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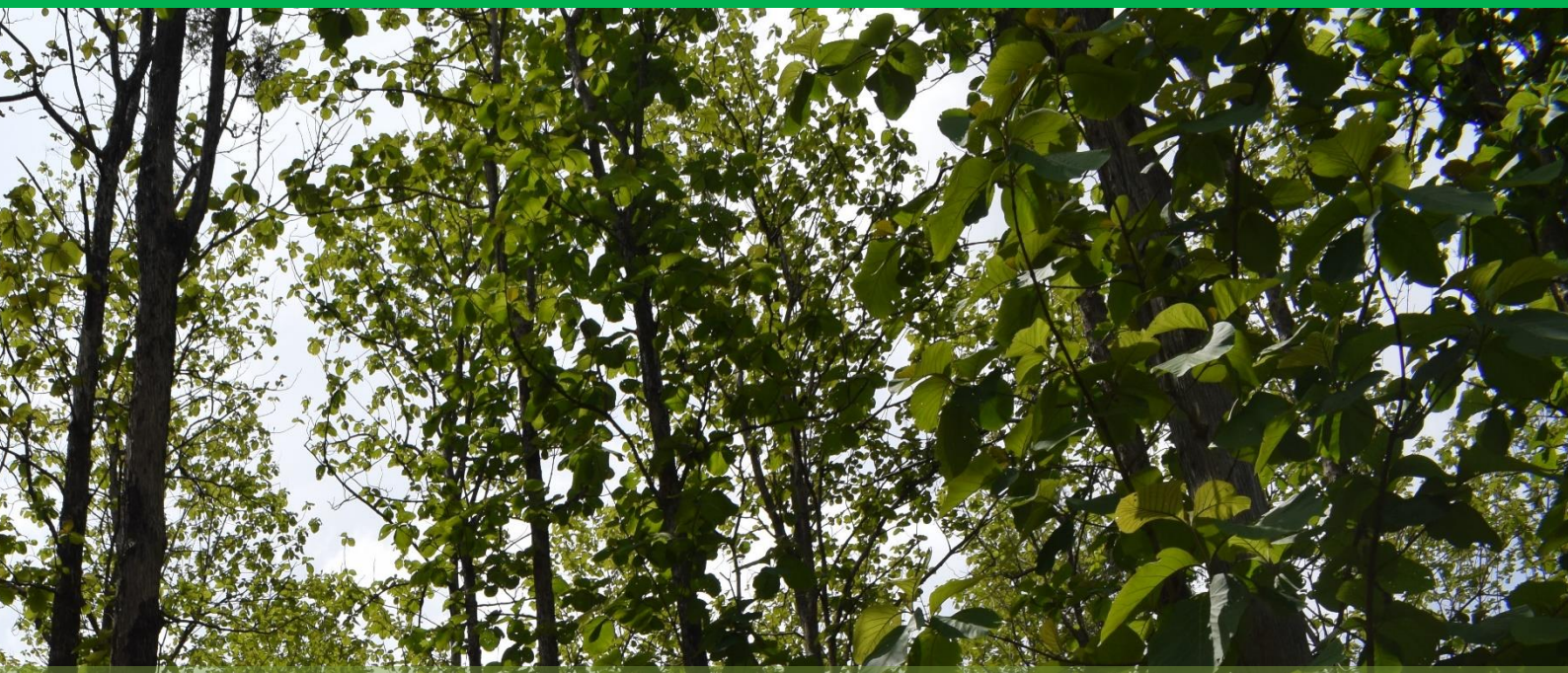

Technical Guidelines for Control and Prevention of Pests and Diseases in Teak Plantations, Myanmar

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AFoCO

FD-AFoCO IPDM Project ၏ အထောက်အပံ့ဖြင့် ထုတ်ဝေသည်။

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Published by Forest Research Institute, Myanmar

Citation: Shin T, Aye ZM, Thu JJ, Aung AM, Aung MH, Aung YL, Oo TN (2024) Technical Guidelines for Control and Prevention of Pests and Diseases in Teak Plantations, Myanmar. Forest Research Institute, Forest Department, Myanmar. 1-112.

Preface

Teak (*Tectona grandis* L.f.) is a tropical hardwood tree species in the family Lamiaceae and it is a large, deciduous tree that occurs in mixed hardwood forests. It naturally grows throughout Myanmar, especially Bago Yoma Mountain Range. Historically, Myanmar initiated the establishment of Teak plantation as early as 1856 on a small scale by using Taungya method. Large scale establishment of forest plantations began in 1980 and about 30,000 ha of forest plantations have annually been established since 1984. In 1998, the Government initiated special teak plantation program to increase timber production. Currently, Teak plantations have been increasingly established according to the annual action plan of the Myanmar Reforestation and Rehabilitation Programme (MRRP). In addition, the private sectors have been granted the long term land lease-based permission to establish teak plantations since 2006. Therefore, Teak plantation areas became about 43 % of total forest plantation area of the country.

However, there is lack of well-studied information on pests and diseases, their impacts on forest plantations and the environment-friendly control measures on incidence of pests and diseases in forest plantations although many records of devastating losses caused by pests are reported in Teak plantations in Myanmar.

In this context, exploring reliable control measures against the pests and diseases, monitoring system and capacity building programme become urgently needed to conduct. Accordingly, the FD-AFoCO IPDM project has been implemented in cooperation with Asian Forest Cooperation Organization (AFoCO) in order to contribute to healthy forests and vitality of Project areas in the western part of Bago Yoma Mountain Range, particularly two districts; Pyay District and Tharyarwaddy District, through exploring pest and disease lists, their possible control and prevention measures, and enhancing capacity building programme for all stakeholders.

In this regard, a series of fieldwork has been conducted in the Project Areas of Myanmar under the auspices of MoU between both parties, resulting in observations of insect pest species and diseases in teak plantations. In the present technical guidelines, 15 species of insect pests (11 major pests and 4 minor pests for teak plantations) are described with possible control measures and 3 species of natural enemies for the pests are also described with their appearance, life cycle and predatory habit.

In addition, disease symptoms, causal organisms, disease cycles and epidemiology, control measures for 10 kinds of diseases observed in project area are described in the present technical guidelines regarding the type of diseases. The present technical guidelines will be useful for pests and diseases management in teak plantations nationwide. Therefore, it can be recognized as one of the achievements of cooperation between Forest Department of Myanmar and Asian Forest Cooperation Organization (AFoCO).

I highly appreciate Asian Forest Cooperation Organization (AFoCO) for its financial support and the FD-AFoCO IPDM Project Team for their efforts at developing the present technical guidelines. I hope the forest entomology and pathology research will upgrade from the present level into next level of formulation of effective control measures in the future.

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Nay Pyi Taw, Myanmar

Executive Summary

The present technical guidelines will provide the brief information on the insect pests and diseases observed in teak plantations which are located in Pyay District and Tharyarwaddy District of Bago Region, Myanmar. In addition, the possible control measures for respective insect pests and diseases are also provided in the present technical guidelines.

In the present technical guidelines, 15 species of insect pests (11 major pests and 4 minor pests for teak plantations) are described with possible control measures and 3 species of natural enemies for the pests are also described with their appearance, life cycle and predatory habit. In addition, disease symptoms, causal organisms, disease cycles and epidemiology, control measures for 10 kinds of diseases observed in teak plantations are described in the present technical guidelines regarding the type of diseases.

The present technical guidelines will be useful for pests and diseases management in teak plantations nationwide. The present study was financially supported by Asian Forest Cooperation Organization (AFoCO). In addition, it can be regarded as one of the achievements of FD-AFoCO IPDM Project in Myanmar.

Contents

Chapter 1: Introduction

AFoCO IPDM Project

Asian Forest Cooperation Organization (AFoCO) collaborated with Forest Department (FD) is implementing Integrated Pest and Disease Management (IPDM) Project (AFoCO/014/2020) in Teak Plantation in Bago Region, Myanmar with the objectives to contribute to healthy forests and the vitality of the West Bago Yoma Region through exploring pest and disease lists, their possible control and prevention measures, and enhancing capacity building programs for all stakeholders.

Project area and project duration

The target project site was West Bago Yoma Region which covers two main Districts; Tharyarwaddy District and Pyay District. The project area included 5 different areas, in which 3 areas (Tharyarwaddy, Minhla and Gyobingauk townships) located in Tharyarwaddy District and 2 areas (Paukkhaung and Padaung townships) in Pyay District (Figure 1). The project duration is from October 2020 to September 2025.

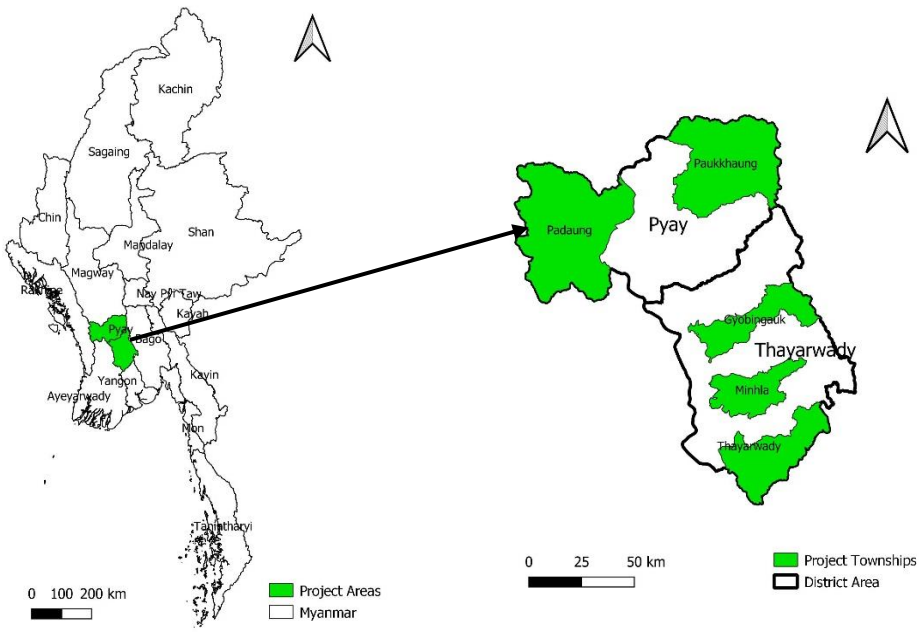


Figure 1: Map of Myanmar, showing the Project Area

Project activities

In order to explore pest and disease lists, a monthly field survey is conducted to record pests, natural enemies, and disease incidence associated with teak plantations. Identification of pests, natural enemies, and diseases is carrying out at the Laboratories of Forest Protection Section, Forest Research Institute (FRI), Yezin. Regarding capacity building, field survey training and public education talk to relevant stakeholders have to organize. Forest protection laboratories and forest protection's museum need to be renovated.

Project achievements

By conducting monthly field survey, 48 kinds of pests,19 natural enemies, 10 kinds of diseases and their pathogens in the teak plantations of the survey areas have been identified. Capacity-building training on practical field survey has been conducted. Moreover, awareness of the incidence of teak pests and diseases has been disseminated to the public. Renovation of forest protection laboratories and forest protection section's museum have been established.

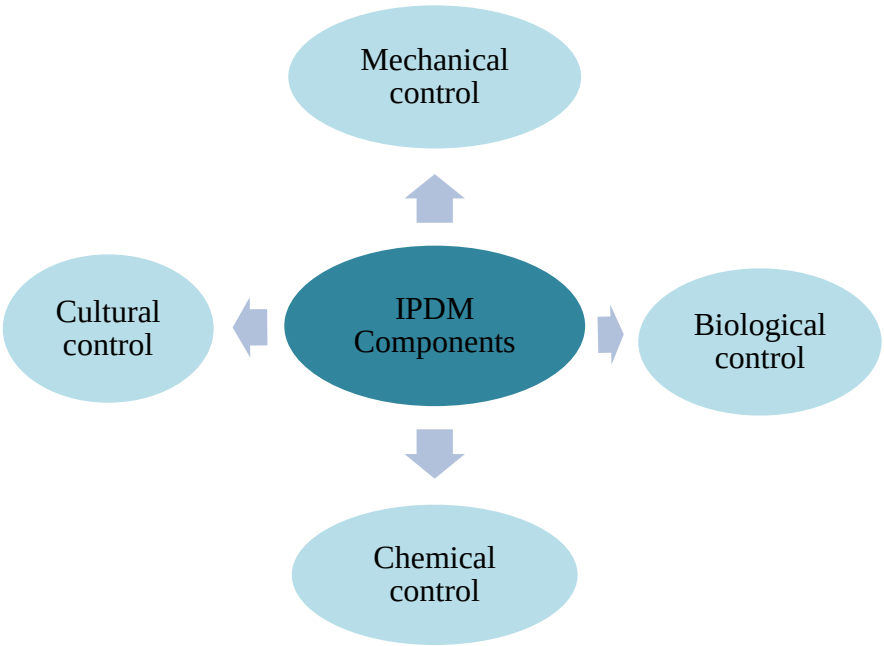
Figure 2: Monthly field survey in teak plantation and nursery

Figure 3: Capacity building trainings to stakeholders

Integrated Pest and Disease Management (IPDM)

Integrated Pest Management (IPM) means a sustainable approach to managing pests by combining biological, cultural, physical/mechanical and chemical tools to minimize economic, health and environmental risks. IPM emphasizes the growth of a healthy crop with the least possible disruption to agricultural ecosystems and encourages natural pest control mechanisms.

Integrated disease management (IDM) includes disease management through applying all possible control measures by continuous field observation. IDM not only minimizes the impact of diseases but also minimizes resource allocation and reduces reliance on chemical control methods, thereby promoting environmental and economic sustainability. Integrated pest and diseases control measures are cultural control, mechanical control, biological control and chemical control.



Chapter 2: Pests infesting Teak (*Tectona grandis* L.f, Lamiaceae) Plantations in Bago Region, Myanmar

Abstract

Integrated Pest and Disease Management in Teak Plantations in Bago Region, Myanmar (AFoCO/014/2020) is targeting to develop pest and disease lists and to implement their possible control and prevention measures. According to the objectives of project, monthly field observation is conducting to record the pests and natural enemies associated with teak plantations in two districts namely Pyay District and Tharyarwaddy District including Paukkhaung Township, Padaung Township, Tharyarwaddy Township, Min Hla Township and Gyobingauk Township during the project period of October 2020 to September 2025. Field observation is adapted as a combination of light traps, yellow sticky traps, sweep nets and visual observation at selected areas. In demonstration plot, molasses traps were also used. In the observation area, teak is attacked by totally 48 species of pests belong to order Lepidoptera, Coleoptera, Hemiptera, Orthoptera, Homoptera and Isoptera were observed. In order Lepidoptera, teak skeletonizer *Eutectona machaeralis* and teak defoliator *Hyblaea puera* of leaf feeder are mainly observed in four townships except Gyobingauk Township. A total number of 19 species of natural enemies representing seven order; order Hymenoptera, Araneae, Coleoptera, Odonata, Orthoptera, Hemiptera and Neuroptera were also found. Out of 48 pest species, 15 species of pests are described with possible control measures. Out of 19 species of natural enemies, 3 species are described with their appearance, life cycle and predatory habit.

Introduction

Teak (*Tectona grandis* L.f.) (Family: Lamiaceae) is highly prized constructional and multipurpose timber species, found in the tropical and sub-tropical forests. Its natural distribution in India, Myanmar and Thailand ranges from sea level to 800 m, even up to 1300 m above sea level. The species has been planted in other tropical regions since the beginning of the 19th century, especially in Asia, Africa and Central America (Keogh, 1979; Dupuy, 1990). Teak, *Tectona grandis*, is a hardwood tree native to much of South and Southeast Asia, including Myanmar. Due to its natural water resistance, teak is sought out for a variety of uses including furniture-making and shipbuilding (Bryant, 1997).

Teak mostly grows in hilly areas below 900 metres (3,000 ft) in elevation. Within the country, teak is most common in mixed deciduous forests as well as evergreen and semi evergreen forests (Gyi and Tint, 1995). In the south of Myanmar, major teak forests existed in the Bago and Tanintharyi Hills. Other notable areas of teak growth include the Arakan (Rakhine) Mountains in the west of the country and the Shan Hills in the East (Gyi and Tint, 1995).

Nearly 294 insects have been identified on teak, which includes 147 species from order Coleoptera, 94 species from Lepidoptera, 23 species from Orthoptera, 21 species from Hemiptera, 7 species from Isoptera, 1 species from Diptera and 1 species from Hymenoptera (Beeson, 1941; Mani 1959; Mathur, 1960; Mathur and Singh, 1960; Muttiah, 1967; Browne, 1968; Vastrad *et al*., 1989; Varma, 1991; Tewari, 1992; Chey, 1996; Roychoudhury et al., 2001). These insects attack all the stages of teak growth, from seed to mature trees. About 196 species of insects are associated with living teak, comprising mainly defoliators (141), sap suckers (17), stemborers (16), root feeders (12) and seed feeders (9) and gall former (1) (Shukla *et al*., 2001). Many of these insects are minor or occasional pests and very few are considered as insect pests of economic importance (Roychoudhury, 1998).

Teak plantations often suffer severe damage from insect attack and outbreak of infestation has been occasionally reported in Myanmar. Myint and Win (2016) earlier reported that shoot borer (*Zeuzea coffeae* Nietner), leaf feeder (*Eutectona machaeralis* Walker), sap sucking bug (*Tingis* sp.), stem borer (*Acalolepta cervinus* Hope), saplingborer (*Sahyadrassus malabaricus* Moore) and termite (*Copotermes curvignathus*) infested young teak plant from an

experiment conducted in Nyaung Chae Thawk Reserved Forest, Oktwin Township, Bago Region and in Palwe Reserved Forest, Lewe Township, Nay Pyi Taw, Myanmar.

In the observation area, a total number of 48 species of pests belong to order Lepidoptera, Coleoptera, Hemiptera, Orthoptera, Homoptera and Isoptera were observed. In order Lepidoptera, teak skeletonizer *Eutectona machaeralis* and teak defoliator *Hyblaea puera* of leaf feeder are mainly observed in four townships except Gyobingauk Township. A total number of 19 species of natural enemies representing seven order; order Hymenoptera, Araneae, Coleoptera, Odonata, Orthoptera, Hemiptera and Neuroptera were also found associated with teak nursery and plantation.

