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Pest Status of Subfamily Lymantriinae (Lepidoptera: Erebidae: Noctuoidea): Review

Amritpal Singh Kaleka[1], Gagan Preet Kour Bali [1, 2)]*

[1]Department of Zoology and Environmental Sciences, Punjabi University, Patiala, Punjab, India
[2]Department of Biosciences, Chandigarh University, Mohali, Punjab, India

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Correspondence

Gagan Preet Kour Bali
E-mail: gaganviren@gmail.com

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Abstract

Plant diseases and pests are important factors determining plant yield production, including mango. Mango fruit rot caused by insects and microbes has become a significant threat to mango production in Southeast Asia and worldwide. Insect plant pathogens affect crop yields' profitability, quality, and quantity. Some infections could occur before harvest and remain dormant until the favourable condition is achieved, and the disease will break out after harvest, reducing mango production. They act as a threat to the crops through various mechanisms of pathogenesis that compromise the immune system of the plants, such as developing any ways to attack the plants, seeking entry *via* open pores or exposed surface or wound, and sourcing nutrients forcefully for their growth and development. Depending on the environmental factors, the insect contracts the host through primary or secondary infection. This paper summarizes mango fruit rot disease caused by insects groups such as fruit borers (*Autocharis albizonalis* and *Citripestis eutraphera*), fruit flies (*Bactrocera dorsalis*), and mango seed weevils (*Sternochetus mangiferae).* This review will provide information about fruit rot diseases on mangoes caused by insects, the mechanism of infection, the interaction between insect damage and fungal infections, effective control methods, and related integrated pest management approaches.

Keywords

Fruit rot, insects, mango, plant disease, pest

INTRODUCTION

Lymantriins, referable to the superfamily Noctuoidea, commonly known as tussock moths, are of moderate size and usually have muted colors (brown and greys). However, some are white, tend to be very hairy, and are well represented in all zoo-geographic regions with about 2500 known species referable to 360 genera (Holloway, 1999), many of which are of agronomic importance (Chao, 2003). The subfamily Lymantriinae is composed of seven well-defined and distinct tribes viz., Lymantriini Hampson, Orgyiini Wallengren, Nygmiini Holloway, Leucomini Grote and Arctornithini Holoway, Daplasini Holloway & Wang and Locharinini Holloway & Wang (Wang et al., 2015).

When slightly disturbed, these moths show no movements and fean dead. These moths can be easily recognized as the adult's resting posture is tectiform or flattened tectiform, with the hairy front and middle legs displayed, the forelegs held out in front, and the middle legs placed laterally (Tweedie & Emmet, 1991), and the presence of hair-like scales on wings. The distinct features include the thoracic tympanum and a bar connecting vein Sc+R_1 with Rs

at the middle of the cell in the hindwing. Some females are flightless, and some have reduced wings. Sexual dimorphism is moderate to extreme, with females tending to be much larger, particularly in the size of the abdomen. The females have much larger wings than males or are flightless, brachypterous, or apterous. Most female Lymantriins have a scale tuft (corethrogyne) at the apex of the abdomen, which is used to cover the egg mass for protection. The males have tympanal organs (Scoble, 1995). This family includes mostly nocturnal species (based on reduced eye size), but Schaefer (1989) listed twenty confirmed diurnal species. Other important features, such as the presence of a well-developed anal tuft in females and the absence of ocelli and proboscis, make these moths distinct from Arctiids.

The larvae are hairy, with hairs packed in tufts. In many species, the hair breaks off easily and irritates the skin (primarily members of the genus *Euproctis* Schaefer). In the larvae of some species, hairs are gathered in dense tufts along the back, which gives them the name "Tussocks or Tussock moths". Lepidoptera, the most significant single radiation of plant-feeding insects, also function ecologically as pollinators and prey. These have a substantial impact on humans and other species. This order also provides essential model systems for studies of genetics, physiology, development, ecology, and evolutionary biology (Mitter et al., 2016).

