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Review Article

# Defoliators Infestation of Mulberry Plant (*Morus Alba* L) and Its Damages and Management: A Review

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**Abstract**

Sericulture is an agro-based industry and as well as it is one of the important branches of agriculture entomology. This industry produces four types of silk such as mulberry, muga, eri and tassar. Among these mulberry silk having great demand in the world agriculture market. This mulberry silk is produced by the mulberry silkworm, *Bombyx mori* (Order: Lepidoptera & family: Bombycidae). Mulberry silkworm (*Bombyx mori*) feeds only the mulberry (*Morus alba* L) plant. During the cultivation of mulberry silkworm (*Bombyx mori*) host plants play a very important role for complete successful rearing. But various insect pests infestation the host plant very badly. Among these, defoliators are the major insect pest for the mulberry plant. They affect the various part of the plant such as the leaf, bud, stem, etc. Infested plants stop the growth and decreased leaf production. As well as affected leaves are not suitable for silkworm bodies. This review mainly focuses on defoliators (Order: Lepidoptera, Orthoptera, Coleoptera) of the mulberry plant, their damages, and management.

**Keywords:** *Sericulture, Lepidoptera, defoliator, Bombyx mori, damage, pest, light trap.*

## Introduction

Sericulture is one of the important agro-based industries among all the industries of the agriculture sector. This industry solves the unemployment problem of society. The Sericulture industry produces four types of raw silk such as mulberry, muga, eri and tassar (Dandin. *et al*., 2000). Among these, mulberry silk plays a very important role in the agriculture market. Mulberry silk is produced by the silkworm, *Bombyx mori*. Mulberry (*Morus alba* L) plant is the main food plant for *Bombyx mori* (Ganga & Chetty. 1997). It is one type of perennial tree (Aruga. 1994). Quality of silk and farmer economic conditions fully depends upon in successful rearing of the silkworm. For one successful rearing, one healthy host plant is very much important (Ullal & Narasimhanna. 1977). A healthy host plant plays a very vital role in the growth and development of the silkworm body. Generally, mulberry plants are very much susceptible to various numbers of pests (Sengupta. *et al*., 1990). All the pest attacks the mulberry plant very dangerously and it causes reduction of the leaf yield. The pest is divided into two main categories such as insect and non-insect pests (Mahima & Kumar. 2010). On the basis of mode of feeding insect pests are categorized in a group such as defoliators, sapsuckers, borers, and non-insect pests are snails, slugs, millipedes, mites (Sakthivel. *et al*., 2019). Among all the insect pests, defoliators are one of the destructive pests of the mulberry plant and defoliators such as leaf Webber, Bihar hairy caterpillar, cutworm, moringa hairy caterpillar, tussock caterpillar, noctuid moth, wasp moth, May-June beetle, wingless grasshopper (Sakthivel. *et al*., 2019). Defoliators generally affect the main leaf and shoot tissues. They are biting and chewing different plants parts of plants. It causes less leaf yield (Hemalatha & Shree. 2008). That's why management of a pest is very much important to keep the host plants

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healthy and as well as complete one successful rearing.

**Defoliators insect**

**Cutworm (*Spodoptera litura* Fabricius)**

It is one of the destructive pests of the mulberry plant. They belong to the order Lepidoptera and the family Noctuidae (Sengupta. *et al*., 1991). The insect is multivoltine in nature and having eight generations in a year. They completed the life cycle within 30 to 40 days. This insect incidence is more during the winter season and it occurs between August to February (Hemalatha & Shree. 2008). The adult moth is strong, fatty, and brown in color. Fore wings are variegated patterns and dark in color. Hind wings are white in color and have a brown color margin. The female moth layings egg 200 to 300 on the lower surface of the leaves (Sakthivel. *et al*., 2019). The eggs are covered by brown scales. Eggs are hatching within 4 to 5 days. The hatching larvae don't have hair and the final instar caterpillar is greenish-brown in color (Singh & Saratchandra. 2011). The size of the last instar is 50 mm in length, cylindrical shape and they have longitudinal grey and yellow bands. During the daytime, the older larvae are found in the soil near the base of the plants (Rajadurai, 2005). They are nocturnal (night feeders) in nature. The larval period is 2 to 3 weeks. Then pupa is formed in an earthen cocoon in the soil and pupas are dark brown in color. The pupal period is two weeks. During the nighttime, the moths are attracted to the light (Govindaiah. 2005).