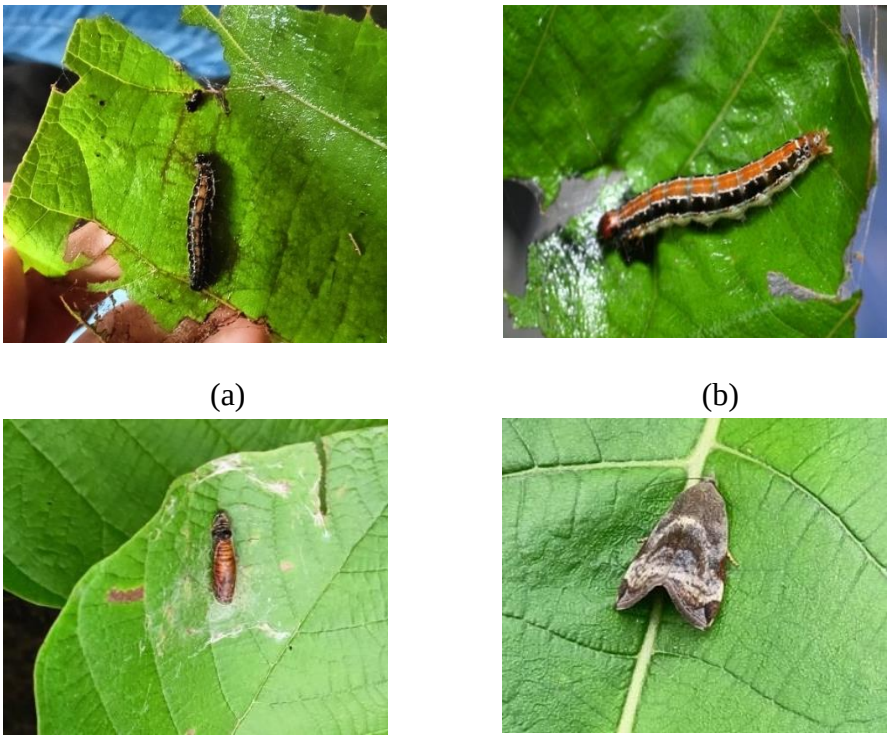
Pests of Teak (*Tectona grandis* L.f, Lamiaceae) in Bago Region, Myanmar

1. Teak defoliator (ကျွန်းရွက်စားပိုး)

Hyblaea puera (Cramer, 1777)
Order: Lepidoptera
Family: Hyblaeidae

Distribution
Australian and Oriental regions like India, Sri Lanka and Malaysia and also present in South Africa and many parts of East Africa (Browne, 1986)

Host Range
Tectona grandis, Alstonia scholaris, Avicennia spp., *Callicarpa* spp., *Pterocarpus macrocarpus, Rhizophora* spp., *Vitex* spp.
Verbenaceae, Bignoniaceae, Araliaceous, Juglandaceae and Oleaceae. (Mathur, 1960).



(a) (b)

(c) (d)

Figure 1: Developmental stages of Teak Defoliator (a) 3rd instar larva (b) 4th instar larva (c) pupa (d) adult

Observed Locations

Tharyarwaddy, Minhla, Paukkhaung and Padaung Townships

Life Cycle and Biology

Mated female lays eggs singly near the veins on the under surface of the tender leaves. A single female can lay about 400 eggs. The eggs hatch 2 - 3 days and newly emerged tiny larvae feed on the tender leaves of the teak plant. The larva moults for 5 times and prefers only young and tender leaves of teak for feeding. Larva fold leaf margin and feed inside. Larva stage lasts for 12- 15 days or may extend up to 20 days in cold weather. Pupal period ranges from 6 to 8 days. Total life cycle varied from 21 to 28 days. Pest complete 7 generation in a year from June to November (Sharma et al.,2013)

Nature of damage

H. puera is a serious pest to *T. grandis*, causes considerable loss in increment and quality. Only the larvae are destructive. They feed on tender leaves of teak and affect the growth of the plant. The larvae create shelters for themselves by cutting pieces of leaves and folding them together. They come out of the shelters to feed by night. Initially, the larvae defoliate seedlings and considerable defoliation of young trees, 2-5 years old, in the plantations. Periodic outbreaks occur in March-April and September-October. The larvae pupate on the leaves by curling the leaf tips over their body. Repeated and severe defoliation causes volume decrement of timber in grownup trees of Teak to the level of 4.5m^3 per ha in a year (Nair, 1996).

Figure 2: Leaf folded by larva of Teak Defoliator

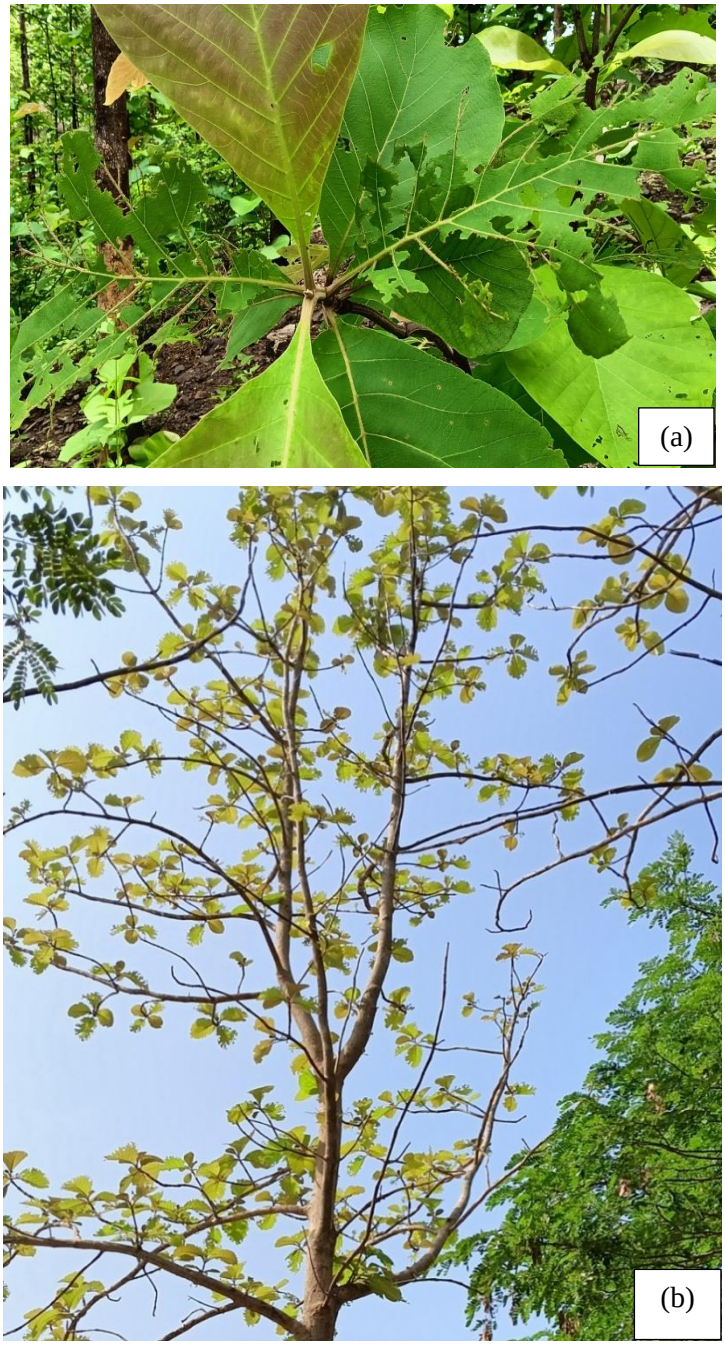


Figure 3: (a) damaged leaves and (b) damaged plant by Teak Defoliator

Control Measures

- Clip badly affected leaves with larva.
- Set up of light trap to trap adult moths.

- Collect and destroy the egg masses, larvae and pupae.
- Clean cultivation and digging the field for exposing pupae to natural mortality factors, is helpful in reducing the incidence of the pest.
- Pheromone traps may be utilized to attract and kill the pest.
- Spray Curacron 50 EC (profenofos) 2 ml/ litre of water using foot sprayer. (Sangha et al.2016)

2. Teak leaf skeletonizer (ကျွန်းရွက်ကြဲပိုး)

Eutectona machaeralis (Walker)
Order: Lepidoptera
Family: Pyralidae

Distribution

India, Sri Lanka, Myanmar, Indo-China and throughout Malayan region to Australia (Beeson, 1941; Mathur, 1960; Browne, 1968).

Host Range

Tectona grandis, *Callicarpa arborea*, *C. Cana*, *C. macrophylla* and *Tectona hamiltonia* (Beeson, 1941; Mathur, 1960)

Observed Locations

Tharyarwaddy, Minhla, Paukkhaung, Padaung Townships

Figure 4: *Eutectona machaeralis* infected teak leaves symptom

Life Cycle and Biology

The moths of *E. machaeralis* are small, bright yellow, having pink or reddish markings in the form of zig-zag or serrate line on the forewings and an orchreous or reddish marginal line or band in the hindwings (Fig.5.b). The female moth lays an average of 250-550 greenish white eggs single on the ventral side of the leaf. The newly hatched larvae are dirty white, which changes to pale green in due course of time. There are five larval instars, the growth and development differs in respect to instars and a distinct pre-pupal stage. The larvae consume the whole fleshy tissues of the leaf leaving the vein network intact thereby skeletonizing the leaf. The larvae feed on teak leaves at different levels of maturity and quality. However, larvae prefer soft tender leaves (Roychoudhury et al., 1995). Larval period varies from 10-14 days or more depending on the climatic factors. Pupation occurs in small loose cocoon on green or fallen dry teak leaves. In central and north India, the pest undergoes pre-pupal diapause for 4-5 months, whereas in south India and Myanmar, there is no evidence of diapause in this insect (Beeson, 1941).

Nature of damage

Teak leaf skeletonizer is a key pest of teak in nurseries, plantations and natural forests. Larvae of this insect feed only on the leaf green matter leaving all the veins intact, thus qualifying for the name, skeletonizer. Larvae feed on leaves of all qualities till before natural leaf fall.

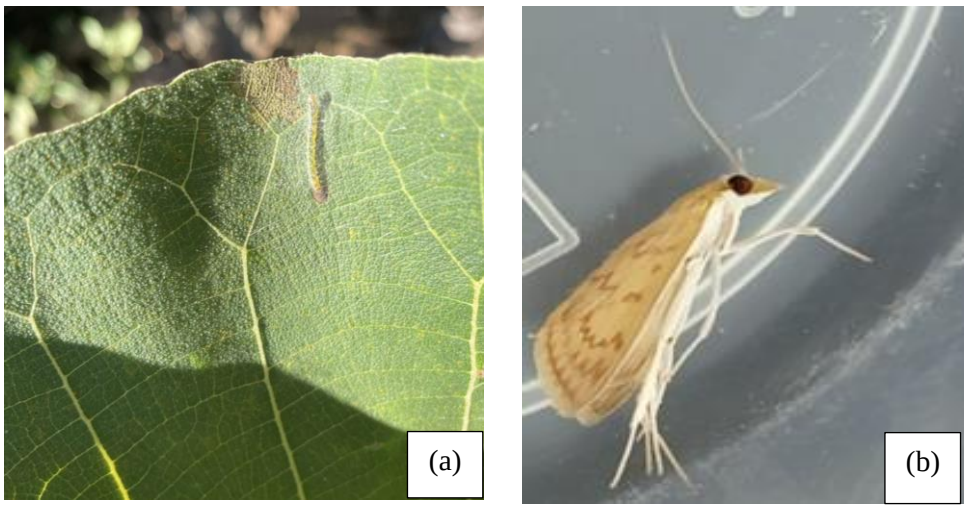


Figure 5: Teak skeletonizer (a) Larva and (b) adult

Control Measures

- The desirable plant species acting as food plants of other defoliators should be grown in association with teak, to maintain the population of parasites and predators.
- Use of teak seeds from relatively resistant genetically superior teak trees should be considered for long term solution of leaf skeletonizer. (Roychoudhury, 2002; Roychoudhury and Mishra, 2020a).
- Introduce egg parasitoid, Trichogramma sp. 1.25 lakh/ha in teak forests between July to September (Joshi et al., 2007; Roychoudhury et al., 2018, 2020). Carbaryl 0.1% or Malathion 0.05% for effective larval killing of this skeletonizer (Singh and Gupta, 1978) (Singh, 1988).
- Foliar application either Delthamethrin 0.002% or Fenvalerate 0.003% or Alphamethrin 0.003% or Cypermethrin 0.003% or Monocrotophos 0.03% or Chlorpyriphos 0.05% or Phosphamidon 0.05% or Dichlorvos 0.06% or Methyl demeton 0.06 % kills larvae of this insect (Roychoudhury and Joshi, 2000).

3. White grub (ဖိုးလမင်းကျိုင်း)

Holotrichia sp.
Order: Coleoptera
Family: Scarabaeidae

Distribution
India, Myanmar

Host Range
Tectona grandis, *Shorea robusta*, guava, sugarcane, coconut, areca nut, tobacco, potato and many other oilseeds, pulses and vegetable crops.

Observed Locations
Paukkhaung Township

Life Cycle and Biology
In the sub-tropical areas, the life cycle is normally annual with a larval period of 8 to 10 months; in the mountains above 2000 meters the life cycle lasts for 2 years (ICFRE, 2020).

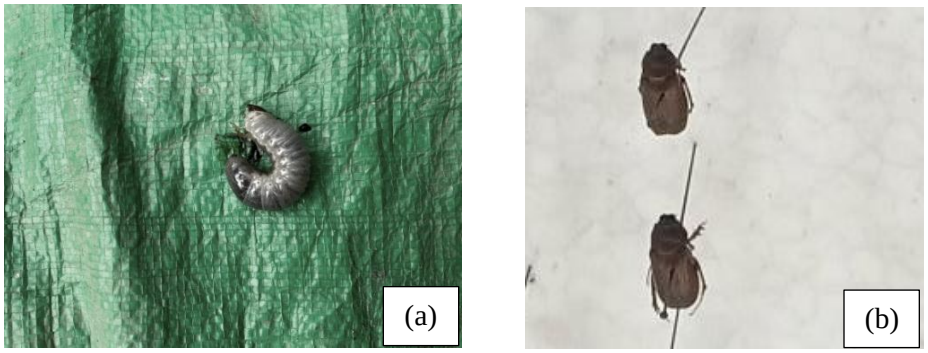


Figure 6: White grub (a) semi-circular shaped grub and (b) adult

The adult beetles are 18-20 mm long and 7-9 mm wide. They emerge from the soil during dusky hours (7PM to 10PM) after good rains in mid-May or later. Once active, the beetles follow the daily rhythm of emergence and congregation on host trees at dusk and return to soil at dawn. The beetles feed on the foliage of variety of host trees such as, ber, drumstick, tamarind, banyan, acacia, neem, mahagoni, jamun, guava, sapota, banana, mango, fig etc found in and around the farm. The mated females return to soil in early morning and start egg-laying. The white grub, *H. consanguinea* completes its life cycle in 76-96 days. The egg period is 8-10 days, larval period is 56-70 days and pupal period is 12-16 days. The grubs are active in their second, third and fourth instar larval stages during rainy seasons (July-October) and feed on organic matter until they come in contact with living roots of plants. Eggs are white and round in shape. The young grubs are white translucent whereas mature grubs are 'C' or semi-circular shaped (Fig 6). Before pupation the grub ceases to feed and descends down in the soil to the depth of 40-70 cm. A short pre-pupal period is spent preparing an earthen chamber for puapation. The beetles remain in the soil in inactive state at a depth of about one meter till the next monsoon rains (Nataraja, 2015).

Nature of damage

Chafer or white grub *Holotrichia* is injurious to seedlings in teak nurseries and a serious problem in forestry. The adults are defoliators while the grubs are subterranean in habit and most of the year lives near the roots of the seedlings and plants, feeding voraciously upon them. Chafer beetles feed on trees at dusk and do not fly by day. Eggs laid in the soil, the females often burrowing several centimeters deep for the purpose. The larval stage is passed

in the soil near the roots of the plants on which it feeds. In very cold and in hot dry weather the grubs descend to the deeper layers of the soil, in wet and cool weather they come within a few centimeters of the surface, but do not leave it to travel above ground. Seedlings are killed by the destruction of the rootlets or removal of bark of the tap root (ICFRE, 2020)

Damage is caused by grubs where, young grubs feed on fine rootlets while mature grubs feed on both roots and pods. The affected plants show varying degrees of wilting, which ultimately die and died plants can easily be pulled out. The grubs cause infestation in patches leading to 'patchy appearance' of field (Nataraja, 2015).

Control Measures

- As a control measure, the nursery beds have to be prepared before May-June, i.e., the swarming time of chafers.
- Sowings of autumn or winter should be done at a time when the beetles are not on the wing so that they may not lay eggs into the beds.
- The surface of the beds should be covered with sand in advance of swarming time of beetles.
- It is inadvisable to weed during the flight period as disturbance of the surface soil invites oviposition. Folithion, 10% dust, or Thimet 10 gm or Furadon 3 gm.
- When mixed mechanically into the soil at the time of seed bed preparation gives effective control.
- White grubs in teak nursery, can be controlled by applying 200 gm thimet 10 G per bed (10 mx1m) if applied in split dosages, half at the time of sowing and rest after one month of germination (ICFRE, 2020).
- The chemical control may be initiated if the pest population is one grub per square meter. Adult control place 1 light traps/ha between 7PM to 10PM.
- Spray insecticides such as imidacloprid 1.5 ml/L or monocrotophos 1.6 ml/L during the evening hours on trees and shrubs.
- Grub control, take up deep summer ploughing to expose the pupae and predation by birds.
- Use well decomposed organic manures. Add Carbofuran 3G in soil before sowing. Seed furrow application of insecticides such as, thiamethoxam or

fipronil. Seed treatment with chlorpyriphos 20 EC, 6.5-12.0 ml/kg or imidacloprid 2.0 ml/kg seed.

- Drench the root zone of crop with chlorpyriphos 20 EC, 4.0 L/ha or quinalphos 25 EC, 3.2 L/ha three weeks after the adult emergence. (Nataraja, 2015).

4. Ash Weevil (နှာတံရှည်ကျိုင်း)

Myllocerus sp.
Order: Coleoptera
Family: Curculionidae

Distribution
India and Sri Lanka, Asia especially from south East Asia, Africa, Australia, the Palearctic and North America.

Host Range
Tectona grandis, sweet potato, cash crops, forest trees, agriculture crops and shrubby vegetation, millet, maize, sorghum. *Acacia auriculiformis* Benth, *Anacardium occidentale* L., *Calliandra calothyrsus* Meisen, *Cassia auriculata* L., *Cassia fistula* L., *Cassia hirsuta* L., *Cassia tora* L., *Cassia aurantifolia*, *Citrus reticulate* Blanco, *Eucalyptus robusta* Smith, *Eugea gambolana* Lam., *Eupatorium odoratum* L., *Helianthus annus* L., *Helicteres isora* L., *Ipomea batatus* (L.) Lam., *Ponagamia pinnata* L, *Populus deltoids* W., *Sapindus tripliatus* L., *Solanum violacium* Ortega, *Tamarindus indica* L. (Ahmad, 1989)

Observed Locations
Tharyarwaddy, Gyobingauk Townships

Life Cycle and Biology
Weevils develop through four life stages: egg, larva, pupa, and adult. Many species have only one generation per year and overwinter as larvae in plant parts or soil. The peak abundance of adults commonly is during spring and summer.

Nature of Damage

There are many species of weevils which are small, scaly, snout beetles defoliate the plants. The adults, who are active from April to July, feed on the leaves of various dicotyledonous trees like *Azadirachta indica*, *Santalum album*, *Tectona grandis* and *Toona ciliata*. Infestation period of insects is April-July. Damage the foliage of seedlings, saplings and trees. Feeds on the leaves mostly at night, from the edges towards the midrib. Sometimes the distal half of the leaves is cut off because of circular holes in a line made by the adult weevils.

Figure 7: Ash Weevils

Control Measures

- Collect and destroy adult weevil.
- Apply Neem cake 500 kg/ha at the time of last ploughing.
- Apply lindane 1.3 D before planting 25 kg/ha.

- In endemic areas apply carbofuran 3G, 15 kg/ha, 15 days after planting.
- Spray carbaryl 50 WP 2 kg + wettable sulphur 2 kg or endosulfan 35 EC 1.5 L or malathion 50 EC 1.5 L.
- Attack on young plants up to 2 years can be controlled by prophylactic spraying of 0.1 percent Carbaryl.
- Spraying may be concentrated on the under surface of the leaves.
- Application of the insecticide may be done twice a year, once during May and again in September. (TNAU Agritech Portal, Crop Protection, 2016)
- Spraying of 0.02 – 0.05 % of Monocrotophos, Quinalphos, Chlorpyriphos or neem formulations as per the recommended dosage. Preference to be given to contact insecticides (ICFRE, 2020).