Lymantria means "defiler," and several species are important defoliators of forest trees, including the gypsy moth *Lymantria dispar* Linnaeus, the Douglas-fir tussock moth *Orgyia Pseudotsugata* Mcdunnough, and the Nun moth *Lymantria monacha* Linnaeus. *Lymantria mathura* Moore is one of the most important defoliators of deciduous trees especially *Quercus* Linnaeus (oak). Its outbreak results in complete defoliation, followed by outbreaks of wood borers of the family Scolytidae and Cerambycidae. The defoliated forest loses its ability to provide essential ecosystem services such as air purification, water quality, temperature mitigation, wildlife habitat, and biodiversity. Its attack leaves forests susceptible to pest outbreaks and pre-disposes them to forest fires. The reforestation of such areas is complicated and takes much time, leading to severe environmental changes (Zlotina et al., 1999).

Another species, i.e., *Lymantria obfuscata* Walker, is a serious pest of about two hundred broad-leaved tree species, particularly willow (*Salix* Linnaeus), poplar (*Populus* Linnaeus), oak (*Quercus* Linnaeus), walnut (*Jugulans regia* Linnaeus), apple (*Malus domestica* Borkh), apricot (*Prunus armeniaca* Linnaeus), cherry (*Prunus avium* Linnaeus) throughout India (Beeson, 1941; Dharmadhikari et al., 1985; Rishi & Shah, 1985). The spongy moths pose significant economic, ecological, and recreational costs as their populations defoliate natural and urban areas. Due to defoliation, the entire habitat is affected, and even tree defoliation along streams results in higher water temperatures and increased loading of organic material (ODA, 2015). The spongy moths prevent shipments of trees, lumber, and nursery plants by forcing quarantine restrictions, further affecting an infested area's economy. The spongy moths are highly polyphagous, and their larvae feed on more than three hundred host tree species in North America (Liebhold et al., 1995). These moths tend to have broader host plant ranges than most Lepidoptera. *Lymantria monacha* Linnaeus is one of the most important defoliators in Eurasian coniferous forests, especially in pine and spruce forests in central Europe (Maksymov, 1978). Its larvae feed primarily on needles and male cones of conifers (*Pinus* et al.) and also on leaves of deciduous trees and shrubs such as *Fagus* Linnaeus, *Carpinus* Linnaeus, *Betula* Linnaeus, and *Quercus* Linnaeus (Sliwa & Sierpinski, 1986). *Arctornis riguata* Snellen has been reported as one of the important pests of *Magnifera indica* Linnaeus (Sutrinsno et al., 2013).

Tintumol et al. (2014) noticed the tussock moth caterpillars on coffee (*Coffea arabica* Linnaeus) seedlings in nursery at Regional Coffee Research Station Farm, Chundale, Kerala. *Arctornis submarginata* Walker is reported as a defoliator of mature and young leaves and *Somena scintillans* (Walker) as a minor pest of tea (*Camellia sinensis* (Linnaeus)) plantation (Biswas et al., 2015). *Orgyia antiqua* (Linnaeus) is an occasional pest on *Pelargonium* Heritier (Viggiani, 2015). *Euproctis lunata* Walker, commonly known as the castor hairy caterpillar, is a serious pest of castor *Ricinus communis* Linnaeus (Kamboj et al*.,* 2016). *Euproctis chrysorrhoea* Linnaeus and *Lymantria dispar* Linnaeus are notable pests of shade and fruit trees including apple (*Malus domestica* Borkh), pear (*Pyrus communis* Linnaeus), cherry (*Prunus avium* Linnaeus) and the foliage of garden plants like cranberries (*Vaccinium oxycoccos* Linnaeus) and even resulting the death of infested trees. *Orgyia leucostigma* Smith is a destructive pest of orchards including pear (*Pyrus communis* Linnaeus), plum (*Prunus domestica* Linnaeus), quince (*Cydonia oblonga* Miller) and other deciduous trees except

conifers (Isaacs & Timmeren, 2009; Hall & Buss, 2014). The fruits are scarred by the shallow feeding of caterpillars on the surface. Several species namely *Euproctis fraterna* Moore (host: cowpea *Vigna unguiculata* (Linnaeus)), *Euproctis subfasciata* Walker (host: cabbage *Brassica olerracea* Linnaeus var. *capitata*), *Olene mendosa* Hubner (host: potato *Solanum tuberosum* Linnaeus), *Perina nuda* Fabricius (host: jackfruits *Artocarpus heterophyllus* Lamarck), *Somena scintillans* Walker (hosts: sunnhemp *Crotalaria juncea* Linnaeus, capsicum *Capsicumannum* Linnaeus, cowpea *Vigna unguiculata* (Linnaeus) and pea *Pisum sativum* Linnaeus) are minor pests of vegetables (Butani & Jotwani, 1984; Gupta, 1990).