**Damage and Symptoms**

They affect the young mulberry plants, especially in the shoot portion of the plant, and cut them. The shoot portion becomes dries up and falls off (Singh & Saratchandra. 2011). They are the voracious eater of mulberry leaves. In the affected mulberry garden, the plants can be seen without a shoot portion or with dried leaves (Manjunath. 2004).

**Management Practices**

The cultural method like cleaning, plowing, digging should be done around the base of the mulberry plant for exposing the pupae to sunlight (Singh. *et al*., 2000). Light traps can be used to attract the moth and kill them. Collect and destroy the egg, young caterpillars (Sengupta. *et al*., 1991). After 20-25 days of pruning, spraying of DDVP (0.15%) EC (76%) (2ml/liter) to the mulberry plants. Spraying should be done during the evening time. Pheromone trap (Spodolure) 2 lures/acre can be used to attract the male moth and kill them (Sakthivel. *et al*., 2019). It can be used two times at an interval of 15 days after the 25$^{th}$ day of pruning.

**Bihar Hairy Caterpillar (*Spilosoma Obliqua* Walker)**

Bihar hairy caterpillar is a major pest of the mulberry plant. It is also called a black-headed caterpillar. They belong to the order Lepidoptera and the family Arctiidae (Narendran. 2001). It is polyphagous insect and multivoltine in nature (Kotikal *et al*., 1985). They have the number of generations in a year, but it is different from country to country and from season to season. It occurs throughout the year and infestation is more from March to April and July to November (Kotikal. 1982) The female moth laying eggs about 1000 to 1200 in small clusters on the undersurface of the leaves (Narayanswamy. *et al*., 2001). The eggs are green in color. Eggs are hatch within 5 to 7 days. The newly hatched larvae are white in color and have small dense hairs. The middle portion of the caterpillar is yellowish-brown in color (Singh & Thangavelu. 1994). As well as. The anterior and posterior portions are black in color. Mature caterpillars are 5 cm in length (Narayanswamy. *et al*., 2001). The larval period is 27 to 31 days. Pupation takes place in the soil near the mulberry plant and it is dark brown in color. The moth has emerged within 15 days. The life cycle is completed about 45 to 50 days (Kishore *et al*., 1994).

**Damage and Symptoms**

The young caterpillars feed the chlorophyll layer of the lower surface of the leaves (Vijayakumar. *et al*., 2005). A mature caterpillar feeds the entire leaf. In the end, in the affected plant only stems are left (Kishore *et al*., 1994).

**Management Practices**

Collect and destruction of eggs, larvae and burn them. Following the cultural method such as digging and plowing into the field to expose the pupae to the sunlight and predators (birds) (Singh. *et al*., 2000). Flood irrigation can be used in the mulberry field to destroy the pupae that live in the soil. Light traps can be used to attract the moth and kill them (Katiyar. *et al*., 2020). After pruning of 20 days, spraying of 0.1% Dimethoate 30% EC to the mulberry plant (Sengupta. *et al*., 1991).

**Leaf Webber (*Diaphania Pulverulentalis* Hampson)**

Leaf Webber is another destructive pest of the mulberry plant. They belong to the order Lepidoptera and the family Pyralidae (Seelan. 1999). It occurs at the onset of the monsoon. The infestation is more from November to February. The moth is laying the eggs on the apical portion of each shoot (total fecundity ranges 80 to 150). The shape of the egg is flat and pink in color (Rangaswamy. *et al*., 1976). The eggs are hatching within 5 to 7 days (Vijaya Kumari. 2014). The newly hatched larvae are greenish-brown in color and the head portion are black in color. The larval period is 10 to 15 days. They pupate dry leaves at the base of the plant. The pupal period is 8 to 10 days and it is dark brown in color (Hemalatha & Shree. 2008). The moth has emerged from the pupae which are present in the soil. The moth is grayish-white in color and size 10 mm in body length. The life cycle is completed within 28 to 30 days (Seelan. 1999).