5. Aphid (ပျ)

Aphis gossypii
Order : Hemiptera
Family : Aphidoidea

Distribution
North and South America, South East Asia, Central Asia, Africa, Australia, Brazil, East Indies, Mexico and Hawaii and in most of Europe

Host Range
Tectona grandis, cucurbit vegetables, pepper, eggplant, okra, asparagus, citrus, cotton and hibiscus.

Observed Locations
Tharwaddy, Paukkhaung, Padaung Townships

Life Cycle and Biology
The life span of female is about twenty days in which time it can produce up to 85 nymphs. These mature in about twenty days at 10 °C and in about four days at 30 °C. Aphids reproduce mostly by parthenogenetic vivipary and also by sexual reproduction. Nymphs are tiny, complete four instars in a period of 9-16 days and become adults. A single female can produce around 35-50 young ones in a short period.
Aphis gossypi are small, soft bodied, pyriform, black coloured sucking pests and feeds on the sap by sucking through stylets. Also secretes honeydew which

invites sooty mould growth and turns the leaves black. Prevalent throughout the year in all categories of plants (Tripathy and Rout, 2018).

Nature of Damage

The adults and nymphs feed on the underside of leaves or on the growing tips of shoots, sucking juices from the plant. Yellowing of leaves indicate symptom of damage by aphid. The foliage may become chlorotic and die prematurely. There is often a great deal of leaf curling and distortion which hinders efficient photosynthesis. Honeydew is excreted by the aphids and this allows sooty moulds to grow. The aphids are a vector of crinkle, mosaic, rosette and other virus diseases.

Control Measures

- Removal and destruction of aphid infested plant parts help to minimize their infestation and spread.
- Conservation of natural enemies such as syrphids, coccinellids (*Pseudospidemerus circumflexa* Mots., *Cryptolaemus montrouzieri, Menochilus sexmaculata, Coccinella transversalis*, *Scymnus* sp., *Illeis cincta*), lace wing bugs, mantispid flies etc.
- Carbamates and organophosphates are commonly used against *Aphis. gossypii* around the world (Han, 1998).
- The neonicotinoids are among the most effective group of insecticides against sucking insects such as aphids (Elbert et al., 1998, Horowitz et al, 1998)

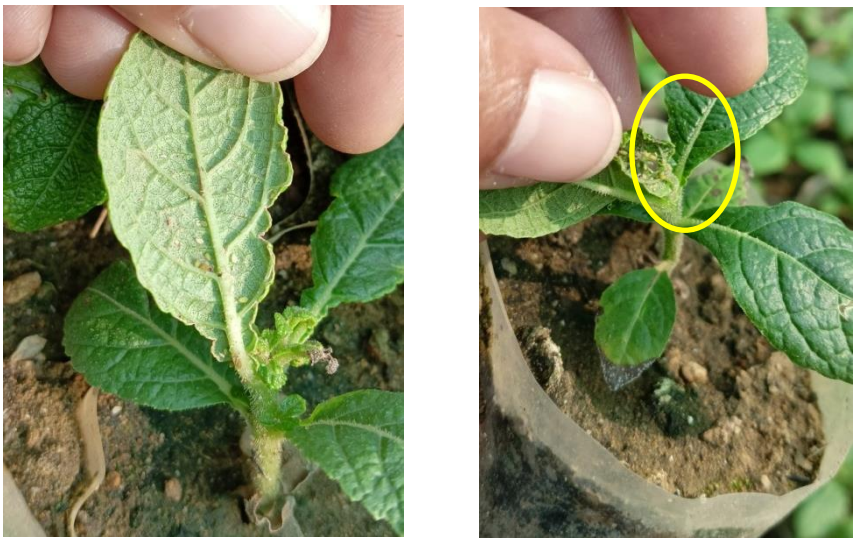


Figure 8: Aphid infested teak seedlings in Khittaya Nursery – Pyay Township

Figure 9: Leaf curling and distortion symptom of aphid infested teak seedlings in Khittaya Nursery – Pyay Township

6. White fly (ယင်ဖြူ)

Bemisia tabaci
Order: Hemiptera
Family: Aleyrodidae

Distribution
South East Asia, India, Pakistan, Bangladesh, Nepal.

Host Range
Tectona grandis, agricultural crops

Observed Locations
Tharyarwaddy, Paukkhaung, Minhla Townships

Life Cycle and Biology
The life cycle from egg to adult may be 18 days under warm temperatures (86°F) but may take as long as 2 months under cool conditions. The number of eggs produced is also greater in warm weather than in cool weather. The rate of reproduction ranges from 50 to 400 eggs (avg. 160, of which about ⅔ are female)/female.
Immature stages begin with a pointed oblong yellow egg (0.2 mm) which darkens at the apex just before hatching. The first instar or crawler stage (0.2-0.3 mm) settles down on the underside of leaves close to the egg shell and goes through three more molts as a sessile, flattened oval nymph. Late third and fourth instars begin to develop eye spots and are often referred to as red-eyed nymphs. The last instar, or "pupal stage" (0.7-0.8 mm, late instars are shown in the photo), has very distinct eye spots.
Eggs, nymphs and pupae are typically located on the undersides of leaves. The adult is small, about 0.9 to 1.2 mm in length and holds solid white wings roof-like over a pale yellow body at rest. (David, 2018).

Nature of Damage
Large whitefly populations may cause plant stunting, wilting and possibly death. It directly damages the plants by feeding on phloem sap, and excretes honeydew on the leaves and fruit. The sticky, sugary surface forms a substrate for the growth of black sooty mold fungi that stain the crop and cover the leaves, thus preventing proper photosynthesis. The resulting stickiness and

discoloration greatly reduce the value of agricultural crops such as ornamentals, vegetables and cotton. In the latter, the honeydew may cause fiber stickiness that interferes with the spinning process in the textile mills, and greatly reduces the product's value (Hequet et al. 2007).

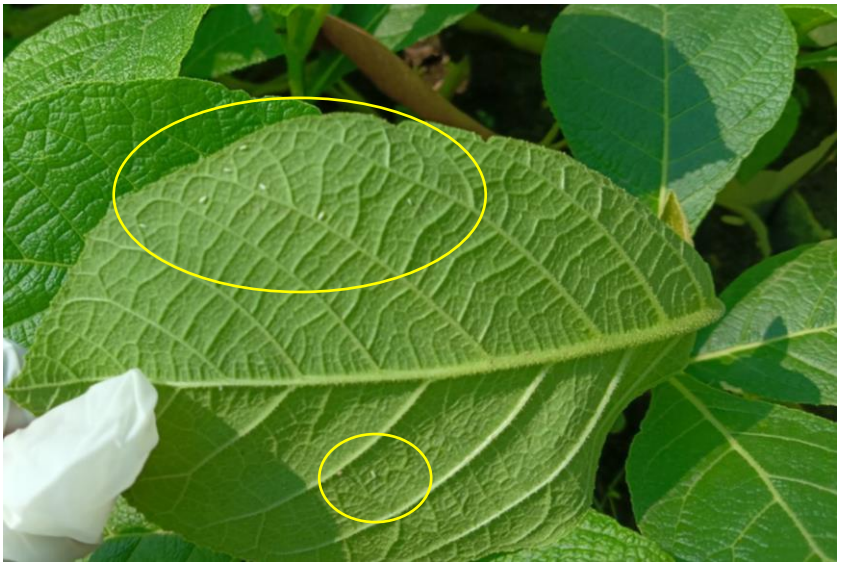


Figure 10: White fly infested leave of seedling at Shwe Ywar Myaing nursery in Minhla Township

Figure 11: White flies on the underside of the teak leaf in Tharyarwaddy Township

Control Measures

- Remove weeds from adjacent areas as many weeds serve as a reservoir for whiteflies.
- Placing yellow sticky cards among plants, just above the canopy, to capture the adult of white flies and be used to monitor changes in populations of whiteflies.
- Biological control agents for whiteflies are Encarsia and Eretmocerus parasitoids. These tiny wasps lay eggs inside or beneath whitefly nymphs.
- White flies can be control by predator such as lacewing or coccinelid larvae and by insect pathogens such as *Beauvaria, Verticillium* species.
- Dispose of plants heavily infested with whiteflies.
- Prune out or remove plant parts with whiteflies and dispose of everything in plastic containers.
- Horticultural Oils and Azadirachtin can be used to control the adult (David, 2018).
- Malathion or Pyrethrins are effective for killing whiteflies. Follow mixing instructions on the product label and then spray both the top and the underside of leaves, where whiteflies hang out. It is need to spray again every 72 hours (3 days) until there are no whiteflies.
- The systemic insecticide: imidacloprid can be applied before white flies populations reach high levels.
- The neonicotinoids are among the most effective group of insecticides as exhibit systemic and translaminar properties, and high residual activity especially against sucking insects such as whiteflies. (Horowitz et al, 1998).

7. Lace bug, Tingis bug (သစ်ရည်စုပ်ကျိုး)

Tingis sp.
Order: Hemiptera
Family: Tingidae

Distribution

Worldwide

Host Range

Tectona grandis

Observed Locations

Lewe, Nay Pyi Taw

Life Cycle and Biology

The eggs are laid in small groups on the lower leaf surface with part of the egg inserted into the leaf tissue. Eggs will hatch into nymphs after about two weeks. The nymphs feed for three to four weeks. They leave their molted skins clinging to the foliage. There are five nyphal instars. Life cycle takes five to seven weeks, depending on the weather, and there was only one full generation per year. In the spring, the adults fly to their hosts and begin feeding on the first fresh leaves. They mate and lay small groups of tiny eggs on leaf undersides, near the mid-vein. Once matured into winged adults, they mate and lay a second round of eggs, which will hatch, molt, and reach adulthood, and feed until late summer or fall.

Nature of Damage

Sap sucker. Both nymphs and adult of the lace bug feed almost entirely at the base of leaf blade on the under surface or at the axils. The leaf lamina becomes spotted with brownish patches near the base. The leaf ultimately wither and fall, leading to complete defoliation of the host plant. Aggregate in large numbers on stem and branches and feed gregariously at the base of the leaf blade and sucking sap from larger veins ultimately leaves become spotted, discoloured and wither. Eventually shoots die back. The damage becomes most noticeable when populations are large in mid to late summer. If feeding is heavy, leaves may drop prematurely.

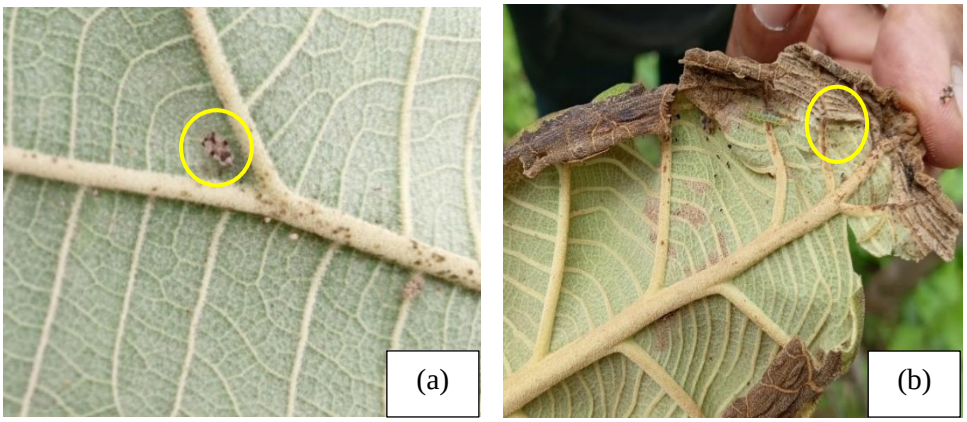


Figure 12: Lace bug (a) underside of the leave and (b) lace bug infested leaves symptom

Figure 13: Lace bugs collected from leaves

Control Measures

- Keep the soil bare under plants, remove any leaves or debris to overwintering adults or eggs that may be hiding out, or tilling the debris into the soil.
- Remove any weeds from the plantation that may serve as alternate hosts for the bugs.
- Planting a variety of ornamental shrubs rather than a lot of one type reduce the spread of this pest if an infestation occurs.
- Assassin bugs, jumping spiders, pirate bugs, mites, ladybugs, green lacewings, and parasitic wasps such as mymarids will all target lace bugs.
- Attract and build up a healthy population of these beneficial insects by planting the flowering plant species near the plantation.
- Use contact and systemic insecticides such as Imidacloprid.
- For lace bugs, Bifenthrin, cyfluthrin, permethrin, pyrethroids, Carbaryl products such as Sevin are useful and effective.
- Chemical contact pesticides must be applied properly to fully cover the undersides of the leaves (Dekker, 2021).

8. Teak canker grub

Dihammus cervinus
Acalolepta cervina (Hope)
Order: Coleoptera
Family: Cerambycidae

Distribution
India, Myanmar, Thailand

Host Range
Tectona grandis

Observed Locations
Paukkhaung Township

Life Cycle and Biology
Female lays 60 eggs. Incubation period is 5 days. Larval period lasts for 3 months. Pupal period is 14-19 days. Emergence of adults is during April.

Nature of Damage
Adults feed on the bark of teak saplings 2-8 years old and lay eggs on the bark, near ground level. Feeding and tunneling by larvae causes formation of a bulging canker all around the stem at which point the saplings may break.

Figure 14: Teak canker grubs (adult)

Control Measures

- The grubs also feed on roots in the nursery. Apply phorate 10G or Carbofuran 3G two teaspoon full mixed with fine sand.
- The use of *Beauveria bassiana* proparations for control of *Acalolepta cervinus* (Hope) is effective.

9. Termites (ခိုး)

Order: Isoptera
Coptotermes curvignathus Holmgren
Family: Rhinotermitidae
Odontotermes sp.
Order: Isoptera
Family: Termitidae

Distribution
Africa and Asia

Host Range
Tectona grandis, *Pinus* spp., *Araucaria* spp., and *Agathis* spp.

Observed Location
Tharyarwaddy, Minhla, Gyobin gauk, Pauk khaung, Padaung Townships

Life Cycle and Biology
In the beginning only a few eggs are laid. The eggs hatch after one week during the summer and within 6 weeks the larvae develop to form soldiers or workers. The queen is capable of laying many millions of eggs during her life.

Nature of Damage
In the growing trees, the termites attack only the outer dead bark and are mostly restricted to the dead portions. The worker termites eat away thin layers of the bark surface. The attack usually under earthen galleries which covers the bark and under which workers and soldiers travel to and from the ground connection leading to sometimes to tree branches or inside the trunk through wood scars of branches and freedom heart wood.
Most termite damage young plantations immediately after planting up to one year, is by and large, a primary causal factor. Here, the tap root is ring barked after feeding on secondary hosts, which is completely eaten up followed by wilting and drooping of tender leaves, and ultimate death of the seedlings or young plants. The attacked plant can be easily pulled out from the ground or falls down automatically in due damage. This is a most common cause of mortality during the first year of planting (ICFRE, 2020).

Figure 15: Damage to teak trees by termites

Control Measures

- The area where termite attack is high, plantations and surroundings must be cleaned by removing all plant debris to maintain crop protection from termite attack.
- Destroy the termite reservoirs or mounds to reduce activities of termites.
- Remove the king from the colony, which may destroy the whole colony.
- The termites are efficiently controlled at high temperatures. Heating and smoke by burning of the crop residues at the mounds.
- Imidacloprid should be applied once a year. Imidacloprid is a non-repellent insecticide, and caused more than 90% mortality.
- Where the pest is of regular occurrence the soil should be mixed with endosulfan 4D or quinolphos 1.5 D, 35 kg/ha at the time of sowing.
- If the incidence of pest is noticed in standing crop dilute 2.5 L of endosulphan 35 EC in 5 L of water and mix it with 50 kg of soil and broabcast even in 1 ha followed by light irrigation.(NAIP).

10. Blister beetle (ဖူးယောင်ကျိုင်း)

Mylabris phalerata Pallas
Order: Coleoptera
Family: Meloidae

Distribution
India, Myanmar, China

Host Range
Leguminosae, alfalfa, Baptisia, bean, pea, and sweet clover; potato and cotton.

Observed Locations
Paukkhaung and Padaung Townships

Life Cycle and Biology
This beetle lays eggs in the soil in August. The eggs hatch about 40 day to larva in mid-September. There are five larva developmental stages before they mature into an adult, the last being their overwintering stage, in which they spend six months in the soil before pupating in May and emerges as adults in June. Their developmental temperature range is 18 °C to 34 °C (Zhu, 2005). The amount of period during their overwinter stage is depended by soil temperature (Zhu, 2006). The adult body size varies from 25 mm to 34 mm long and 4 mm wide, with the average female's body is 33 mm length and the average male's body length is 26 mm. The adult beetles are black with large orange spots behind their head, followed by 2 wider orange bands (Zhu, 2005).

Nature of Damage
The adult beetles severely damage buds, flowers and even tender leaves by feeding either solitarily or gregariously. The damage caused to flower is so extensive that there is no pod and seed setting resulting indrastic yield reduction (Dhingra and Sarup 1992).

Figure 16: Blister beetles

Control Measures

- Remove the plant debris from the field.
- Remove the weeds from field.
- The beetles can be controlled manually by picking them by hand
- Lambda – cyhalothrin 5 EC of 10 ml/10 litre (pyrethroid). Contact and stomach action. Some has repellent properties.
- Carbaryl 10% at 20 kg/ha (Carbamate). Stomach and contact activity with slight systemic properties.
- Cypermethrin 10 EC at 10ml/10 litre (Pyrethroid).
- Use proper quantity of water
- Deep ploughing at summer season.
- Application of neem seed kernel extract (5%) as a repellent for egg laying.
- Quinalphos 1.5% at 20 kg/ha (Organophosphate). Broad spectrum contact and stomach poison (CABI, 2014).

11. Short horned grasshopper (ငှမ်တိုနှံကောင်)

Acrida sp.
Order : Orthoptera
Family: Acrididae

Distribution
Africa, Europe, Asia, North America, Hawaii, and Australia.

Host Range
Agricultural crops, grasses and forest tree

Life Cycle and biology
Acridoids pass through three stages: egg, nymph and adult (Evans, 1984; Symmons and Cressman, 2001). The nymphs and adults of are usually similar in shape and habits (Coronado and Marquez, 1986). Some acridoids has one to two generation or more generations per year. Female acridoids lay eggs in batches and are usually deposited in the soil, but some species prefer to oviposit within the roots of plants. Females may produce around 100 to 500 eggs or more (Carpintera and Sechrist, 1982).

Nature of damage
Irregular feeding on seedlings and leaf blade*;* Large portions of leaf edges consumed. (ICAR, 2012).

Figure 17: Short horned grasshopper

Control Measures

- Dusting malathion 5%, 20kg/ha.
- Foliar sprays of insecticides can also control grasshoppers.
- Scelionid wasps parasitize the eggs of short- horned grasshopper. A platystomatid fly and mite prey on the eggs of oriental migratory locust.
- Different species of ants feed on the nymphs and adults.
- They are also prey to birds, bats, field rats, mice, wild pigs, dogs, millipedes, fish, amphibia, reptiles and monkeys (ICAR, 2012).

12. Butterfly (ဒိန်ပြာ)

Catopsilia pomona
Order : Lepidoptera
Family : Pieridae

Distribution

Sri Lanka, India to Myanmar, Thailand, Laos, Cambodia, Vietnam, Hainan, China, Taiwan, Langkawi, W.Malaysia, Tioman, Singapore, Sumatra, Java, Borneo, Palawan, Philippines

Host Range

Butea monosperma, *Cassia fistula*, *Bauhinia* species, *Pterocarpus indicus*, *Senna alata* and *Sesbania* species and Leguminosae (Fabaceae).

