illnesses that have been linked to mulberries that originated in India. It is brought on by the mosaic virus, which only appears in temperate climates during the rainy season. The disease's symptoms include inward curling of the leaves, especially at the border and tip, as well as chlorotic lesions on the surface of the leaves. There are no existing controls that are compatible. Plants that are impacted may be pulled out and burned (Sengupta *et al.*, 1991).

1. **Yellow Net Vein:** The disease is spread by aphid sap and is brought on by a virus (Raychaudhury *et al.*, 1965). The disease's symptoms include chlorosis and wrinkles on the ventral surface of the leaves. Twisted and deformed leaves develop.
2. **Root Knot Nematode- *Meloidogyne Incognita*:** Root-knot nematodes are widespread throughout the world and harm numerous crops economically under a variety of climatic circumstances (Lamberti and Taylor, 1979; Anwar *et al.*, 2021). The first report of root knot disease on Indian mulberry was made by Narayan *et al.* in 1966. This disease is brought on by *Meloidogyne incognita* (Kofoid and White) Chitwood. It belongs to the family Heteroderidae, class Nematoda, and order Tylenchida. Recent research in South India has shown that sandy soil types with irrigation are where the disease is more prevalent. While the root-knot nematode, which is essentially a parasite of the roots, is difficult to identify and the damage very frequently goes unreported, the signs of fungal and bacterial illnesses that typically affect the foliage are simple to distinguish and may be easily handled. Furthermore, a weak parasite can do a lot of harm when nematodes are

present because they are known to generate disease complexes in conjunction with other microbes like fungus, bacteria, and viruses.

- **Symptoms:** The main signs include stunted plants, marginal necrosis, and yellowing of the foliage. Underground symptoms include the growth of distinctive knots or galls on the roots. Plant wilting is another occurrence. Roots that have been nematode-damaged do not use water and fertilizers as efficiently as healthy roots do. So, in addition to compromising leaf quality, inadequate plant growth also results in a loss of leaf yield of between 10 and 12 percent (Govindaiah, 1991).
- **Disease Cycle:** The life cycle of a nematode has three stages: egg, larva, and adult. Through the openings created by the stylet, the second stage female larvae enter the roots and dwell in the sub epidermal layer. It immediately begins eating the parenchymatous cells after entering. Characteristic knots can be seen on the roots as a result of the nematode-induced hypertrophy and hyperplasia. The larvae go through four moults in the roots before maturing into an oval or spherical female that lays eggs. 200–300 ellipsoidal eggs wrapped in gelatin are laid by each female. The eggs batch and larvae are released in the soil under favorable conditions. The life cycle takes 30 to 40 days to complete, and it occurs 2–4 times per year. Nematode disrupts the conduction of food and water by harming the xylem and phloem tissues. The nematode can grow best in soil that is between 15°C and 30°C and has a moisture content of 40–60%. The intensity of the nematode is very low in soils with no water and no moisture at all (Vangundy, 1985).
- **Control Measures:** The crop life cycle, overall lifespan, and cropping pattern all affect any nematode management method. Mulberry is a perennial crop, hence crop rotation is no longer feasible. Therefore, it would be crucial to control the disease in its early stages using several integrated approaches. The condition can be managed and kept at levels that are less harmful using a variety of strategies.
  - **Deep Digging/Ploughing:** During the summer, nematode eggs and larvae are exposed to the sun when an afflicted garden is dug up or ploughed. The majority of the nematodes die as a result of the high soil temperature and poor moisture.
  - **Nematicidal Plants can be Interplanted:** According to Brodie *et al.* (1970), nematicidal plants include sun hemp (*Crotalaria spectabilis*) and marigold (*Tagetes patula*). The production of a thick covering of antinematic chemicals traps the nematodes when they reach the root systems of these plants (Belcher and Hussey, 1917). In between mulberry rows, 10 marigold and sun hemp plants per square meter can be cultivated. These plants can be interplanted and mulched in the soil following vegetative growth to add more organic matter and improve soil fertility in addition to disease management.
  - **Use of Organic Oil Cakes to Improve the Soil:** The impact of various oil-cakes has been demonstrated by numerous workers. According to Khan *et al.* (1974) and Alamet A1. (1979), these oil-cakes are widely employed in agricultural crops to prevent pests and diseases and increase soil fertility. Neem oil cake was shown to

be among the most efficient cakes tested for fighting root-knot nematode illness. Neem oil-cake applied at a rate of 1 tonne per ha per year in four equally spaced dosages has been proven to be beneficial in mulberry (Sikdar *et al.*, 1986). The neem oil cake has no lingering harmful effects on the silkworm.

- **Application of Nematicides:** According to Ahuja (1983) and Sikdar *et al.* (1986), organic phosphates and carbomates are particularly successful at controlling the root-knot nematode disease. For the control of root-knot nematode disease, it is advised to apply temik 10 G (Aldicarb) or Furadon (carbofuran) at 3D kg/ha/year in four equal split dosages along with fertilizers. Rugby 10G, a brand-new nematicide produced by Rallis India, Ltd., was also shown to be quite successful when applied at a rate of 20 kg./ha./year. Nematicides should be well mixed into the soil during digging after which they should be regularly watered.
- Green leaf mulching is also beneficial in preventing the root-knot nematode disease (Govindaiah *et al.*, 1989C). Neem (*Azadirachta indica*) and pongamia (*Pongamia pinnata*) green leaves can be mulched at a rate of one ton per acre every crop.
- Three split doses of a biocontrol formulation combining *Verticillium chlamidosporium*, neem oil cake, and FYM (1:24:200) @ 200gm/plant are advised (Sharma *et al.*, 2009).

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