Dorado et al. (2016) reported *Lymantria dispar dispar* Linnaeus (European gypsy moth) as a major pest of exotic radiata pine (*Pinus radiata* D. Don) from Spain. It causes extensive defoliation as its larvae feed extensively on pine needles from the first instar and continue till pupation. Sun et al. (2016) reported *Leucoma salicis* (Linnaeus) as a major pest of *Camellia sinensis* (Linnaeus) and *Salix* Linnaeus. Nair et al. (2017) reported six species namely *Somena scintillans* (Walker), *Euproctis fraterna* (Moore), *Artaxa guttata* (Walker), *Dasychira mendosa* (Hübner), *Calliteara strigata* (Moore) and *Orgyia postica* (Walker) associated as minor pests of pigeon pea *Cajanus cajan* (Linnaeus) in Tripura. Arya and Farooq (2019) reported *Lymantria obfuscata* Walker and *Lymantria concolor* Walker as major pests of apple (*Malus domestica* Borkh) from Uttarakhand. Roychoudhury et al. (2020) reported *Lymantria mathura* Moore as a potential insect foliator in the sal (*Shorea robusta* Gaertn) forests of Odhisa. Cristina and Robert (2021) studied the evolution, degree of attack, application of measures, and means of combating invasive species *Lymantria monacha* Linnaeus on an annual basis in the Miercurea Sibiului forest in Romania. Magsi et al. (2021) reported the tea black tussock moth, *Dasychira baibarana* (Matsumura), as an insect pest species from various parts of southern China as its larvae feed on leaves and tender shoots of tea plants, resulting in crop loss.

They also annoy the people living in infested areas, as urticating hairs and setae have venom glands in tussocks and hair pencils on the larvae (Gilmer, 1925). The caterpillar hairs packed in tufts in many species, such as *Lymantria dispar* Linnaeus, *Euproctis chrysorrhoea* Linnaeus, and *Shrageidus similis* Fuessly can cause allergic reactions such as skin or eye rashes and respiratory problems (Mccullough & Bauer, 2000). The hairs on larvae or in cocoons frequently cause dermatitis and allergic reactions in sensitive individuals, a condition known as tussockosis (Hossler, 2009; Hall & Buss, 2014). The presence of leaf fragments and barren trees due to damage from tree defoliation and abundance of caterpillars and frass (caterpillar droppings) also create annoyance.

Table 1: The pest species, crops associated, and pest status of subfamily Lymantriinae

No	Species	Crops associated with	Pest Status	Reference
1.	*Leucoma salicis* (Linnaeus)	*Camellia sinensis* (Linnaeus); *Salix* Linnaeus	Major pest	Sun et al., 2016
2.	*Lymantria concolor* Walker	*Malus domestica* Borkh	Major pest	Arya and Farooq, 2019
3.	*Lymantria dispar* Linnaeus	*Malus domestica* Borkh; *Prunus avium* Linnaeus;*Vaccinium oxycoccos* Linnaeus	Major pest	Brewer, 2008
4.	*Lymantria dispar dispar* Linnaeus	*Pinus radiata* D.Don	Major pest	Dorado et al., 2016
5.	*Lymantria mathura* Moore	*Quercus* Linnaeus ; *Shorea robusta* Gaertn	Major pest	Zlotina et al., 1999; Roychoudhury et al., 2020
6.	*Lymantria monacha* Linnaeus	*Pinus* Linnaeus; *Picea* Miller; *Abies* Miller; *Larix* Miller; *Fagus* Linnaeus; *Carpinus* Linnaeus; *Betula* Linnaeus	Major pest	Maksymov, 1978; Sliwa and Sierpinski, 1986