Observed Locations

Tharyarwaddy Township

Life Cycle and Biology

The entire life cycle stages of *C. pomona* is divided into egg, five larval stages, pupal stage and adult stage. The eggs of the butterfly are laid on various species of plants. The eggs are usually laid singly on the underside, at the margin of the leaves. Each egg is white, bottle shaped, and ribbed vertically. They deposited an average of 94.8 eggs per plant. The eggs hatch in 3–4 days. The newly hatched caterpillar (larva) is about 0.5 cm long and is yellowish green. In later instars, the colour changes to a leafy green. The head is green and spotted with tiny black tubercles. The paired lines are found on both sides of the body and run from head to anus. The larval period lasts for 10 to 15 days. Fully grown larva stops feeding and becomes inactive before pupation.

Pupation takes place low to the ground. Its entire body is bright leaf green. Pupa is oval in shape with both the ends pointed at their tips. The color of pupa changes from bright green to dull green. Two thin pale yellowish lines are also seen on either side from tip to end. The average length of pupa from its tip is 3.0 to 3.5 mm and average duration of adult emergence is 5 -6 days.
Upper side of adults is pale yellow or white with sulphur yellow base always in male but usually in female. Female possess black border in the fore-wings. The life cycle of C. pomona is about to 15 - 21 days under laboratory condition (Joydeb and Agarwala, 2018).

Figure 18 : The adult stage of *C. pomona* butterfly.

Nature of Damage

Butterflies of Pieridae are common in tropical parts of the world and few of them are also considered as pests of economically important plants (Capinera 2008). The first instar larva, soon after emergence, feeds on epidermis of leaflets. It feeds diurnally on many trees, shrubs and herbaceous plants in the, favouring Cassia.
Damage was mainly due to caterpillars. Larvae of this pest found to be serious defoliator. Larval feeding resulted in denuding of plant. Larvae pupated on plants and remain attached with the silken thread. About 44-96 percent infestation was recorded on senna.

Control Measures

- *Bacillus thuringiensis* can be used to control caterpillars.
- Vinegar spray: A vinegar and water solution will kill and repel most garden pests, including caterpillars. Mix two tablespoons of vinegar with 1 gallon of water, and spray wherever you've seen caterpillars.

- Use of Pyrethrin, bifenthrin, permethrin, cyfluthrin, cyhalothrin, Sevin and malathion to control caterpillars.
- Neem oil is effective to control this caterpillar. (Glen, 2022).

13. Mealy bugs (ဝိုးဇေးနှဲ)

Pseudococcus sp.
Order : Hemiptera
Family : Pseudococcidae

Distribution
Worldwide

Host Range
Malvaceae, Solanaceae, Leguminaceae and a few ornamentals plants

Observed Locations
Tharyarwaddy, Paukkhaung Townships

Life cycle and biology
Female lay eggs in an egg sac (about 600 eggs) of white wax on the twigs, branches, bark of the plant, leaves and terminal ends. Eggs hatch 3-9 days and under normal conditions, nymphal stages of mealybugs take about 30 days. There may be as many as 15 generation per year.

Nature of damage
Infested plant parts become stunted. Both nymphs and adults suck the sap from leaves becoming withering and yellowing of leaves. Heavy infestation can cause fruit dropping and defoliation and death of the host plant.

Control Measures
- Infested plant parts, debris and weed should be removed and burned to prevent mealybug populations invading to the new plant.
- Manual picking of bugs can be done in plants that are not severely infested in nursery.
- Coccinellid beetles (predators) should be released to feed the mealy bug numphs.
- Insecticides such as Pyrethroids (Permethrin, Bifenthrin) and carbamate (carbaryl 50 WP) could be sprayed. Azadirachtin can also be applied.

Figure 19: Different plants infested with mealy bugs in nursery

14. Armyworm (ငရုတ်ပြောင်တောင်)

Spodoptera litura
Order : Lepidoptera
Family : Noctuidae

Distribution
South and *East* Asia, Oceania, some African islands and *Hawaii*

Host Range
Agricultural crop, horticultural crops and wild plants

Observed Locations
Tharyarwaddy, Paukkhaung Townships

Life cycle and biology
There are four stages in life cycle eggs, larva, pupa and adult stage. Females lay eggs in masses of 200 to 300 eggs and hatch 3-4 days. Total life cycles complete about 40 days (Aravinthraju et al., 2022).

Nature of damage
The young larvae first feed gregariously and scrape the leaves. Older larvae spread out and can cause defoliation and poor growth of plants.

Figure 20: Hand collected Armyworms

Control Measures

- Plough the soil to expose and kill the pupae
- Grow castor along border and irrigation channel as trap crop
- Flood the field to drive out the hibernating larvae
- Set up light trap at 1/ha
- Collect and destroy egg masses in nursery
- Hand picking of grown up larvae and kill them
- Avoid pre-monsoon sowing.
- Pyrethroid (Cypermethrin), Carbamate (Carbosulfan) can be applied (TNAU, 2016).

15. Golden Tortoise Beetle

Aspidimorpha sanctaecrucis
Aspidomorpha miliaris
Order : Coleoptera
Family : Chrysomelidae

Distribution
Southeastern Asia, Southern China, Southwestern India, Central Asia. (Swietojanska and Borowiec,2006)

Host Range
Fabaceae, Verbenaceae, Convolvulaceae, Ipomoea species.

Observed Locations

Gyobin gauk and Tharyarwaddy Townships

Life cycle and biology

Golden Tortoise Beetle lays eggs (about 11 eggs) underneath fully opened leaves. Life cycle (eggs, larva, pupa and adult stages) complete about 30-37 days. (Nakamura et al.,1989).

Nature of damage

This beetle feed the plant leaves and left irregular circular holes on the leaf' surface. They eliminate most of a leaf surface area until only the skeleton of the leaf is left over. Heavy feeding of both adult and larvae can become defoliation and reduction in yield. (Ghate et al.,2003) (Asio and Ferraren, 2021)

Control Measures

- Hand picking of beetles and destroy.
- Weeding should be done.

Figure 21: Golden Tortoise Beetles

Natural Enemies of Teak (*Tectona grandis* L.f, Lamiaceae) in Bago Region, Myanmar

Predators

1. Ladybird beetles (လိပ်ခုံးကျိုင်း)

Coccinella sexmaculata (Fabricius)
Coccinella transversalis (Fabricius)
Order : Coleoptera
Family : Coccinellidae

Figure 21: Lady bird beetle *Coccinella sexmaculata* and *Coccinella transversalis*

Appearance

Coccinella sexmaculata (Fabricius)
This beetle is a small round and 3-4 mm body length, its color varies from yellow to canary yellow and forum with a black elytrum and also present. This beetle has been recorded in India, Nepal, Japan, Indonesia and China.
Coccinella transversalis (Fabricius)
This beetle is about 5 mm body length and its color is red orange with black inverted "V'' markings on elytra (Balbarino and Ceniza, 2005). This beetle has been recorded in India, Nepal, Sri Lanka, Bangladesh, Indochina, Indonesia, Australia and New Zealand (Poorani, 2002).

Observed Locations

Tharyarwaddy, Minhla, Paukkhaung, Padaung Townships

Life Cycle

Female beetles lay yellow to orange oval eggs in clusters on leaves or stems. Eggs hatch into larvae that complete 4 instars within 12-16 days before pupating. The pupa can be found on plant leaves and stems. Adults emerge wtihin 4-10 days. Beetles overwinter as adults in leaf litter. Eggs are elongated, usually yellow to orange in colour and are laid in clusters of 10-50 eggs near the prey (e.g. aphid). The larvae are soft bodied and wingless. Their colour varies from black to dark brown with various types of markings or spots. Some larvae are covered with white wax. Larvae are very active moving around in search of prey. The pupae are oval-shaped and are glued to the leaf surface.

Predatory habit

The adults and larvae of ladybird beetles are important predators of aphids. A single ladybird can eat 200-300 aphids over its lifetime. Both adults and larvae prey on aphids, leafhoppers, mealybugs, mites, scales and whiteflies. The larvae eat more pests (particularly aphids) than adults. A single ladybird can consume approximately 200 - 300 aphids over its lifetime of 1-3 months. The adults and larvae are predacious. Lady beetles also feed on caterpillars, moth eggs and other soft-bodied insects. As conservation: Grow strips or groups of non-crop flowering plants such as fennel, thistles, coriander, carrots. Pesticides spraying should be avoided. But if it is necessary, selective pesticides and methods should be used.

2. Praying mantis (ရိုးခိုးကောင်)

Mantisa religiosa
Order : Orthoptera
Family : Mantidae

Figure 22: Praying mantis on sticky trap

Appearance

Praying mantis is a predatory insect. It has a number of adaptations for capturing and devouring its mainly insect prey. These include powerful mandibles (mouthparts) and long, spiked forelegs, has an elongated body from 5 to 9 cm (2 to 3.5 in), long, slender limbs, and two pairs of wings. It has a very large distribution range, being found in Europe, Africa, Asia, and (possibly) Australia (Activewild, 2019).

Observed Locations

Tharyarwaddy, Minhla, Gyobingauk, Paukkhaung, Padaung Townships.

Life Cycle

There are three stages to the European mantis life cycle: egg; nymph; and adult 'incomplete metamorphosis'. Mating usually takes place in September or October during the warmest part of the day. Females lay eggs in a dense, foamy case called an ootheca, which contain up to 400 eggs (Activewild, 2019).

Predatory habit

When the eggs hatch the nymphs may cannibalize each other if no other food is available. Both nymphs and adults are indiscriminate eaters. Mantids will eat nearly anything they can catch including flies, moths, crickets, grasshoppers, bugs, etc., but also on natural enemies such as beneficial bugs, flies and spiders. As conservation, avoid spraying broad spectrum pesticides. Maintain vegetation as natural habitats for mantids (Activewild, 2019).

3. Dragonflies (ပုစဉ်း)

Sympetrum fonscolombii
Order : Odonata
Family : Aeshnidae

Figure 23: Dragonfly

Appearance

Sympetrum fonscolombii can reach a body length of 38 to 40 millimetres (1.5 to 1.6 in). Males have a red abdomen. The wings have red veins and the wing bases of the hind-wings are yellow. It can be seen on the wing throughout the year. Its main flight period is May to October and it is scarce during the winter months.

Observed Locations

Tharyarwaddy, Minhla, Gyobingauk, Paukkhaung, Padaung Townships

Life Cycle

Adult females lay eggs by flying low over the surface of water and tapping the tail end of their abdomen on the water, shaking eggs out as they fly. Eggs may also be laid on aquatic vegetation. 1500 eggs are laid and they take about a week to hatch into aquatic nymphs. The nymph stage of dragonflies lasts up to five years in large species, and between two months and three years in smaller species. Larvae develop in the water and are predacious on other aquatic insects. Once mature, they climb out of the water to pupate and take to the skies. It has more than one generation per year. Some larvae overwinter.

Predatory habit

Dragonflies are strong, agile fliers and have keen eyesight. They catch their prey in the air and feed on midges, mosquitos, butterflies, damselflies, tadpoles, and small fish. Their staple diet of nymph is mostly bloodworms and other insect larvae, but they also feed on tadpoles and small fish.

References

Ahmad, M. (1989). Feeding Diversity of *Myllocerus viridanus* Fabricius (Coleoptera: Curculionidae) from South India. Indian Forester, 115(11), 832-838.

Aravinthraju, K., Moorthy, A. V., and M. Roopika. (2022). Biology of *Spodoptera litura* (Fab.) in cassava, Manihot esculenta (L.). The Pharma Innovation Journal; SP-11(7): 813-814.

Asio, L. and D. Ferraren (2021). Biology of tortoiseshell beetle (Aspidimorpha miliaris Fabr.) on sweetpotato (Ipomoea batatas Lam.) and its relatives as affected by hosts' nutritional profiles. Annals of Tropical Research –ResearchGate.

Beeson, C. F. C. (1941). The Ecology and Control of Forest Insects of India and the Neighbouring Countries. Government of India, New Delhi. 766 pp.

Browne, F. G. (1968). Pests and Diseases of Forest Plantation Trees. Clarendon Press, Oxford, UK, 1330 pp.

Bryant, R. L. (1997). The Political Ecology of Forestry in Burma: 1824 - 1994. Honolulu: University of Hawai`i Press.

CABI (2014). PlantwisePlus Knowledge Bank .Pest Management Decision Guides. https://doi.org/10.1079/pwkb.20147801466

Capinera, J. L. (2008). Encyclopedia of Entomology, 2nd Edition. Spinger.

Capinera, J. L. and T. S. Sechrist. (1982). Grasshoppers (Acrididae) of Colorado: Identification, Biology and Management. Colorado Agricultural Experiment Station Bulletin 584S.

Chey, V. K. (1996). Forest pest insects of Sabah, Sabah Forest Record No. 15, Sabah, 111pp.

Coronado, R. and A.Márquez. (1986). Introducción a la Entomología. Morfología y taxonomía de insectos. Edit. Limusa, México.

David, G. R. (2018). White flies. University of Georgia.

Dekker, S. (2021). How to identify and control lace bugs.

Dhingra, S. and P. Sarup. (1992). Mylabris pustulata Thunb. to various insecticides evaluated during the last quarter century. J. Ent. Res. 16(3): 231-235.

Dupuy, B. (1990). Notes de voyage in Chine tropical loss d'um seminaries region sur le teek. Bois et Forets des Tropique 226: 69-76.

Elbert, A., R. Nauen, and W. Leicht. (1998) Imidacloprid, a novel chloronicotinyl insecticide: Biological activity and agricultural

importance. In: Ishaaya I, Degheele D(eds) Insecticides with novel modes of action: mechanism and application. Springer, Berlin Heidelberg New York, pp 50-73.

Evans, H. E. (1984). Insect biology. Addison-Wesley, Melno Park. CA.

Ghate, H., L. Borowiec, N. Rane, and S. Ranade (2003). Tortoise beetles and their host plants from Pune (Maharashtra State, India) and nearby places (Coleoptera: Chrysomelidae: Cassidinae) ResearchGate.

Glen, C. (2022). Controlling caterpillars on trees and shrubs. NC Cooperative Extension.

Gyi, K. K. and K. Tint. (1995). Management status of natural teak forests. In: Teak for the Future - Proceedings of the Second Regional Seminar on Teak, Yangon.

Han, Z., Moores, G. D., Denholm, I., and A. L. Devonshire. (1998). "Association between Biochemical Markers and Insecticide Resistance in the Cotton Aphid, *Aphis gossypii* Glover". *Pesticide Biochemistry and Physiology*.

Hequet, E., Henneberry, T. J., and R. L. Nichols. (2007). Sticky cotton: causes, effects, and prevention. USDA-ARS Technical Bulletin No 1915.

Hill, M. G., Borgemeister, C., and C. Nansen. (2002). Ecological studies on the larger grain borer, Prostephanus truncatus (Horn) (Col.: Costrichidae) and their implications for integrated pest management. Integr. Pest Manag .Rev., 7: 201-221.

Horowitz, A. R., Mendelson, Z., Weintraub, P. G., and I. Ishaaya. (1998). Comparative toxicity of foliar and systemic applications of two chloronicotinyl insecticides, acetamiprid and imidacloprid, against the cotton whitefly, Bemisia tabaci. Bull Entomol Res 88:437–442.

https://british-dragonflies.org.uk/species/red-veined-darter/

https://www.activewild.com/european-mantis/European mantis facts.

ICAR, (2012). TANU Agritech Portal http://www. agritech. tnau.ac. in, cppests_ grass hopper.

ICFRE, (2020). A User Manual on Forest Insect Pests and Diseases Indian Council of Forestry Research and Education, Dehradun, India.

Joshi, K. C., Sambath, S., Chandra, S., Roychoudhury N., Yousuf, M., and N. Kulkarni. (2007). Evaluation of Trichogramma spp. to minimize the attack of teak skeletonizer, Eutectona machaeralis (Walk.). Indian J. Forestry, 30(3): 267-271.

Joydeb, M. and B. K. Agarwala. (2018). Biology of *Catopsilia pomona* F. (Pieridae: Lepidoptera) with special reference to host specificit.

Keogh, R. M. (1979). Le teek essence forestiere ideale pour 1 Amerique tropicale: les plantations de teek aux Antilles, an Amerique Centrale , an Venezuela et an Colombia. Unasylva 31: 13 -19.

Majumder, J and B. K. Agarwala. (2018). Biology of *Catopsilia pomona* F. (Pieridae: Lepidoptera) with special reference to host specificity.

Mani, M. S. (1959). On a collection of plant galls and gall midges from india Agra Univ. J. Res. 2 (2): 91-279.

Mathur, R. N. (1960). Pests of teak and their control. Indian Forest Record, 10(3):43-65.

Mathur, R. N. and B. Singh. (1960). A list of insect pests of forest plants in India and adjacent countries. Indian for. Bull. 171(9): 1-116.

Muttiah, S. (1967). An insecticide trial for the control of cock chafer larvae (Amphimallon majale) in teak nurseries. Ceylon For. 8 (1 / 2): 12-19.

Myint, K. M. and T. T. Win. (2016). Effective Control Measures of Some Major Insect Pests in Young Teak (Tectona grandis Linn.f.) Plantations, Myanmar. Abstract.

Myint, W. W. (1997). A Preliminary Study on the Outbreaks of Teak Defoliator (Hyblaea Puera Cramer) in Teak Plantations. Forest Department, Ministry of Forestry, Government of the Union of Myanmar, Leaflet No. 5/1997.

Nair, K. S. S. (1996). Sudheendra Kumar VV, Varma RV, Chacko KC, Jayaram K. Effect of defoliation by *Hyblaea puera* and *Eutectona machaeralis* (Lepidoptera) on volume increment of teak. Proceedings of the IUFRO Symposium on Impact of diseases and insect pests in tropical forests held on Nov.23-26 at Peechi, Kerala, India, 257-273

Nakamura, K., A. Idrus and H., Ahsol (1989). Survivorship and fertility schedules of two Sumatran tortoise beetles, Aspidomorpha miliaris and A. Sanctaecrucis (Coleoptera: Chrysomelidae) under laboratory conditions. Society of Population Ecology. 31 (1): 25–34.

Nataraja. M. V. (2015**)**. White grubs and their management in groundnut. ICAR-directorate of groundnut research po box -5, ivnagar road, junagadh 362001 gujarat.

National Agriculture Imagery Program (*NAIP*). Pests of pulses: Major pests: termites. http://www.eagri.org/eagri50/ ENTO331/lecture05/ 009.html.

Poorani, J. (2002). An annotated checklist of the Coccinellidae (Coleoptera) (excluding Epilachninae) of the Indian sub-region. J. Oriental Insects, 36: 307 – 383.

Roychoudhury, N. (1998). Teak entomology: its importance. Teaknet Newsletter 11: 1-2.

Roychoudhury, N. and K. C. Joshi. (2000). Relative toxicity of some insecticides against larvae of teak leaf skeletonizer, Eutectona machaeralis Walker. Pestology, 24(7): 80-84.

Roychoudhury, N. and R. K. Mishra. (2020). Resistance in teak for the management of major insect pestsa review. Pestology, 44(9): 21-38.

Roychoudhury, N., Chandra, S. and R. B. Singh. (2018). Biological control of Hyblaea puera and Eutectona machaeralis by introduction of native egg parasitoid, Trichogramma raoi in teak forests. Pestology, 42(6): 36-41.