**Damage and Symptoms**

Normally, leaf Webber affects the apical portion of the mulberry shoot. Mature caterpillars are voracious feeders and they feed tender leaves (Seelan. 1999). The infestation is occurred in mulberry fields after pruning of 12 days through 70 days. This plant affects the growth and development of the plant which reduces the leaf yield (Hemalatha & Shree. 2008).

**Management Practices**

Deep plowing should be done to expose the pupae to sunlight and predators (Singh & Singh. 2013). Collect and burn the dry leaves to destroy the pupae. Light traps can be used to attract adult moths and kill them. After pruning of 12 to 15 days, spraying of 0.076% DDVP 76% EC (1ml/liter) to the mulberry field (Singh. *et al*., 2000). Flood irrigation can be used to kill the pupae. Release of egg parasitoids *Trichogramma chilonis*, larval parasitoids *Bracon brevicornis* and pupal parasitioids *Tetrastichus howardii* to the field. Insecticides should not be sprayed on the garden after releasing parasitoids (Singh. *et al*., 2000).

**Moringa Hairy Caterpillar (*Eupterote Mollifera* Walker)**

It is one of the major pests of the mulberry plant. They belong to the order Lepidoptera and the family Eupterotidae (Hemalatha & Shree. 2008). Generally, it is found in tropical countries. This pest occurs from August to February. They are univoltine in nature (having one generation in a year). The moths are large in size and they have a light yellowish-brown wing (Kishore. *et al*., 1994). The moth is laying eggs in the cluster on leaves and stems. Eggs are hatched within 5 to 7 days. Mature caterpillars are brownish in color and have dense hairs. In the larval period, it has 4 molts and 5 instars (Sengupta. *et al*., 1991). The larval period is 68 days. Pupation takes place in a thin cocoon that is made up of silk released along with the hairs of caterpillars. The pupae are dark in color and the pupal period is 35 to 60 days (Singh & Saratchandra. 2011).

**Damage and Symptoms**

They feed gregariously bark and foliage. Serious damages lead to defoliation of the plants. It can be noticed without the leaves branch of the plant (Kotikal. 1982).

**Management Practices**

Collection of egg, caterpillar and kill them (Singh. *et al*., 2000). We can use burning touch to kill the larvae. Light traps can be used to attract the moth and kill them. After pruning of 20 days, spraying of 0.1% Dimethoate 30% EC to the mulberry field (Sathe. 1998).

**Tussock Caterpillar (*Euproctis Fraternal* Moore)**

Tussock caterpillar is another dangerous pest of the mulberry plant. It belongs to the order Lepidoptera and the family Lymantriidae (Sakthivel. *et al*., 2019). They are multivoltine in nature, having six generations in a year. It occurs throughout the year and decreased in the winter season. The adult moths are yellowish in color and black spots are present on the forewing (Rama Kant & Bhat, 2010). The abdomen portion is covered by a tuft of hair (Singh & Saratchandra. 2011). The moth is laying in the eggs in the group underside of the leaves. Eggs are hatching within 5 to 10 days (Sengupta. *et al*., 1991). The caterpillar body is reddish-brown in color and white hairs are present around the body. It has six larval instars. The larval period is 13 to 29 days. They pupate in a silken cocoon in leaf and the pupal period is 9 to 25 days (Hemaletha & Shree. 2008).

**Damage and Symptoms**

The caterpillars feed the epidermal tissues of the leaves by scraping the chlorophyll layer (Ganga & Chetty. 1997). In later stages, they feed the entire leaf and lead to defoliation of leaves. In severe infestation, branches can be seen without leaves (Sakthivel. *et al*., 2019).

**Management Practices**

Collection of caterpillars affected leaf and burns it (Jadhav & Venkatesh. 2019). Light traps can be used to attract adult moths and kill them (Sakthivel. *et al*., 2019). After pruning of 20 days, spraying of 0.1% Dimethoate 30 % EC (safe period 20 days) or 0.15% DDVP 76% EC to the mulberry field (Singh. *et al*., 2000).