No	Species	Crops associated with	Pest Status	Reference
7.	*Lymantria obfuscate* Walker	*Salix* Linnaeus;*Populus* Linnaeus; *Quercus* Linnaeus; *Jugulans regia* Linnaeus; *Malus domestica* Borkh; *Prunus armeniaca* Linnaeus; *Prunus avium* Linnaeus	Major pest	Beeson,1941 Dharmadhikari et al., 1985; Rishi and Shah, 1985; Arya and Farooq, 2019
8.	*Orgyia leucostigma* Smith	*Pyrus communis* Linnaeus; *Prunus domestica* Linnaeus; *Cydonia oblonga* Miller	Major pest	Isaacs and Timmeren, 2009; Hall and Buss,2014
9.	*Orgyia pseudotsugata* Mcdunnough	*Pinus* Linnaeus; *Quercus* Linnaeus; *Abies* Miller; *Larix* Miller	Major pest	Shepherd, 1985
10.	Tussock moth sp.	*Coffea arabica* Linnaeus	Major pest	Tintumol et al., 2014
11.	*Arctornis riguata* Snellen	*Magnifera indica* Linnaeus	Minor pest	Sutrinsno et al., 2013
12.	*Arctornis submarginata* Walker	*Camellia sinensis* (Linnaeus)	Minor pest	Biswas et al., 2015
13.	*Dasychira baibarana* (Matsumura)	*Camellia sinensis* (Linnaeus)	Minor pest	Magsi et al*.,* 2021
14.	*Euproctis fraterna* Moore	*Vigna unguiculata*(Linnaeus)	Minor pest	Butani and Jotwani, 1984; Gupta, 1990
15.	*Euproctis lunata* Walker	*Ricinus communis* Linnaeus	Minor pest	Kamboj et al*.,* 2016
16.	*Euproctis subfasciata* Walker	*Brassica olerracea* Linnaeus var. *capitata*	Minor pest	Butani and Jotwani, 1984; Gupta, 1990
17.	*Olene mendosa* Hubner	*Solanum tuberosum* Linnaeus	Minor pest	Butani and Jotwani, 1984; Gupta, 1990
18.	*Perina nuda* Fabricius	*Artocarpus heterophyllus* Lamarck	Minor pest	Butani and Jotwani, 1984; Gupta, 1990
19.	*Somena scintillans* Walker	*Crotalaria juncea* Linnaeus; *Capsicum annum* Linnaeus; *Pisum sativum* Linnaeus	Minor pest	Butani and Jotwani, 1984; Gupta, 1990
20.	*Orgyia antiqua* (Linnaeus)	*Pelargonium* Heritier	Occasional pest	Viggiani, 2015

Spongy moth host list as listed on the CAB Compendium (CAB International, 2007)

Major Hosts*:*

Acer saccharum (sugar maple), *Betula papyrifera* (paper birch), *Quercus alba* (white oak), *Quercus coccinea* (scarlet oak), *Quercus ellipsoidalis* (Northern pin oak), *Quercus garryana* (Garry oak), *Quercus ilex* (holm oak), *Quercus lobata* (California white oak), *Quercus montana* (basket oak), *Quercus muehlenbergii* (Chinquapin oak), *Quercus palustris* (pin oak), *Quercus petraea* (durmast oak), *Quercus*

robur (common oak), *Quercus rubra* (northern red oak), *Quercus suber* (cork oak), *Quercus velutina* (black oak), *Salix fragilis* (crack willow).

***Minor Hosts**:*

Acer (maples), *Acer negundo* (box elder), *Acer platanoides* (Norway maple), Acer *rubrum* (red maple), *Acer saccharinum* (soft maple), *Alnus* (alders), *Alnus rhombifolia* (white alder), *Betula* (birches), *Betula alleghaniensis* (yellow birch), *Betula lenta* (sweet birch), *Betula populifolia* (gray birch), *Carpinus* (hornbeams), *Carya* (hickories), *Castanea sativa* (chestnut), *Corylus*, Eucalyptus *camaldulensis* (red gum), *Fagus* (beeches), *Fagus grandifolia* (American beech), *Fagus sylvatica* (common beech), *Fraxinus americana* (white ash), *Fraxinus pennsylvanica* (downy ash), *Glycine max* (soyabean), *Hamamelis virginiana* (Virginian witch-hazel), *Larix* (larches), *Larix kaempferi* (Japanese larch), *Larix occidentalis* (western larch), *Liquidambar styraciflua* (Sweet gum), *Litchi chinensis* (lichi), *Lithocarpus edulis*, *Malus* (ornamental species apple), *Malus domestica* (apple), *Ostrya virginiana* (American hophornbeam), *Picea abies* (common spruce), *Picea jezoensis* (Yeddo spruce), *Pinus* (pines), *Pinus contorta* (lodgepole pine), *Pinus echinata* (shortleaf pine), *Pinus resinosa* (red pine), *Pinus rigida* (pitch pine), *Pinus strobus* (eastern white pine), *Pinus sylvestris* (Scots pine), *Pinus taeda* (loblolly pine), *Pistacia vera* (pistachio), *Platanus acerifolia* (London plane tree), *Populus* (poplars), *Populus grandidentata* (Big tooth aspen), *Populus nigra* (black poplar), *Populus tremuloides* (trembling aspen), *Prunus* (stone fruit), *Prunus armeniaca* (apricot), *Prunus domestica* (plum), *Prunus salicina* (Japanese plum), *Prunus serotina* (black cherry), *Prunus serrulata* (Japanese flowering cherry), *Pseudotsuga menziesii* (Douglas-fir), *Pyrus* (pears), *Quercus ilicifolia* (bear oak), *Robinia* (locust), *Robinia pseudoacacia* (black locust), *Salix* (willows), *Salix babylonica* (weeping willow), *Taxodium distichum* (bald cypress), *Tilia americana* (basswood), *Tilia cordata* (small leaf lime), *Vaccinium* (blueberries), *Zea mays* (maize).