Roychoudhury, N., Jain, A. and K. C. Joshi. (1995). Alteration of growth and development in leaf skeletonizer, Eutectona machaeralis Walker, due to variations in teak leaves of different maturity. Indian Journal of Experimental Biology, 33(3): 227-229.

Roychoudhury, N., Jain, A. and K. C. Joshi. (2001). Insect pests of teak and breeding for insect resistance. In: Genetics and Silviculture of teak

Roychoudhury, N., Joshi, K. C. and M. Chourasia. (2002). Insect pests of Tectona grandis L.f.: an update. Advances in Forestry Research in India, 25: 196-224.

Roychoudhury, N., Meshram, P. B., Singh, R. B. and R. K. Mishra. (2020). Native egg parasitoid, Trichogramma raoi : a potential biocontrol agent against defoliator and skeletonizer in teak forests of Madhya Pradesh. Journal of Tropical Forestry, 36(1&2): 62-73.

Sangha, S., Ashwinder, K. D., and S. T. Parminder. (2016).Kamalded Identification and management of nsect and disease of forestry tree.

Sharma, S., Tara, J. S. and S. Bhatia. (2013). Bionomics of *Hyblaea puera* (Lepidoptera: Hyblaeidae), a serius pest of teak (*Tectona grandis*) from Jammu (India). Munis Entomology & Zoology, 8 (1):139-147.

Shukla, P. K. J. and N. Roychoudhury. (2001). Diseases and Insect Pests of Teak. ICFRE Brochure No. 68, Jabalpur, 76 pp.

Singh, P. and B. K. Gupta (1978). Laboratory evaluation of insecticides as contact sprays against forest pests. I. Teak skeletonizer, Pyrausta machaeralis (Walk.) (Lepidoptera: Pyralidae). Indian Forester, 104(5): 359-366.

Swietojanska, J.and L. Borowiec (2006). *Aspidimorpha* (s. str.) tibetana, a new species from China (Coleoptera: Chrysomelidae: Cassidinae)". Wroclaw. 17 – ResearchGate.

Symmons, P. M. and K. Cressman. (2001). Desert Locust Guidelines. 1. Biology and Behaviour. 2nd ed. Rome: Food and Agriculture Organization of the United Nations.

Tanu. (2016). Crop protection: pests of potato. https://agritech.tnau.ac.in/crop_protection/potato/potato_4.html

Tewari, D. N. (1992). A Monograph on Teak (tectona grandis Linn. F.). International Book Distributors, Dehradun, India, 479 pp.

Tripathy, M. K. and M. Rout. (2018). Diversity of Insect Pests and their Natural Enemies Infesting Teak (Tectona Grandis, Verbenaceae) in Coastal Odisha. Int.J.Curr.Microbiol.App.Sci. 7(11): 1421-1432. doi: https://doi.org/ 10.20546/ijcmas.2018.711.164

Vastrad, A. S., Rai, P. S. and K. A. Kulkarni. (1989). Occurrence of Eucoptacra ceylonica Kirby (Coptacridinae : Orthoptera) in India. Entomon 14 (3 / 4): 277 – 279.

Verma, R. V. (1991). White grub damage and its control in teak nurseries. Proceedings of International Teak Symposium, Trivandrum, and Kerala (Cyclostyled).

Zhu, F., F. Xue., and C. Lei. (2006). The effect of environmental conditions on diapause in the blister beetle, *Mylabris phalerata* (Coleoptera: Meloidae). European Journal of Entomolo gy. 103 (3): 531–535.

Zhu, F., Lei, C. L., and F. S. Xue. (2005). The morphology and temperature-dependent development of *Mylabris phalerata* Pallas (Coleoptera: Meloidae). The Coleopterists Bulletin. 59 (4): 521–527. doi:10. 1649/838.1.

Zul, M. I. H, Carranza, J. A., and R. Yañez-López. (2012). Elements for the sustainable management of acridoids of importance in agricultureAfrican Journal of Agricultural Research Vol. 7(2), pp. 142-152.

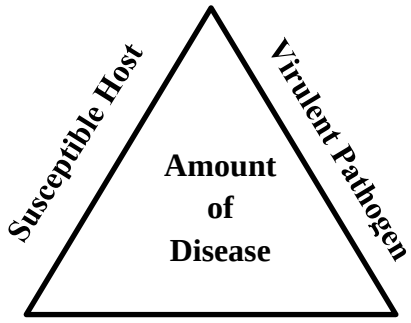
Chapter 3: Diseases of Teak (*Tectona grandis* L.f, Lamiaceae) in Bago Region, Myanmar

Abstract

Asian Forest Cooperation Organization (AFoCO) collaborated with Forest Department (FD) is implementing Integrated Pest and Disease Management (IPDM) Project in Teak Plantation in Bago Region, Myanmar with the objectives to contribute to healthy forests and the vitality of the West Bago Yoma Region through exploring pest and disease lists, their possible control and prevention measures, and enhancing capacity building programs for all stakeholders. The project duration is from October 2020 to September 2025. The target project site was West Bago Yoma Region which covers two main Districts; Tharyarwaddy District and Pyay District. The project area included 5 different areas, in which 3 areas (Tharyarwaddy, Minhla and Gyobingauk) located in Tharyarwaddy District and 2 areas (Paukkhaung and Padaung) in Pyay District. Moreover, demonstration plots have been established at Paukkhaung, Oktwin, Latpadan, Lewe Townships. The main criteria for selecting different plantation areas based on the age of plantations and spatial distribution. Five different age of teak plantations from each township were selected for disease survey. Assessment of disease was designed to be able to conduct in different seasons (summer, monsoon and winter). 10 kinds of diseases have been observed in project's implementation area. Those are teak rust, powdery mildew, rhizoctonia leaf blight, curvularia leaf blight, alternaria leaf blight, colletotrichum leaf spot, cercospora leaf spot, fusarium wilt, sooty mold and mistletoe. Observed location, disease symptoms, causal organisms, disease cycles and epidemiology, control measures are described in detail regarding the type of diseases.

Introduction

Forest trees are subject to injury and disease caused either by abiotic agents, eg. climatic and edaphic factors, chemical pollutants, or by biotic infectious agents. They may be affected at all stages in their life cycle, from seed to mature tree. Diseases produce a variety of effects and can cause losses in economic, environmental, recreational, and aesthetic values produced by the forest. Diseases of forest trees are responsible not only for tree death, but also for reductions in growth and growth abnormalities. Diseases operate in many ways to reduce the yield and quality of timber and other values of trees. In forestry, tree diseases are caused by a diverse range of organisms, including fungi, bacteria, phytoplasma, parasitic higher plants, viruses and nematodes. Among them, the fungi are the largest group causing disease in forest tree. Plant diseases are recognized by the symptoms (external or internal) produced by them or by sick appearance of the plant. Morphological symptoms appear externally on the whole part of diseased plant. They are detected by visual means. Physiological or histological symptoms appear in the tissues of affected plants which are detected only by microscopic examination of diseased tissue. Disease symptoms usually develop as a result of a complex interaction between the susceptible tree, predisposing environmental conditions, or a living infectious agent. The interaction between these three factors can be envisaged and defined by the disease triangle (Parthasarathy et al. 2021).



Teak, tropical deciduous forest tree, inhabits naturally in Myanmar, India, Thailand and Laos. Teak is one of the most expensive timbers in tropical countries (Kaosa-ard 1989) and it is a source of premium hardwoods for diverse applications (eg, furniture, construction, panel work, railway carriages

(Keogh 2009). Its reputation of teak timber is due to its matchless combination of qualities: termite, fungus and weather resistance, lightness with strength, attractiveness, workability and seasoning capacity without splitting, cracking, warping or materially altering shapes (Hoe 1969). Teak constitutes about 75% of the world's high quality tropical hardwood plantations. Myanmar has 6% amount of teak plantations while India, Indonesia, Thailand and Tropical Africa constitute 43%, 31%, 7% and 5% respectively (Verhaegen et al. 2010). In Myanmar, teak mainly occurs in dry and moist deciduous forests growing together with other deciduous trees species such as Legumes, *Lagerstroemia* species, *Terminalia* species and bamboo (Thein et al. 2007). Robertson (2002) reported that teak is susceptible to various kinds of pests and diseases. Different genera of various fungal groups are associated with cultivated plants and forestry species, such as teak (Nagadesi and Arya 2014). In Myanmar, teak plantations often suffer severe damage from insect and disease attack and outbreak of infestation have been occasionally reported. The occurrence of teak rust has recorded by Common wealth Mycoligical Institute (CMI) (Mulder and Gibson 1973). Teak rust incidence was also observed in plantation type (nursery seedling/road side/group/special planting) of Mandalay, Mawlamyine, Yezin, Yangon and Pathein (Than 2000). Teak seedling blight caused by *Phytophthora* spp. occurred in East Bago Yoma teak nurseries (Doo 1983). Teak mistletoe infection in Moeswe teak plantation was recorded by Win and Than (2015). Investigation of teak diseases and reliable control measures is important.

Therefore, assessment of teak diseases was designed to be able to conduct in different seasons (summer, monsoon and winter) in five townships, Bago Yoma Region. Five different age of teak plantations from each township were selected for disease survey. The main criteria for selecting different plantation areas based on the age of plantations and spatial distribution. Moreover, demonstration plots have been established at Paukkhaung, Oaktwin, Latpadan, Lewe Townships. Ten kinds of diseases have been observed in project's implementation area. Those are teak rust, powdery mildew, rhizoctonia leaf blight, curvularia leaf blight, alternaria leaf blight, colletotrichum leaf spot, cercospora leaf spot, fusarium wilt, sooty mold and mistletoe. Observed location, disease symptoms, causal organisms, disease cycles and epidemiology, control measures are described in detail regarding the type of diseases.

Teak Diseases

1. Teak Rust (သံချေးရောဂါ)

Observed Location

Tharyarwaddy, Minhla, Gyobingauk, Paukkhaung, Padaung, Lewe and Latpadan Townships

Symptom

Infected leaves showed angular brown to grey necrotic areas on the upper leaf surfaces due to the formation of flecks. As lesions coalesced, large necrotic areas were evident. The necrotic areas corresponded to numerous subepidermally erumpent orange yellow uredinia on the lower leaf surfaces. Rust causes severe and premature defoliation regardless of tree's growth stage (nursery and plantation), causing reduction in photosynthetic yield.

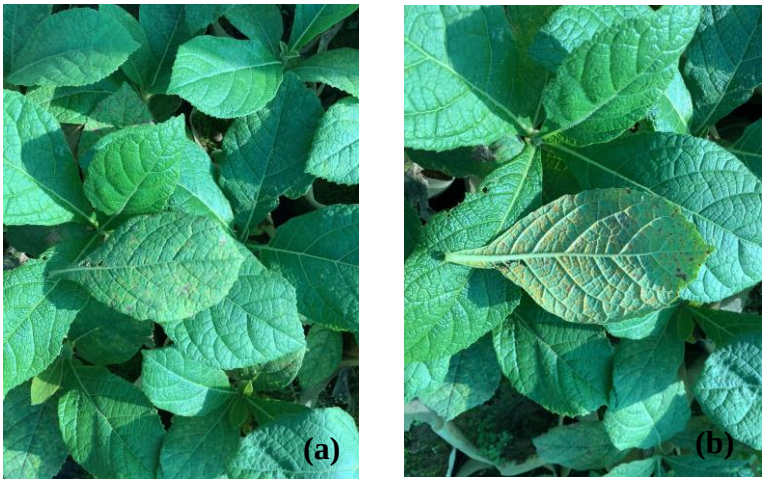


Figure 1: Uredinia of *Olivea tectonae* on the upper (a) and lower leaves surface (b) of *Tectona grandis* in nursery

Figure 2: Uredinia of *Olivea tectonae* on the lower leaf surface in plantation

Causal Organism

Teak leaf rust is caused by *Olivea tectonae*. Hyaline to pale brown incurved uredinial paraphyses are observed. Only uredinial stage is observed. Urediniospores are subglobose, ellipsoid and produced singly on a short pedicel. Urediniospores are pale brown or yellow, echinulate with spines. Teliospores are not observed (Daly et al. 2006). *Olivea tectonae* has also been reported from Asia, mainly in Bangladesh, Myanmar, China, India, Indonesia, Pakistan, Philippines, Sri Lanka, Taiwan, Thailand and Vietnam (Kaneko et al. 2007), Brazil (Cabral et al. 2010), Australia, Central America (Daly et al. 2006) and South America (EPPO 2005). In South East Asia, *Olivea tectonae* is a serious pathogen of young seedlings (Su-See 1999).

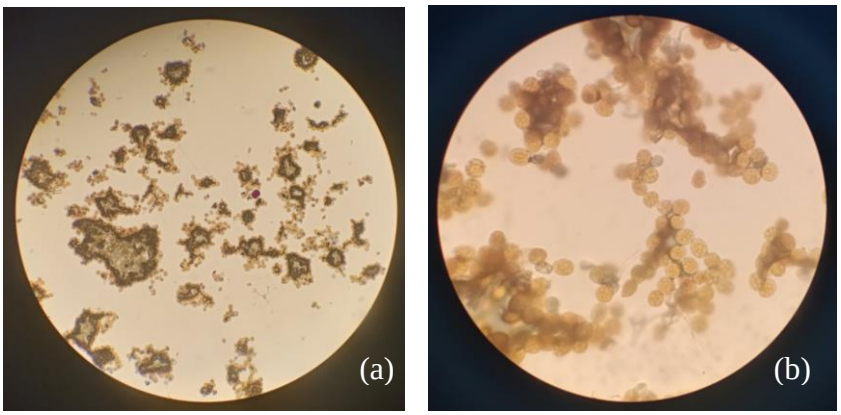


Figure 3: Subglobose and ellipsoid urediniospores of *Olivea tectonae* 10x (a) and 40x (b)

Disease Cycle and Epidemiology

A common pattern of a rust life cycle involves five distinct spore stages on two unrelated hosts. This life cycle is called macrocyclic (long) cycle. Teliospores which overwintered on dead host tissue germinate in place undergo meiosis to produce basidiospores which are forcibly ejected into the air. Basidiospores are fragile and cannot tolerate drying, hence they do not travel long distances. Basidiospores invade host tissues to produce pycnidia. Pycnidium is produced minute, simple pycnidiospores that embedded in insect-attracting nectar on the host's surface – leaves, petioles, woody stems or flower parts and can be bright orange to (less often) colourless. Insects or surface moisture (rain or dew) distribute pycnidiospores on the host surface or

between neighboring plants, resulting in fertilization and formation of aecium and aeciospore. For rust species that infect leaves, this usually occurs on the lower leaf surface as dikaryotic hyphae grow through the leaf and proliferate to form an aecial colony near the undersurface. Aecia do not usually occur singly and the colour of the aecial mass is often light orange. Aeciospores are produced in quantity, and can travel long distances. This is necessary considering that they need to find another host. Once deposited on suitable host tissues, usually leaves, aeciospores germinate rapidly and usually invade cells through stomata. The resultant infection and colony formation results in another pustule called uredinium, containing urediniospores. When plant derived nutrients are declining, uredinia convert to telia and produce increasing numbers of teliospores. These teliospores are thick-walled and resistant to cold or drying, and they serve as the resting stage for the fungus through the dormant state of the host (Kolmer et al. 2009).

The pathogen spread is favored by the wind in dry periods and requires rainfall or leaf wetness to become established within the planted area. Good rains followed by dry period appeared to be conductive for buildup of severe rust infection. The temperature around 20 °C allowed leaf wetness to form and probably favored urediniospore germination, starting leaf infection, and possibly favoring the incidence in disease severity (Sales et al. 2017). Rust occurred almost round the year, it was most prevalent during August to January/ February (Sharma et al. 1985). The rust occurs round the year, it is most prevalent during winter season and is common in nursery and young plantations (Parthasarathy et al. 2021).

Control Measures

- The infected seedlings can be segregated and kept in isolation.
- Severely infected and dead seedlings can be burnt or away from the nursery to prevent the spread of disease.
- Rust control is achieved by pruning and thinning to encourage better ventilation in young plantations.
- Splashing water onto the leaves should be avoided.
- The disease may be controlled in the nursery by the application of sulphur or copper based fungicides (sulphur/ copper sulphate/ copper oxychloride) on both sides of leaves.
- Application of mancozeb, azoxystrobin, tebuconazole, chlorothalonil can be effective in controlling teak rust.

2. Powdery Mildew (ဖားဥမှိုရောဂါ)

Observed Location

Tharyarwaddy, Minhla, Paukkhaung, Padaung and Lewe Townships

Symptom

Fungus attacks on the upper surface of leaf gradually spread over the whole surface and it looks as outer coating, chlorophyll disappears. Irregular white patches appeared on the upper surface. As disease progressed, these patches coalesced and developed greyish-white powdery appearance. The fungus also forms white powdery coating on the undersurface of teak leaves and later develops dark coloured cleistothesia over the white fungus weft. Due to severe infection, the whole leaf surface is covered with mycelial growth which substantially reduces the photosynthetic area, consequently causing premature leaf fall.

Figure 4: Powdery patches on teak upper leaf

Causal Organism

Erysiphe tectonae, widely occurs in nurseries and forests in central and southern India. *Erysiphe tectonae* is restricted to the upper leaf surface and infected leaves are coated with a dull white mycelium and conidia borne on conidiophores. Conidia are air-borne which are produced abundantly and cause fresh infection. *Erysiphe tectonae* occurred on *T. grandis* is characterized by having conidiophore arising from hyphae to bend upward at the base. Conidia are formed singly and cyclidric without fibrosin bodies. Conidia are disseminated easily by wind and germinate by producing new hyphal branches (Firdousi 2018).

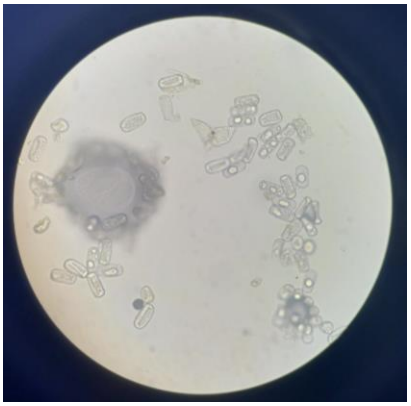


Figure 5: *Erysiphe tectone* causing powdery mildew (40x)

Disease Cycle and Epidemiology

The disease cycle of powdery mildew includes both sexual and asexual reproduction. Asexual spores produce conidia and the sexual stage produces cleistothecia (ascocarps or fruiting bodies) which contain ascospores. The ascocarp can be an over-wintering structure and is important to the survival of the fungi. The asexual, or conidial, stage of the infection serves to spread the disease and intensify its effects. Powdery mildews can also survive winter conditions as dormant mycelia within the buds and other plant tissue of the host. These infected parts of the host can be the source of primary inoculum that can initiate further infection when conditions are right. On perennials, they survive on buds and stem tissue. Certain weeds will also act as hosts through the winter. Young plants grown in heavy shade are the most seriously affected by powdery mildew (Jim 2002).

The optimum conditions for powdery mildew development are warm days followed by cool, humid nights. Dry daytime weather allows spores to spread to other plants on air currents. On a cool evening they absorb enough moisture from the air to germinate and cause infection (University of Maryland 2022). The entire powdery mildew life cycle commonly takes 7-10 days from the time of infection to the development of symptoms and secondary spore production (Grangettos and Garden 2023).

Control Measures

- Plants should be planted in full sunlight in a well-drained area.
- Air flow and ventilation will discourage mildew growth.