**Noctuid Moth (*Tiracola Sp*)**

It is one of the destructive pests of the mulberry plant. They belong to the order Lepidoptera and the family Noctuidae (Ganga & Chetty. 1997). It is an occasional pest. Female moth laying eggs on the underside of the leaves and eggs are creamy in color (Sengupta. *et al*., 1991). Larvae are situated middle portion of the leaves. Neonate larvae are black in color with white hairs. They pupate earthen cocoon in the soil (Sakthivel. *et al*., 2019).

**Damage and Symptoms**

All the larvae are gregarious and feed the leaves by scraping. Later they shifted to other branches and feed more. This leads to defoliation of the leaves (Sakthivel. *et al*., 2019).

**Management practices**

Collection of the egg masses, larvae and kill them (Singh. *et al*., 2000). Plowing should be done in the mulberry field to expose the pupae to birds. In the mulberry garden, placed few water bowls to attract the birds (Dandin. *et al*., 2001). Light traps can be used to attract the moth and kill them. After pruning of 20 days, spraying of 0.1% Dimethoate 30% EC (safe period 20 days) or 0.15% DDVP 76 % EC, 20 days to the mulberry field (Ganga & Chetty. 1997).

**Wasp Moth (*Amata Passalis* Fabricius)**

It is another pest of the mulberry plant. They belong to the order Lepidoptera and the family Arctiidae (Sakthivel. *et al*., 2019). It occurs throughout the year, mainly from February to August. They are multivoltine in nature (having 6 to 11 generations per year). The wasp moth is also known as the sandalwood defoliator (Sengupta. *et al*., 1991). The female moth laying eggs about 500 on the lower surface of the leaves. Eggs are hatching within 7 days (Ganga & Chetty, 1997). Late age larvae are brownish in color and having hairs all around the body. The larval period is 32 days and it has 8 instars (Rajadurai. 2005). The pupate takes place inside the leaf folds within the silken web. The pupae are pink in color and the pupal period is 10 to 12 days (Singh & Saratchandra. 2011).

**Damage and Symptoms**

Young caterpillars feed the chlorophyll layer by scraping the leaf. Mature larvae feed the entire leaf (Sakthivel. *et al*., 2019). It can be seen without leaves in the branch of the mulberry plant (Madan. 1998).

**Management Practices**

Collection of the egg masses, young caterpillars and kill them (Sing. *et al*., 2000). After pruning of 20 days, spraying of 0.1% Dimethoate 30% EC (safe period 20 days) or

0.15% DDVP 76 % EC, 20 days to the mulberry field (Veeranna, 1998).

**Wingless Grasshopper (*Neorthacris Acuticeps Nilgriensis* Uvarov)**

The wingless Grasshopper is one of the pests of the mulberry plant. It belongs to the order Orthoptera and family Acrididae (Sakthivel. *et al*., 2019). The incidence of pest is started from the onset of monsoon and continues up to post moon soon season and infestation is more during October. Females are laying in the eggs (50 to 150) in soil with a depth of 3 inches (Sengupta. *et al*., 1991). Females are larger compare then males. The eggs are hatching within 24 to 31 days (Vijaya. 2014). Then, the nymph converted to adults after 90 to 95 days. The adult period is 45 to 60 days. The entire life cycle is completed within 5 to 6 months (Singh & Thangavelu. 1994).

**Damage and Symptoms**

They feed voraciously leaves and as well as sprouting buds. In serious conditions, the mulberry garden can be seen without leaves (Gopal. 1998).

**Management Practices**

Pest should be collected and kill them. Cultural practices should be done such as field sanitation for free from weeds which are used as alternate host plants (Ullal & Narasimhana. 1977). Plowing should be done in the mulberry garden to expose the egg masses to sunlight and birds. Spraying of 0.076% DDVP 76 % EC (1 ml/ litre) to mulberry leaves (Veeranna. 1998).