Larval Characters

The larvae are voracious feeders, consuming about 1 m^2 of foliage over their life span. Feeding occurs mainly during the day for the first three instars and at night for the later 2-3 instars. The later instars are by far the most voracious feeders, and at outbreak, larval feeding continues through the day. In *Lymantria dispar dispar* Linnaeus, males usually have five instars and females six. The larvae range from 3 mm long during the first instar to 50-65 mm for the 5^{th}or 6^{th}instars (PHA & NGIA, 2009). At maturity, the hairy caterpillars also range in color from black to yellow but typically have two rows of spots of five pairs of blue spots followed by six pairs of red spots on their back.

The population of larvae fluctuate as a result of variable environmental conditions. The complex mixture of phenolics in leaves of plants has defensive oxidative activities that can damage larval midguts. The tussock moths concentrate and ingest tannins without metabolizing (Kopper et al., 2002) and metabolize terpenoids with little effect on larval performance (Raffa & Powell, 2004). Barbehenn et al. (2003) reported that tussock moth larvae are relatively tolerant of plant phenolics and show little phenolic oxidation (which can damage gut epithelial tissues) in their midguts. Their survival is not affected by ingested tannins. Environmental changes cause variations in foliage quality and quantity (Schowalter, 2016). Broderson et al. (2012) reported that larvae fed on hosts with higher nutritional quality showed lower mortality as compared to others. Schowalter (2018) reported that variation in the quality and quantity of food resources affects host preferences, larval growth, and developmental rates. Kopper et al. (2002) reported that young larvae fed diets amended with condensed tannin showed prolonged development times, reduced relative growth rates, and reduced food conversion efficiencies. Johns et al. (2009) found that larvae had 32-65% higher fitness on diets composed of a mixture of foliage age classes, compared with fitness when fed a single foliage class. Larval development rate is related to temperature. Isaacs and Timmeren (2009) reported that larval developmental rate increased significantly with temperature from 16^0C (61^0F) to 28^0C (82^0F), but development ceased below 10^0C (50^0F) and above 35^0C (95^0F).

Lepidoptera, the largest single radiation of plant-feeding insects, also function ecologically as pollinators and prey. These have a substantial impact on humans and other species. Zhang (1994) listed 154 species as economically important species, representing about 10% of economically important Noctuoidea. The spongy moths pose significant economic, ecological, and recreational costs as their populations defoliate natural and urban areas. The larvae population fluctuates due to variable environmental and temperature conditions. The variation in quality and quantity of food resources also affects host preferences, larval growth, and

developmental rates. The descriptive review of the literature justified that the subfamily Lymantriinae is of great economic, ecological, and biological significance.

CONCLUSIONS

The subfamily Lymantriinae, known as tussock moths, consists of about 2500 species with significant agronomic importance. These moths, characterized by their muted colors and hairy bodies, are major crop and tree pests globally. Their larvae are voracious feeders, often causing severe defoliation and leading to substantial ecological and economic impacts, including forest degradation and increased fire susceptibility. Effective management and understanding of their biology are crucial to mitigate the damage caused by these pests.

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