- Powdery mildew thrives where high rates of nitrogen have been used. High nitrogen promotes tender leaf formation, causing dense stands that are more susceptible to infections.
- Immediate removal of infected leaves helps to prevent the disease spread.
- Plants should be watered in the morning to give the plants the rest of the day to dry off.
- Proper sanitation around trees before the rain should be practiced.
- Sulphur dusting and copper fungicides (copper sulphate) are proven to be effective.
- Neem leaf extract/neem oil can be applied during morning hours to inhibit disease spread.
- Azoxystroin, propiconazole, difenoconazole, hexaconazole should be sprayed.

3. Rhizoctonia Leaf Blight (ရွက်ခြောက်ရောဂါ)

Observed Location

Tharyarwaddy, Minhla, Gyobingauk, Paukkhaung, Padaung, Lewe and Latpadan Townships

Symptom

Infected leaves showed wedge shape lesions which develop near the tip and enlarge rapidly to the middle vein. These patches turn brown. Infected leaves dry up and are eventually shed. The disease spreads laterally in the nursery through overlapping foliage of adjoining seedlings often resulting in group blighting of seedlings. In each case of severe infection, defoliation is high.

Figure 6: Leaf blight disease symptom of *Rhizoctonia bataticola*

Causal Organism

Leaf blight is caused by *Rhizoctonia bataticola.* The dark brown, globes and ostiolated pycnidia are often produced on host tissues. Pycnidiospores are ellipitica, thin walled, single-celled, hyaline. The young hyphae typically branch at 45 or 90 angles, with constrictions at the point of origin of hyphal branches and septate near hyphal branches.

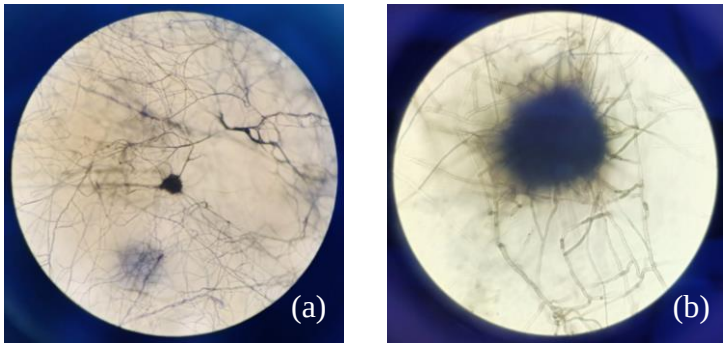


Figure 7: Microsclerotia of *Rhizoctonia bataticola* 10x (a) and 40x (b) on PDA media

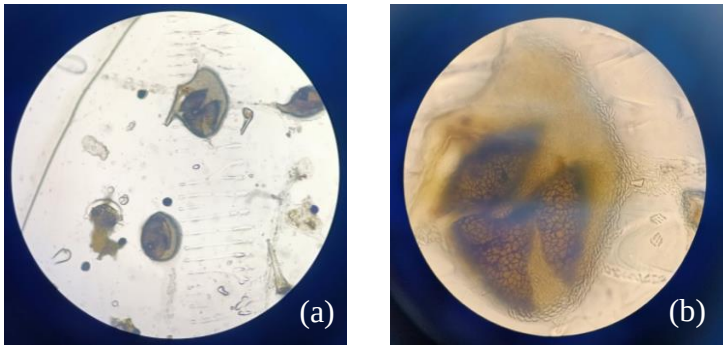


Figure 8: Pycnidia and pycnidiospores of *Rhizoctonia bataticola* 10x (a) and 40x (b) on leaf

Figure 9: Young hyphae of *Rhizoctonia bataticola* branch at 45 angles (40x)

Disease Cycle and Epidemiology

Rhizoctonia is a soilborne fungus with more or less continuous vegetative growth of brown threadlike branching mycelium in warm, moist soil conditions. When soils dry, the fungus becomes dormant as thick walled mycelium (momiloid) or produce sclerotia which allow it to survive for many years. Sclerotia and/or mycelium germinate to produce vegetative threads (hyphae) of the fungus that can attack a wide host range. After the fungus is attached to the plant, it grows continually on the external surface of the plant and then produces either an appressorium or infection cushion. The infection processes are promoted by the production of many different extracellular enzymes that degrade various components of plant cell walls. As the fungus kills the plant cells, the hyphae then continue to grow and colonize the dead tissue of the plant cell, often forming sclerotia. The production of new inoculum is produced on or in a host tissue, and a new cycle are repeated when new substrates become fresh on the new plant emerging (Ken and Andrew 2014b).

Crop residue, stem, leaf debris and living plant are important sources of inoculum for the development of disease caused by *Rhizoctonia* spp. Basidiospores serve as a means of dispersal of the *Rhizoctonia* spp. The dispersal of basidiospores is initiated at high relative humidity and warmer temperature conditions (≥ 90% and ≥ 20°C respectively) (Naito 1996). Under these conditions, basidiospores permit long distance dispersal of the fungus (Agrios 2005). *Rhizoctonia* spp. produce basidiospores (reproductive spores) that lead to foliar diseases in some host crops (Naito 2006).

Control Measures

- Shading should be avoided and soil aeration and water drainage should be improved.
- Excessive weed growth (weed can serve as an alternative host) must be avoided.
- Sufficient space should allow between plants to ensure good ventilation.
- *Trichoderma viride* can be applied as bio-control agent.
- Mancozeb, carbendazim, validamycin, difenoconazole + azoxystrobin and Thiphanate methyl are effective fungicides.

4. Curvularia Leaf Blight (ရွက်ခြောက်ရောဂါ)

Observed Location

Tharyarwaddy, Paukkhaung, Padaung and Lewe Townships

Symptom

Irregular brown necrotic patches can be seen between the veins of leaves at close distance to each other; two or more patches may be fused into a larger size and the border between infected and healthy was reddish brown.

Figure 10: Leaf blight symptom caused by *Curvularia* spp.

Causal Organism

The cause was a fungus *Curvularia* spp. Dark brown, unbranched, septic conidiophores were found. The formed numerous conidia were dark brown, curved to varying degrees, tapering at both ends, with three to four septa, with one or two central cells larger and darker than the terminal ones. *Curvularia* spp. is cosmopolitan, meaning that the spread is very wide, living in tropical and subtropical regions and can be found in plant litter or soil as pathogens in tropical and subtropical plants (Barnett and Hunter 1998).

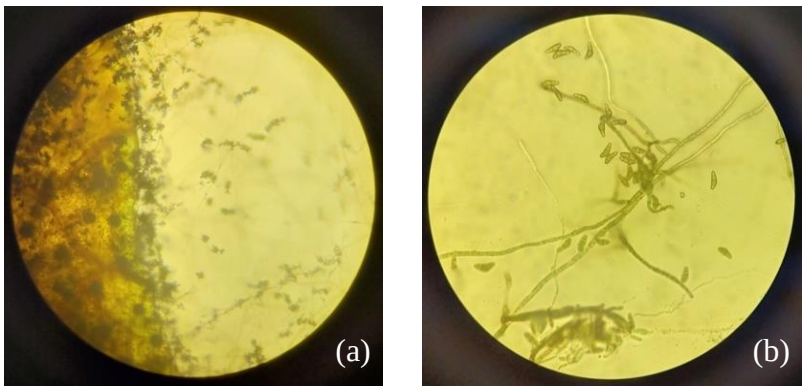


Figure 11: Conidia and conidiophore of *Curvularia* spp. 10x (a) and 40x (b)

Disease Cycle and Epidemiology

Curvularia spp. overwinters in plant residues and can survive in soil at least 3 years. This fungus is wind dispersed to new plants. Leaf wetness encourages conidial germination and primary infections. Conidia from the primary lesions can be released and cause secondary infection through wind and rain on both adjacent plants and other fields. The disease is favored by warm and humid conditions. *Curvularia* spp. occurs at temperatures, 25°C to 35°C. Soil compaction and excessive levels of nitrogen favor for Curvularia disease development (Chen et al. 2000).

Control Measures

- Both overwatering and drought stress should be avoided.
- Application of the correct amount of fertilizer and reduction of soil compaction could be beneficial.
- *Trichoderma harzianum* can be applied as foliar or basal application.
- Tricyclazole, chlorothalonil, thiophanate-methyl and iprodione should be used.

5. Alternaria Leaf Blight (ရွက်ခြောက်ရောဂါ)

Observed Location

Tharyarwaddy, Padaung and Lewe Township

Symptom

The disease symptom on leaves initially appeared as round dark brown necrotic lesions which were surrounded by yellow haloes. Later, these lesions coalesced and developed into larger circular or irregular spots. For severe infections, infected leaves dried and eventually dropped.

Figure 12: Leaf spot symptom of *Alternaria* spp.

Causal Organism

This disease is caused by *Alternaria* spp. The fungus produces long chains conidia. Mycelia were light brown with brown conidiophores. Conidiophores have septa, straight to geniculate and prominent conidial scars. Conidia were brown in color and obclavate. Conidia have short beak with 3-5 transverse septa and 0-3 longitudinal septa. *Alternaria* spores can be air or water borne and are most often found in dead organic matter in soil (Ken et al. 2014c).

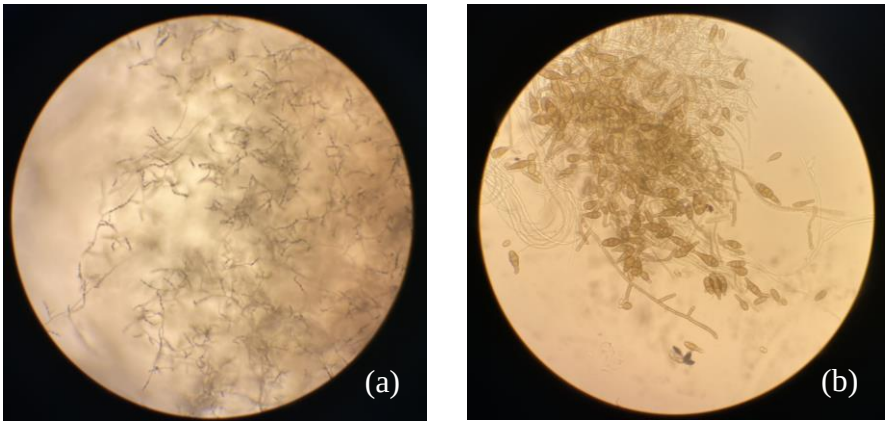


Figure 13: Obclavate conidial spores of *Alternaria* spp. 10x (a) and 40x (b)

Disease Cycle and Epidemiology

Alternaria spp. survives from crop to crop as mycelium or spores in infected plant material left on or in the ground, and on or within the seeds from infected plants. The elongated spores allow for better wind-dispersal, which increases the distances travelled. Healthy plants can pick up the spores from the ground or the air. Under favourable conditions, the spores quickly mature into fungal leaf spots that release more spores that can be carried to other plants by wind and/or splashing rain. This disease cycle will continue throughout the season for as long as favourable conditions persist and a suitable host is present. The most favourable conditions for *Alternaria* spp. are rain or heavy dew occurring when temperatures are between 25-28°C. The major sources of transport of these pathogens are by infected seeds with spores on the seed coat or as mycelium under the seed coat. The dissemination of spores occurs by wind, water, tools and animals. The fungus can survive in susceptible weeds or perennials between cropping cycles or seasons (Ken et al. 2014).

Control Measures

- Overhead irrigation should be avoided especially at night. Watering must be done early in the day.
- Air circulation can be promoted by thinning plant canopies.
- Injuries by insect/pests and plant handling when wet should be noticed.
- Immediate removal of infected leaves in the nurseries helps to prevent the disease spread.
- Severely infected plants parts must be removed and discard.
- Pathogen-free stock and seed should be propagated or used.
- Hexaconazole, propiconazole + difenoconazole, mancozeb can be effective to control *Alternaria* disease.

6. Colletotrichum Leaf Spot (ရွက်ပြောက်ရောဂါ)

Observed Location

Tharyarwaddy, Paukkhaung and Padaung Townships

Symptom

The disease symptom appeared as irregular spot, light to dark brown in colour surrounded by necrotic margin. The individual spots coalesced to form large irregular spots, which caused drying up of leaves and consequently premature defoliation. The disease spreads laterally in the nursery through overlapping foliage of the adjoining seedlings often resulting in group blighting of seedlings. In each case of severe infection, defoliation is high.

Figure 14: Collectotrichum leaf spot symptom

Causal Organism

Colletotrichum spp. (asexual stage) is a pathogen causing leaf spot disease. Sexual stage is known as *Glomerella cingulate*.

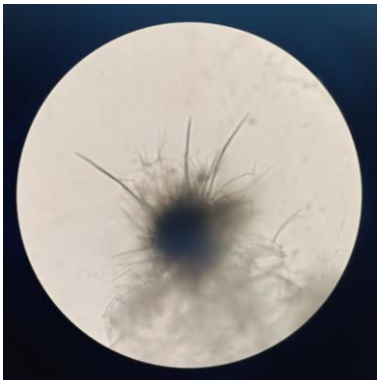


Figure 15: Black setae of *Colletotrichum* spp. on leaf (40x)

Disease Cycle and Epidemiology

Warm, humid and wet conditions favour infection, disease development, sporulation and spread of pathogen. Conidia produced by asexual stage of fungus are produced in large numbers on diseased plant tissue and decomposing leaf litter which gathers at the base of plants. The spores are readily spread to neighboring plants by splashing water. Spores will germinate in the presence of free moisture and warm temperature. Once germinated, spores typically produce appressorium on the surface of plant tissue and directly penetrate into the intact cuticle of plant tissue. The fungus can enter plant tissue via wounds. Once the fungus has penetrated the outer cell layer of the plant tissue, it then proceeds to colonize surrounding tissues. Under favourable conditions (e.g. high humidity), the fungus will produce fruiting bodies in the center of lesions which erupt through the surface of the plant tissue, thus completing the disease cycle (Lindy et al. 2015).

Control Measures

- Overhead irrigation should be avoided especially at night. Watering must be done early in the day.
- Air circulation can be promoted by thinning plant canopies.
- Injuries by insect/pests and plant handling when wet should be noticed.
- Severely infected plants parts must be removed and discard.
- Pathogen-free stock and seed should be propagated or used.
- Application of fungicide (e.g. thiram, chlorothalonil, captan, azoxystrobin) can be effective.

7. Cercospora Leaf Spot (ရွက်ပြောက်ရောဂါ)

Observed Location

Tharyarwaddy, Minhla, Gyobingauk, Paukkhaung, Padaung, Townships

Symptom

The symptoms are angular or sub-orbicular leaf spots, brown to grayish brown at the center with a dark margin, which develop near the tip and along the margin of the leaves. The disease spreads laterally in the nursery through overlapping foliage of the adjoining seedlings often resulting in group blighting of seedlings. In each case of severe infection, defoliation is high.

Figure 16: Leaf spot symptom of *Cercospora* spp.

Causal Organism

Cercospora spp. is a pathogen causing leaf spot disease. Conidiophores are in loose fascicules, 1–5–septate, straight to decumbent, light brown to medium brown, paler towards the apex, geniculate at the apex. Conidia are hyaline, acicular to obclavate–cylindric, 2–13 septate, straight to curved, truncate or obconically truncate at the base, with subacute apex, thickened and darkened (Meeboon 2009).

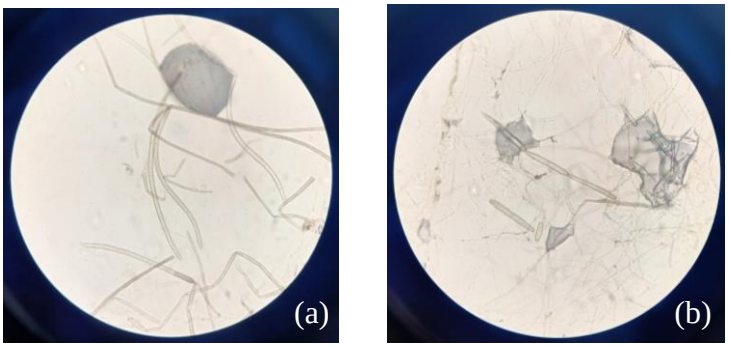


Figure 17: Conidiophores (a) and conidia (b) of *Cercospora* spp. (40x)

Disease Cycle and Epidemiology

The pathogen survives in infested plant debris for up to 3 years. The pathogen can also survive on dead plant tissue. Conidia can be dispersed by wind or rain splash usually resulting in short-range, local movement (within the same field or adjacent fields). Alternative hosts consisting of weeds and other crop species may also be a reservoir for inoculum and form a green bridge for the pathogen to survive between cropping seasons. Infection begins when conidia reach the surface of leaves and penetrate through stomata in a symptomless biotrophic manner. The fungus then grows intercellularly, colonizing the parenchymatous layer. Water droplets must be present for spore germination and germ-tube penetration. Moist wind, irrigation water and insects help in local transmission of pathogen. This disease is common in humid tropic and subtropical regions. For big leaf-type, *Cercospora* leaf spot tends to be less severe under shady conditions, but in nursery environments under shady conditions, frequent overhead irrigations can intensify disease activity and subsequent defoliation and loss of vigor (Pawar 2021).

Control Measures

- Good field sanitation (ie, remove and destroy infected plants/plant parts and weed) can help eliminate inoculum sources in the field.
- Wider plant spacing should be followed to reduce the primary inoculum of pathogen in field.
- A fungicide spray of copper-based fungicides, mancozeb, chlorothalonil, thiophanate-methyl should be followed when conditions are favourable for disease development.

8. Fusarium Wilt (ပင်ညှိုးရောဂါ)

Observed Location

Tharyarwaddy Township

Symptom

Initially symptoms of older (lower) leaves yellowing, leaves abscission were observed and eventually the death of the teak. Trunks of affected teak displayed black darkening of heartwood and sapwood vascular areas.

Figure 18: Wilting plant with dried bottom leaves (a) and vascular browning symptom (b)

Causal Organism

Fusarium spp. is a pathogen causing wilting. The microconidia were predominantly oval to ellipsoid, slightly curve (without septae), single cell, comparatively smaller than macroconidia. Macroconidia were falcate, moderately curved and each with three to five septae.

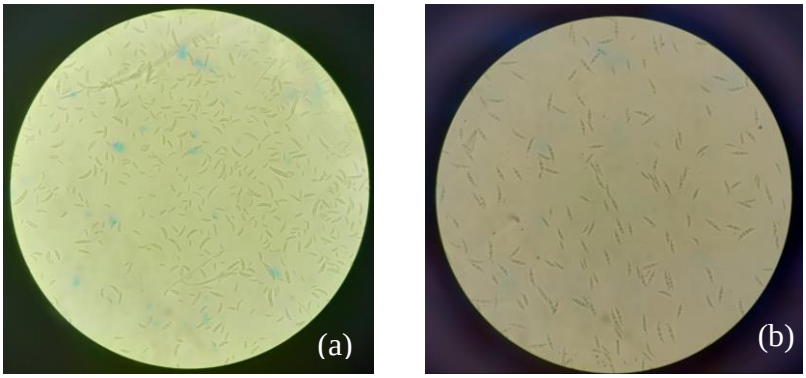


Figure 19: Microconidia (a) and Macroconidia (b) of *Fusarium* spp. (40x)

Disease Cycle and Epidemiology

This pathogen remains dormant as chlamydospores in infected crop debris or seed. They are stimulated to germinate by host roots, root exudates from non-hosts. Root invasion is followed by the development of systemic vascular invasion. This involves passive movement of microconidia through the xylem and host responses that cause blockages of water conducting vessels and wilt. In advanced stages of disease the fungus grows out of the vascular tissue and forms a multitude of conidia and chlamydospores. The chlamydospores are returned to the soil when the dead plant decays and they can remain dormant

for several years. The cycle is repeated when chlamydospores grow saprophytically or by invading a host. *Fusarium* can be dispersed by contaminated seed, cuttings and transplants, water borne, wind and soil borne (Ken and Andrew 2014a).