**May-June Beetle (*Holotrichia Serrata* Fabricius)**

It is one of the destructive pests of mulberry plants. They belong to the order Coleoptera and the family Scarabaeidae (Sakthivel. *et al*., 2019). It is also known as root grubs or white grubs. It is an occasional pest. The beetle is dark brown in color and having grey color hair on the body (Ganga & Chetty. 1997). The female is laying in the egg in the soil at a depth of 10 cm. Grubs are white in color and the length of the grubs is 56 to 60 mm (Kamili Asifa & Masoodi. 2000). They have three instars and the larval period is one year (Madan. 1998). The pupal period is 15 days and creamy white in color. They are nocturnal in nature and during the daytime, they are hiding in the soil (Singh & Saratchandra. 2011).

**Damage and Symptoms**

The newly hatched larvae feed the organic matter and in later stages, they feed the roots of the host plant. In the adult stage, they feed voraciously (Sakthivel. *et al*., 2019). They are nocturnal in nature, that's why the adult beetles enter the mulberry garden at night time and feeding voraciously. In affected plants, black fecal pellets appear below the plants (Singh & Thangavelu. 1994).

**Management Practices**

Collection of the adult beetles and burn them (Sakthivel. *et al*., 2019). Light traps can be used to attract adult beetles and kill them after collection. Plowing should be done to expose the different stages of pests to the predator (Veerana. 1998). During evening hours, spraying of 0.2% DDVP76% EC (2.5 ml/liter) to the mulberry field. The safe period is 15 days (Singh. *et al*., 2000).

## Conclusion

Mulberry silkworm, *Bombyx mori* one of the important species of the sericulture industry. They naturally produce white color silk and it has high demand in the agriculture market. Good agro-climatic and environmental conditions, healthy seeds, healthy host plants are the major elements of silkworm rearing. One healthy host plant plays a very much important role in successful silkworm rearing. The present research concluded that various insect pest is the major problem for mulberry silkworm cultivation due to heavy infestation of host plants. Among these all the insect pests, defoliators are the destructive pest of the mulberry plant. That's why controlling insect pests by implementing scientific methods is very much required for the protection of mulberry silkworm food plants.