Control Measures

- The infected plants should be uprooted carefully and burnt.
- For casualty replacement, the planting should be done in a separate pit dug away from the site of infected plant.
- Do not add any removed portion of an infected teak to any compost piles or mulching systems, as this will only serve to propagate the spread of the fungus.
- Weeds are notorious for hosting destructive pathogens such as 'wilt'. Hand pull weeds from moist (loose) soil, removing as much of the roots as possible.
- Pruning, cutting, and digging equipment should always be cleaned after use. However, when dealing with infected plant or fungal growth, all equipment should be washed in a solution of bleach and water (with a ratio of 1 part bleach to 4 parts water). Disposable gloves should be used to avoid recontamination of the equipment.
- *Trichoderma* spp. can be used as bio-control agents.
- If possible, systemic fungicide like Topsin M (Thiophanate methyl + Thiram) is effective as Fusarium is a soil born pathogen. Azoxystrobin, prothioconazole, captan are also effective fungicides.

9. Sooty Mold (ကြက်ခိုးမှိုရောဂါ)

Observed Location

Lewe and Latpadan Townships

Symptom

Sooty molds appear on the leaves or stems of plants as a superficial, black growth of mycelium forming a film or crust on these plant parts. It usually results from insects, especially aphids and scale insects. The insects need a higher ratio of nitrogen to sugar than the sap provides, so they secrete excess sugars in sweet drops called "honeydew". Honeydew is the primary substrate for the fungal growth, and the plant is not penetrated (Worrall 2018). The fungal growth is so abundant that it gives the leaf a black, sooty appearance and interferes with the amount of light that reaches the plant. This mycelium sometimes forms a black papery layer that can be peeled off from the

underlying leaf. The presence of sooty mold fungi is usually of rather minor importance to the health of the plant, but it does indicate the presence of insects and may be a warning of a severe aphid or scale problem (Adugna and Sethumadhava 2023)

Figure 20: Sooty mold infected teak plant

Causal Organism

The sooty mold fungi feed on honeydew produced by phloem-feeding insects. Some of the common genera of fungi involved are *Cladosporium*, *Aureobasidium, Antennariella, Limacinula*, *Scorias*, and *Capnodium*. Sap- or phloem-feeding insects associated with the disease include whiteflies, aphids, mealybugs, and scales (Scot 2008). In this identification, *Cladosporium* species was found. The fungi produce spores that can spread between plants via splashing water or being blown through the air. In addition, small fragments of the mycelia can be dislodged from the plant and transmitted in the same manner.

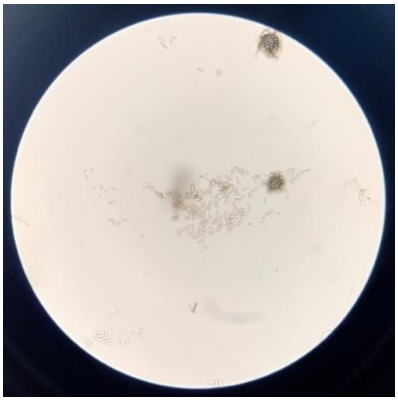


Figure 21: Conidia with scale bars of *Cladosporium* spp. (40x)

Epidemiology

Warm, dry weather can increase the prevalence of sooty molds. Plants that are stressed by lack of moisture are more likely to suffer from aphid infestations, which results in the production of more honeydew. Another factor is that during dry periods, the lack of rain prevents the honeydew from being diluted or washed off the plant, which can increase the incidence and severity of this condition.

Control Measures

- Enough distance between plants and sufficient sunlight should be provided.
- Physical barriers around trees should be built to prevent ants and plant sap-sucking insects from reaching them.
- Sufficient fertilizers and water are provided to ensure an optimal natural resistance of trees to phloem-feeding parasites.
- Sooty molds can be indirectly controlled by reducing populations of sucking insects that excrete honeydew. Appropriate recommended chemicals (Imidachloroprid) that control aphids and other sucking insects should be used.

10. Mistletoe (ကျီးပေါင်းကပ်ပါးပင်)

Observed Location

Tharyarwaddy, Paukkhaung and Padaung Townships

Biology and Habit

Mistletoes grow in many ecosystems and usually attack trees, shrubs, and herbs. Mistletoe colonizes over 450 species and varieties of trees. Mistletoe has two-family, Loranthaceae, and Viscaceae (Choi et al. 2019). The most notoriously damaging species in the Loranthaceae are the honey-suckled (*Dendrophthoe* spp.), the showy (*Helixanthera* spp. and *Psittacanthus* spp.), and the red mistletoes (*Tapinanthus* spp.), while, among the Viscaceae are the Dwarf (*Arceuthobium* spp.), the American (*Phoradendron* spp.), and the European mistletoes (*Viscum* spp.) (Ozturk et al. 2019). In addition, Loranthus, members of the family Loranthaceae, are the most parasites in the tropics (Hawksworth and Johnson 1993). Within Myanmar, the Family Loranthaceae includes 7 Genera and 43 Species, while the Family Viscaceae presents 4 Genera and 12 Species (Kress et al. 2003). Mistletoes are characterized as hemiparasitic plants because of their reduced photosynthetic efficiency and the absence of a true rooting feature (Glatzel and Geils 2008).

A false root-like appendage, known as a haustorium, attaches them to their host plants (mostly trees) and draws water and nutrients from them (Calvin and Wilson 2006). The impact on physiological processes and economic losses of teak due to mistletoe attacks includes a decrease in tree vigour and growth increments, less fruit and seed, drying of branches, logs quality including strength properties of wood and tree mortality (Mohanan 2007). Dead tissues caused by mistletoes provide entry points for decay fungi. Moreover, dead branches and trees in stands damaged by mistletoe can become fire hazards (Hawksworth and Wiens 1996).

Figure 22: Teak trees with mistletoes infection

Disease Cycle

Mistletoe can initiate host infection in three ways: (i) animal dispersal, (ii) explosive discharge of seed, (iii) wind dispersal (Shaw and Robert 2013). Mistletoe seeds were spread by bird species of *Turdus viscivorus* L., *T. pilaris* L., *Bombycilla garrulous* L., and *Sylvia atricapilla* L (Figarski 2019). The first three bird species ingest the mistletoe berries whole and the seeds then lack their characteristic white skin, which is removed in the digestive tract of birds. Germination does not require that seed pass through the bird's digestive system. Wangerin et al. (1937) showed that the low nutritional value of mistletoe berries necessitates that birds eat large quantities of seed to meet their calorific needs (eg., up to 100 berries per day) . This is a key strategy in the survival and spread of *Viscum* species in Viscaceae family. The second spread way of mistletoe is the viscous substance they contain, called viscin. Viscin enables mistletoe seeds to adhere to the host branch, causing a new infection. Mistletoe fruit that are spontaneously shed from Viscum and come in contact with a branch can develop into a new plant. Mistletoe fruit can also stick to the limbs of birds and then be transferred by them over long distances

(Zuber 2004). The Misodendraceae of temperate South America is the only group of mistletoes that have wind dispersed seeds (Shaw and Robert 2013).
In Myanmar, the main flowering and fruiting season of family Loranthaceae is from November to March and this period coincides with the defoliation of teak. During this period, plenty and strong white, some orange colored ripe fruits can be clearly seen on trees and flower-peckerbirds feed on the fruits and disperse the seeds. When feeding the fruits, the sticky seeds stick to beaks of birds and then when these birds visit other branches of trees and the seeds get stuck to the branches of host, germinate new mistletoe clumps. In March, re-sprouting of new regeneration of mistletoe clumps on teak trees was observed (Win and Than 2015).

Park of trees attacked by mistletoe

The initial spread of mistletoe may be unnoticeable because new germinant growth is very slow, however growth rates increases as mistletoe plants become older. Because birds land at the tops of trees and infections start there, the oldest mistletoe plants are found closer to the top of the host tree. Tall trees were visited by birds more frequently, and thus increased the chance to receive mistletoe seeds. Birds are also generally more attracted to tall trees to forage and perch due to their wider. The position and direction of the growth of branches and twigs were known to be closely related to mistletoe infection. Horizontal branches and twigs were more likely to be infested by mistletoe than those with a vertical position. In addition, branches and twigs are also softer than the vertical tree trunk, and thus easier to be penetrated by the haustoria of the mistletoes. Part of twig has thinner bark and mild than branch or even the stem bark in crown area. Those will help in early establishment of mistletoe seeds that are dispersed by birds as vector that can penetrate to cell and tissue of wood and later to be in xylem tapping forming haustorium. As part of branch and stem are relatively thicker, consequently they rather inhibit physically for early establishment or germination of mistletoe seed (Zainal Muttaqin et al. 2016).

Control Measures

Cultural Method

Mixed plantation (shade bearer species & light demander teak) should be more encouraged in establishing plantations.

Physical Method

The most effective way to control mistletoe and prevent its spread is to prune out infected branches as soon as the parasite appears. Using thinning-type pruning cuts, remove infected branches at least one foot below the point of mistletoe attachment in order to completely remove the haustoria. Severe heading (topping) is best to remove severely infested trees because they are a source of mistletoe seed. After pruning, the pruned areas of teak trees were covered with thit-si (*Melanorrhoea usitata*), one of local gums, to prevent insect and fungi infestation. Mistletoes infecting a major branch or the trunk where it cannot be pruned may be controlled by cutting off the mistletoe flush with the limb or trunk. Then wrap the area with a few layers of wide, black polyethylene to exclude light. Use twine or tape to secure the plastic to the limb, but do not wrap it too tightly or the branch may be damaged.

Chemical Method

Mistletoe infection was gradually decreased by spraying herbicide (Sencor 70 WP (Metribuzin)).

References

Adugna, H., and Sethumadhava, G. R. (2023) Diseases of crops in Eritrea, Handbook. Chennai, India. 1-386.

Agrios, G. N. (2005) Plant Pathology. 3rd Ed. London, Elsevier Academic Press

Barnett, H. L., and Hunter, B. B. (1998) Illustrated genera of imperfect fungi. Fourth Edition The Phytopathol. Soc. St. Paul, Minnesota, USA.

Cabral, P. G. C., Capucho, A. S., Pereira, O. L., Zambolim, E. M., Freitas, R. L., and Zambolim, L. (2010) First report of teak rust disease caused by *Olivea tectonae* in Brazil. Australasian Plant Disease Notes 5, 113-114.

Calvin, C. L., and Wilson, C. A. (2006) Comparative morphology of epicortical roots in Old and NewWorld Loranthaceae with reference to root types, origin, patterns of longitudinal extension and potential for clonal growth. Flora-Morphol. Distrib. Funct. Ecol. Plants, 201, 51–64.

Chen, M., Xia, Y., and Chen, W. (2000) Occurrence and control of maize Curvularia leaf spot. Journal of Henan Agriculture Science, 7, 19-20.

Choi, S. U., Kim, S. T., Han, D. G., Hwang, Y. H., Lee, K. Y., Kim, D. U., Cho, K. H., Park, S. Y., Kim, H. C., and Kim, S. B. (2019) Comparative Assessment of Biological Activities of Mistletoes for Cosmetic Applications: *Viscum album* Var. Coloratum (Kom.) Ohwi and Loranthus Tanakae Franch. & Sav. J. Cosmet. Sci., 70, 235–245.

Daly, A. M., Shivas, R. G., Pegg, G. S., and Mackie, A. E. (2006) First record of teak rust (*Olivea tectonae*) in Australia. Australasian Plant Disease Notes 1, 25-26.

Doo, S. C. (1983) Control of Teak Seedling Blight, Forest Research Institute, Myanmar

European and Mediterraneam Plant Protection Organization (EPPO) (2005) Available at http://www.eppo.org/

Figarski, T. (2019) Selected aspects of wintering of Mistle Thrush Turdus viscivours in the Kozienice Forest. Kulon, 14, 1-7.

Firdousi, S. A. (2018) Fungal diseases of teak in nursery, plantation and natural forest in the Jalgaon District, India. Vol 24 (2), 280-282.

Glatzel, G., and Geils, B. (2008) Mistletoe ecophysiology: Host–parasite interactions. Botany. 87, 10–15.

Grangettos, F., and Garden. S. (2023) Life cycle and management of powdery mildew

Hawksworth and Wiens. (1996) Dwarf mistletoe: biology, pathology and systematics, Agricultural handbook.

Hoe, C. (1969) Teak of Myanmar. Myanmar: Sapaybeikman. (Text in Myanmar)

Jim, C. (2002) Powdery Mildew. WSU Extension and WSU Master Gardener. 1- 4.

Kaneko, S., Pham, T. Q., and Hiratsuka, Y. (2007) Notes on some rust fungi in Vietnam. Mycoscience 48, 263-265.

Kaosa-ard, A. (1989) TEAK (*Tectona grandis* L.) it's natural distribution and related factors. Nat. Hist. Bull. Siam.Soc., 29, 55-74

Ken, P., and Andrew, M. (2014a) Fusarium A Formidable Nursery Pathogen, Agri-science Queensland, Department of Agri-culture, Fisheries and Forestry, Ecosciences Precinct, GPO Box 267, Brisbane QLD 4001

Ken, P., and Andrew, M. (2014b) Rhizoctonia A variable and versatile nursery pathogen, Agri-science Queensland, Department of Agriculture, Fisheries and Forestry (DAFF), 1- 6

Ken, P., John, D., and Andrew, M. (2014c) Alternaria diseases in production nurseries, Agri-science Queensland, Department of Agriculture, Fisheries and Forestry (DAFF)

Keogh, R. M. (2009) Planted Forests and Trees Working Paper FP/44E. FAO; Rome, Italy: The future of teak and the high-grade tropical hardwood sector.

Kolmer, James, A., Ordonez, M. E., and Groth, J. V. (2009) The Rust Fungi. In: Encyclopedia of Life Sciences (ELS). John Wiley & Sons, Ltd: Chichester. DOI: 10.1002/9780470015902.a0021264

Kress, W. J., Robert, A., DeFilipps, Ellen, F., and Kyi, Y. Yi. (2003) A checklist of the trees, shrubs, herbs, and climbers recorded from Myanmar. Department of Systematic Biology-Botany, National Museum of Natural History, Washington, DC. 1-601

Lindy, C., Tony, C., and Leif, F. (2015) The biology and management of Colletotrichum diseases in production nurseries, Agri-science Queensland, Department of Agriculture, Fisheries and Forestry, Ecosciences Precinct, GPO Box 267, Brisbane QLD 4001)

Meeboon, J. (2009) Diversity and phylogeny of true cercosporoid fungi from northern Thailand. Ph.D. Thesis. Department of Plant Pathology, Faculty of Agriculture, Chiang Mai University, Chiang Mai, Thailand.

Mohanan, C. (2007) Disease of Teak in India and their Management. Processing and Marketing of Teak Wood Products of Planted Forests, Proceedings of the Regional Workshop, Kerala Forest Research Institute, Peechi, India.

Mulder and Gibson. (1973) CMI Description of Pathogenic Fungi and Bacteria. No. 365.

Nagadesi, P. K and Arya, A. (2014) Delignification of valuable timbers decayed by India lignicolous fungi. *International Letters of Natural Sciences* 16, 101-120.

Naito, S. (1996) Basidiospore dispersal and survival. Rhizoctonia species; Taxonomy, Molecular Biology, Ecology, Pathology and Disease Control. Springer

Naito, S. (2006) Ecological Studies on Teleomorphic and Anamorphic Stages in Rhizoctonia Fungi. Journal of General Plant Pathology, 72, 400-403.

Ozturk, M., Coskuner, K. A., Usta, Y., Serdar, B., and Bilgili, E. (2019) The effect of mistletoe (*Viscum album*) on branch wood and needle anatomy of Scots pine (*Pinus sylvestris*). 40, 352–365.

Pawar, A. B. (2021) Estimation of Production of Extracellular Phenol, by Cercospora tectonae a leaf spot pathogen of teak, International Journal for Innovative Research in Multidisciplinary Field, 7 (5), 217-219.

Robertson, B. (2002) Growing Teak in the Top End of the Agnote. Darwin Vol. 346 (20), 1-7.

Sales, N. I. S., Leao, E. U., Correia, L. C. M. A., Siqueira, C. A., and Santos, G. R. (2017) Temporal progress of teak rust in a tropical area of Tocantins State, Brazil. Vol 47 (3), 277-280.

Scot, N. (2008) Sooty Mold. College of Tropical Agriculture and Human Resources, Department of Plant and Environmental Protection Sciences. (52), 1- 6

Sharma, J. K., Mohanan, C., and Maria Florence, E. J. (1985) Disease survey in nursery and plantations of forest tree species grown in KERALA. KFRI Research Report 36, 16-49.

Shaw, D. C., and Robert, L. M. (2013) Forest diseases caused by higher parasitic plants Mistletoes, USA.

Su-See, L. (1999) Forest health in plantation forests in South-East Asia. Australasian Plant pathology 28, 284-291.

Than, W. W. (2000) Teak rust *Olivea tectona*e: Occurrence, Epidemiology, Its Chemical Control in vitro and reaction of teak clones and provenances. Forest Research Institute

Thein, H. M., Mamoru, K., Maki, F., and Min, Y. (2007) Structure and composition of a teak-bearing forest under the Myanmar selection system: Impacts of logging and bamboo flowering. *Southeast Asian Studies* 45, 303-316.

University of Maryland. (2022) Powdery mildew diseases on trees and shrubs

Verhaegen, D., Inza, J. F., Logossa, A. Z., and Ofori, D. (2010) What is the genetic origin of teak (Tectona grandis L.) introduced in Africa and Indonesia. Tree Genetics and Genomes, Springer Verlag., 6, 717-733.

Wangerin, W., Loranthaceae, W., Lebensgeschichte, B. M., Kirchner, O. L. E., Schroeter, C., Ulmer: Stuttgart, Germany (1937) Volume 2, pp. 953–1146.

Win, T. T and Than, W. W. (2015) Study on Distribution of Teak Mistletoe (*Loranthus pulverulentus* Wall.) Control Measures and Teak Growth Assessment in Moeswe Teak Plantation, Myanmar, 8pp.

Worrall, J. J. (2018) Foilage diseases of trees, Forest pathology, College of environmental science and forestry.

Zainal, M., Sri, W. B. R., Basuki, W., Iskandar, Z. S., and Corryanti. (2016) Assessing Intensity of mistletoe infestation in Teak Clonal Seed Orchard (CSO) Padangan, East Java. Procedia Environmental Sciences 33, 404-415.

Zuber, D. (2004) Viscum album L.199, 181–203.

Chapter 4: Integrated Pest anf Disease Management (IPDM) Strategies in project area

FD-AFoCO IPDM project has established demonstration plots at Paukkhaung, Oktwin, Latpadan, Lewe Townships with IPDM concepts.

Cultural Control

- ➢ Collect and remove plant debris (dropped leaves and pruned wood) and weed control to reduce overwintering pest populations in the plot.
- ✓ Cultural practices include crop rotation, proper sanitation, managing planting densities, providing adequate irrigation and drainage, and practicing good weed control. Cleaning create unfavourable conditions for pathogens and promote plant health and resilience. Cleaning can be used to reduce disease incidence and severity because weeds are the best reservoirs of pathogens.

Figure 1: Control measure for cultural control (cleaning of alternative host (weeds)

Mechanical control

- ➢ Infected leaves, insects and egg masses will be destructed or removed by hand.
- ➢ Yellow sticky traps are used to reduce pest infestation and to act as monitoring pest population devices.
- ➢ Molasses Traps are used white plastic bottles of 1000 ml capacity with two side openings and filled with molasses 500 ml, the insects will be attracted, kept in and killed.