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## References

1. Aruga, H. "Principles of Sericulture (Translated from Japanese)." *Oxford & IBH Publishing Co. Pvt. Ltd*. (1994).
2. Dandin, S. B., Jayant, J. and Giridhar, K. "Hand Book of Sericulture Technologies." *Central Silk Board* (2000).
3. Dandin, S. B., Jayant. J. and Giridhar, K. "Handbook of Sericulture technologies." (2nd edition). *Central Silk Board* (2001).
4. Govindaiah, D., V.P. Gupta., D.D. Sharma, S. Rajadurai. and V.N. Naik. "Mulberry crop protection." *Central Silk Board Publication* (2005).
5. Gopal, A. "Illustrated Textbook on Sericulture." *Oxford & IBH Publishing Co. Pvt. Ltd*. (1998).
6. Ganga, G. and J. S. Chetty. "An Introduction to Serculture." *Oxford & IBH Publishing Co. Pvt. Ltd*. New Delhi (2012).
7. Shree, M. P. "Incidence and population dynamics of mulberry defoliators." *Journal of Entomological Research* 32.1 (2008): 7-10.
8. Jadhav, Y. T., V. Venkatesh. and N. Deekshitha. "Review on major pests of mulberry and its management protocol." *International Journal of Plant Protection* 12.1 (2019): 77-80.
9. Kamili, A. S. M. and Masoodi, A. "Principles of Temperate Sericulture." *Kalyani Publishers* (2000).
10. Katiyar, R. L., P. K. Sathya., P. R. Shivpuje. "Integrated management of Bihar hairy caterpillar." *Indian Silk* (2002): 15-16.
11. Kishore, R., D. Manjunath., P. Kumar., V. Kumar. and R. K. Datta. "Bihar hairy cater pillar and its management." *Indian Silk* 32.12 (1994): 13-15.
12. Kotikal, Y.K. "Studies on pests of mulberry *Morus Alba* L. with special reference to the black headed caterpillar Spilosoma obliqua Walker (Lepidotera: Arctiidae)." *M. Sc.(Agri.) Thesis, University of Agricultural Sciences, Bangalore, India* (1982): 37-38.
13. Kotikal, Y. K., and M.C. Devaiah. "Insect and non-insect pests of mulberry, *Morus alba* L." *Proceedings of the National Seminar on the Prospects and Problems of Sericulture in India*. 1985.
14. Manjunath, D. "Pests of mulberry and their management." *Advances in disease and pest management in sericulture* (2004): 31-39.
15. Mahiam, A. S. and S.P. Kumar. "Diversity of Insects in the Mulberry Ecosystem." *A Silkworm blog online* (2010).
16. Madan, M.R. "A Textbook of Sericulture." *B.S. Publications* (1998).
17. Narayanaswamy, T.K., Srinivasagowda, R. and Sannaveerappanavar, V.T. "Lepidopteran insects on mulberry." *Sericologia* 41.3 (2001): 343-365.
18. Narendran, T.C. "Taxonomic entomology: Research and education in India." *Current science* 81.5 (2001): 445-447.
19. Rajadurai, S. "Mulberry Defoliators." *Indian Silk* (2005): 12-14.
20. Kant, R. A. M. A. and M.M. Bhat. "Mulberry foliar fungal diseases and insect pests calendar in Uttarakand." *Indian Silk* 45.5 (2010): 10-13.
21. Rangaswami, G., M. N. Narasimhanna., K. Kasiviswanathan., C.R. Sastry. and M.S. Jolly. "Sericulture Manual I- Mulberry Cultivation." *Food and Agricultural Organization of Unite Nations, Rome* (1976): 72-73.
22. Sakthivel, N., Narendra, K. J. B., Dhahira, B. N., Devamani, M., Teotia, R. S. "Mulberry Pest, Current Status & Management Practices." *Central Sericultural Research & Training Institute, Mysore. Central Silk Board, Ministry of Textiles, Govt of India* (2019): 17-28.
23. Sathe, T.V. "Book on Sericultural Crop Protection." *Asawari Publication*, New Delhi (1998).
24. Sengupta, K., Pradip, K., Baig, M. and Govindaiah, M. "Handbook on pest and disease control of mulberry and silkworm." *Economic and Social Commission for Asia and Pacific, UNESCAP (United Nations Economic and Social Commission for Asia and the Pacific), Bangkok* (1990): 17-40.

25. Govindaiah, K.S. and P. Kumar. "Diseases and Pests of Mulberry and their Control." *Central Sericultural Research and Training Institute, Sriampura, Mysore* 45 (1991).
26. Seelan, V. "Biology and management of leaf webber. Diaphaneapulverulentalis (Hampson) (Lepidoptera: Pyralidae) on mulberry. M.Sc. (Agri.) Thesis." *Tamil Nadu Agricultural University, Coimbatore*. (1999): 84.
27. Singh, R. N., M.V. Samson. and R.K. Datta. "Pest management in sericulture." *Indian Publ. Distributors, Delhi.* (2000).
28. Singh, R. N., B. Saratchandra. "Sericultural Entomology." *A.P.H. Publishing Corporation* (2011).
29. Singh, T.P. and K. Singh. "Mulberry Crop Protection." *Discovery Publishing House Pvt. Ltd.* (2013).
30. Singh, R. N. and K. Thangavelu. "Pest of silk host plant and their management in forest Entomology." *Ashish Publication House, New Delhi* (1994): 279-311.
31. Ullal, S. R. and Mudupanna, M. N. "Handbook of Practical Sericulture." *Central Silk Board, Bombay* (1977).
32. Vijaya, K. N. "Eco-friendly technologies for disease and pest management in mulberry-A Review." *Journal of Agriculture and Veterinary Science* 7(2014): 1-6.
33. Vijayakumar, R., Ravikuamr, J., Qadri, S.M.H. and Jayaraj, S. "Tamil Nadu: Incidence of Red hairy caterpillar and its management." *Indian Silk* 44(2005): 9.
34. Veerana, G. "Insect pests of mulberry and their management in china." *Indian Silk* (1998): 5-9.

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