- Light traps are setting up to attract and kill the nocturnal insects.

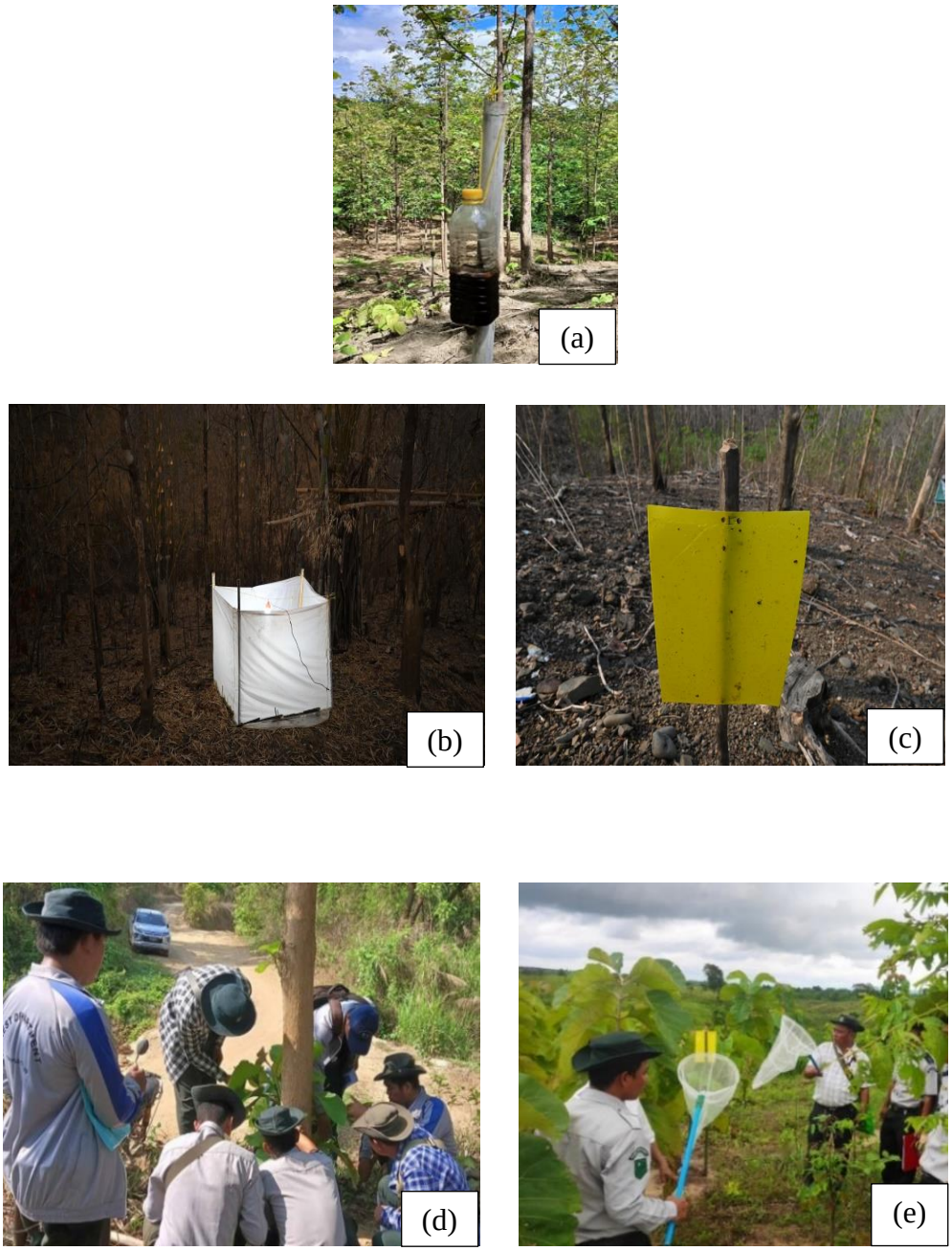


Figure 2: Control measures for mechanical control (a) molasses trap (b) light trap (c) sticky trap (d) removal of pests (e) sweet net for catpturing insect pests

- ✓ Removal of infected leaves and plant parts are performed to eradicate pathogens by eliminating infected plant parts that provide ready source of inoculum.

Figure 3: Control measure for mechanical control (removal of infected leaves and plant parts)

Biological Control

- Biological control is the use of living organisms, such as parasitoids (parasites), predators, or pathogens to suppress a pest population. Ladybeetles are common examples of predators employed in biological control. *Bacillus thuringiensis* (Bt) can be used as a biological control agent. Native natural enemies' populations, insect predators and parasitoids are conserved to reduce pest population. In project area, wasps (parasitoid) were conserved by covering nylon mesh bag over the dropped leaves and this method is only allowed to escape wasps not allowed to escape Lepidoptera.

Figure 4: Control measures for biological control (covering nylon mesh bag)

- ✓ *Trichoderma* species are commonly used as effective biological control agents against pathogens especially soil borne fungi. The biocontrol mechanisms of *Trichoderma* are based on the activation of multiple mechanisms, either indirectly, by competing for space and nutrients, promoting plant growth and plant defensive mechanisms, and antibiosis, or directly, by mycoparasitism.

Figure 5: Control measures for biological control (multiplication of *Trichoderma* spp.)

Chemical Control

- Pesticides are used when the pests are unable to controlled by natural means.

Figure 6: Control measure for chemical control (pesticides)

- ✓ When other methods are insufficient, chemical control involves the targeted use of pesticides to manage plant diseases. Fungicides, bactericides, and nematicides are commonly employed to control specific pathogens. It is crucial to use these chemical treatments judiciously, following labeling instructions and considering their potential impact on non-target organisms and the environment.

Figure 7: Control measure for chemical control (spraying of fungicides)

Chapter 5: Field Observation

Figure 1: Damage leaves by teak leaf defoliator at Padaung Township

Figure 2: Damage leaves by teak leaf defoliator at Paukkhaung Township

Figure 3: Pupa stage of teak leaf defoliator on the weeds under the teak trees

Figure 4: Damage leaves by teak leaf skeletonizer at LeweTownship

Figure 5: Damage leaves by teak leaf skeletonizer at Paukkhaung Township

Figure 6: Aphid infested on teak seedling of Pyay Township

Figure 7: Aphid infested on teak seedling of Tharyarwaddy Township

Figure 8: Tingis bug infested plants at Lewe Township

Figure 9: Teak tree infested by termite at Padaung Township

Figure 10: Lady bird beetle *Cheilomenes sexmaculatus* an aphid predator in nursery of Tharyarwaddy Township

Figure 11: Teak Rust Infection at Palwe Reserved Forest, LeweTownship

Figure 12: Teak Rust Infection at Mokkha Reserved Forest, Minhla Township

Figure 13: Powdery Mildew Infection at Teak Plantation, Mokkha Reserved Forest, Minhla Township

Figure 14: Powdery Mildew Infected Teak Leaves at Mokkha Reserved Forest, Minhla Township

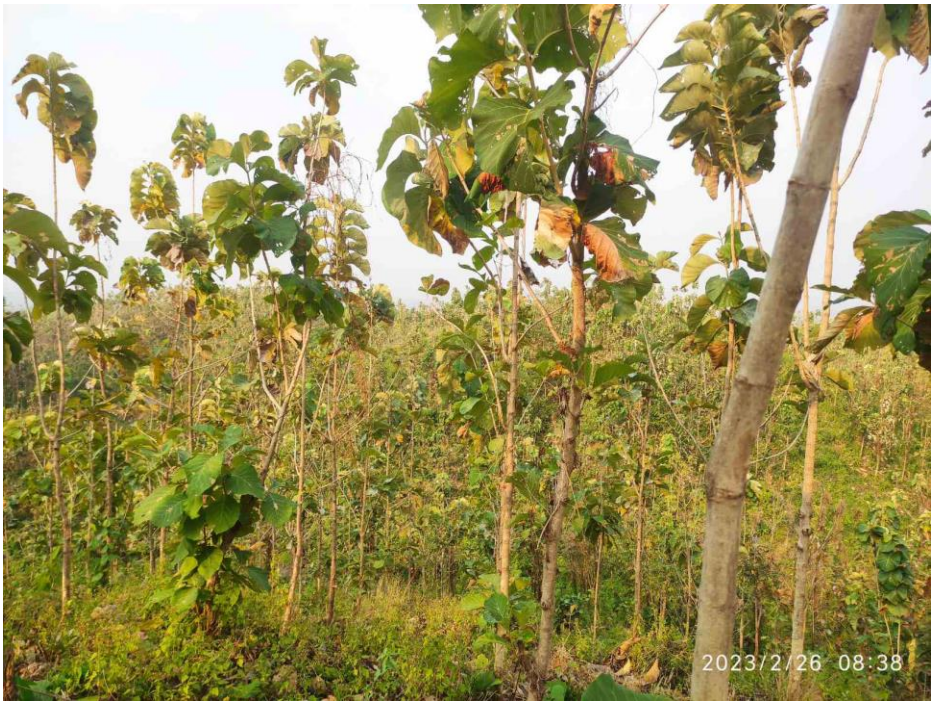


Figure 15: Leaf Blight Infection at Teak Plantation, Mokkha Reserved Forest, Minhla Township

Figure 16: Leaf Blight Infected Teak Leaves at Thonese Reserved Forest, Tharyarwaddy Township

Figure 17: Teak Leaf Blight Infection at Thuyetan Reserved Forest, Padaung Township

Figure 18: Teak Leaf Blight Infection at Bawbin Reserved Forest, Gyobingauk Township

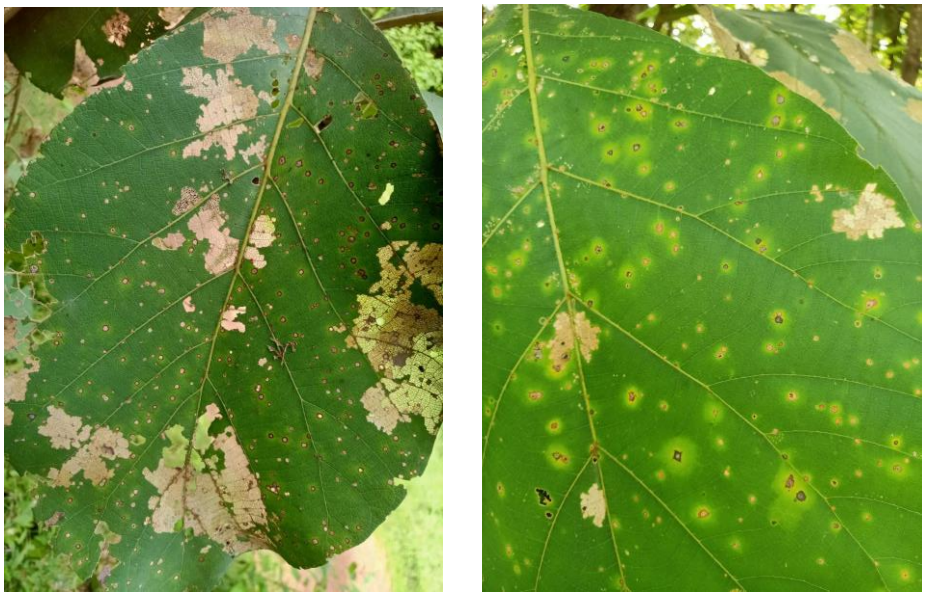


Figure 19: Leaf Spot Infected Teak Leaves at Thonese Reserved Forest, Tharyarwaddy Township

Figure 20: Leaf Spot Infected Teak Leaves at Thuyetan Reserved Forest, Padaung Township and Leaf Spot Infection at Nawin (South) Reserved Forest, Paukkhaung Township

Figure 21: Sooty Mold Infection at Teak Plantation, Mokkha Reserved Forest, Latpadan Township

Figure 22: Mistletoe Infection at Teak Plantation, Nawin (South) Reserved Forest, Paukkhaung Township

Figure 23: Mistletoe Infected Teak Trees at Nawin (South) Reserved Forest, Paukkhaung Township

Figure 24: Mistletoe Infection at Teak Plantatipn, Thuyetan Reserved Forest, Padaung Township

Figure 25: Mistletoe Infection at Teak Plantation, Thonese Reserved Forest, Tharyarwaddy Township

Appendices

Appendix 1: List of Pests Infesting on Teak (*Tectona grandis*) in Pyay and Tharyarwaddy Districts, Bago Region

No.	Common Name	Scientific Name	Order	Family	Pest Category	Observed Locations	Control Measures
1.	Army worm	*Spodoptera litura* Fabricius	Lepidoptera	Noctuidae	Defoliator	PK	(A), (C), (H), (L)
2.	Ash weevil	*Myllocerus* sp.	Coleoptera	Curculionidae	Foliage Feeder	TWD,GBK	(A), (K),
3.	Black beetle	*Colasposoma* sp.	Coleoptera	Chrysomelidae	Foliage Feeder	PK	(D), (K), (F)
4.	Black Pumpkin beetle	*Aulacophora* sp.	Coleoptera	Chrysomelidae	Foliage Feeder	TWD	(D), (F), (K)
5.	Blue beetle	*Colasposoma* sp.	Coleoptera	Chrysomelidae	Foliage Feeder	PK	(D), (F), (K)
6.	Black bug	unidentified	Hemiptera		Foliage Feeder	TWD, MH,	(D), (F), (G)
7.	Butterfly	*Catopsilia pomona*	Lepidoptera	Pieridae	Foliage Feeder	TWD	(A), (B), (C), (E)
8.	Common hairy caterpillar	*Spilosoma obliqua*	Lepidoptera	Erebidae	Foliage Feeder	MH, PK	(A), (C), (D), (I), (K)
9.	Cricket	*Tarbinskiellus* sp.	Orthoptera	Gryllidae	Foliage Feeder	TWD, MH, GBK, PK, PD	(B), (C), (K)
10.	Teak Defoliator	*Hyblaea puera*	Lepidoptera	Hyblaeidae	Defoliator	TWD, MH, PK, PD	(A), (C), (D), (F), (I), (K)
11.	Golden tortoise beetle	*Aspidimorpha sanctaecrucis*	Coleoptera	Chrysomelidae	Foliage Feeder	GBK, TWD	(A), (I), (J)
12.	Leaf miner	*Phyllocnistis tectonivora* Meyrick	Lepidoptera	Gracillariidae	Foliage Feeder	TWD, MH, GBK, PK, PD	(A), (B), (D), (L)
13.	Long horned Grass Hopper	*Conocephalus maculatus*	Orthoptera	Tettigoniidae	Foliage Feeder	TWD, MH, PK, PD	(B), (D), (E)
14.	Rough-winged katydid	*Pterophylla* sp.	Orthoptera	Tettigoniidae	Foliage Feeder	TWD, MH, PK, PD	(B), (D), (E)
15.	Bush cricket	*Mecopoda elongate*	Orthoptera	Tettigoniidae	Foliage Feeder	TWD, MH, PK, PD	(E)
16.	Red Pumpkin beetle	*Aulacophora foveicollis*	Coleoptera	Chrysomelidae	Foliage Feeder	TWD	(D), (F), (K)
17.	Short horned grasshopper	*Acrida turrita*	Orthoptera	Acrididae	Foliage Feeder	TWD, MH, GBK, PK, PD	(B), (D), (E)
18.	Short horned grasshopper	*Oxya chinensis*	Orthoptera	Acrididae	Foliage Feeder	TWD, MH, GBK, PK, PD	(B), (D), (E)
19.	Rice field grasshopper	*Oxya yezoensis*	Orthoptera	Acrididae	Foliage Feeder	TWD, MH, GBK, PK, PD	(B), (D), (E)
20.	Skeletoniser	*Eutectona machaeralis* Walker	Lepidoptera	Pyralidae	Defoliator	TWD, MH, PK, PD	(A), (C), (D), (F), (I), (K)
21.	Tawny coster	*Acraea violae*	Lepidoptera	Nymphalidae	Foliage feeder	MH, PK, PD	(A), (D)
22.	Aphid	*Aphis gossypii* Glover	Hemiptera	Aphididae	Sap Feeder	TWD, PK, PD	(A), (B), (G), (L), (M)
23.	Cicada	*Burmacicada* sp.	Homoptera	Cicadidae	Sap feeder	PK	(B), (D), (K)

No.	Common Name	Scientific Name	Order	Family	Pest Category	Observed Locations	Control Measures
24.	Cotton stainer bug	*Dysdercus cingulatus*	Hemiptera	Pyrrhocoriidae	Sap Feeder	PK	(A), (H)
25.	Green leaf hopper	*Bothrogonia ferruginea*	Homoptera	Cicadallidae	Sap Feeder	TWD, MH, GBK, PK, PD	(B), (G), (L)
26.	Gundhi Bug	*Leptocorisa oratoria*	Hemiptera	Alydidae	Sap Feeder	TWD, GBK, PK, PD	(D), (E)
27.	Horned shield bug	*Placosternum* sp.	Hemiptera	Pentatonidae	Sap Feeder	TWD, MH, PK, PD	(B), (D),(E)
28.	Lace bug	*Tingis* sp.	Hemiptera	Tingidae	Sap Feeder	TWD, MH, PK, PD	(A), (B), (D), (E),(F),(K), (L)
29.	Mealy bug	*Icerya* sp.	Hemiptera	Coccidae	Sap Feeder	PK	(A), (K), (L), (M)
30.	Mealy bug	*Pseudococcus* sp.	Hemiptera	Pseudococcidae	Sap Feeder	PK, TWD	(A), (K), (L), (M)
31.	Scutellerid bug (Jewel bug)	*Chrysocoris purpureus*	Hemiptera	Scutelleridae	Sap Feeder	PK	(D), (E), (L)
32.	Eggplant horned planthopper	*Leptocentrus Taurus* Fabricius	Hemiptera	Membracidae	Sap Feeder	TWD	(B)
33.	White fly	*Bemisia tabaci*	Hemiptera	Aleyrodidae	Sap Feeder	TWD, PK	(A), (B), (D), (G), (L)
34.	Jewel beetle	*Chrysochroa fulgidissima*	Coleoptera	Buprestidae	Stem borer	PD	(D)
35.	Sapling borer	*Sahyadrassus malabaricus* Moore	Lepidoptera	Hepialidae	Stem borer	PK	(D)
36.	Redborer	*Zeuzera coffeae* Nietner	Lepidoptera	Cossidae	Stem borer	TWD, MH, PK	(F), (J), (M)
37.	Teak canker grub	*Acalolepta cervinus*	Coleoptera	Cerambycidae	Stem borer	PK	(F), (K), (L)
38.	Rubber Termites	*Coptotermes curvignathus* Holmgren	Isoptera	Rhinotermitidae	Bark Feeder	TWD, MH, GBK, PK, PD	(K), (L)
39.	Fungus-growing Termites	*Odontotermes* sp.	Isoptera	Termitidae	Bark Feeder	TWD, MH, GBK, PK, PD	(K), (L)
40.	Trunk borer, Carpenterworm	*Alcterogystia* sp.	Lepidoptera	Cossidae	Stem borer	PK	(D), (J), (K), (L)
41.	Blister beetle	*Mylabris phalerata*	Coleoptera	Meloidae	Flower and seed Feeder	PK, PD	(A), (F), (K), (M)
42.	Yellow peach moth	*Conogethes punctiferalis*	Lepidoptera	Pyralidae	Flower and seed Feeder	PK	(D), (F), (K), (L)
43.	Chafer beetle	*Amphimallon majale*	Coleoptera	Scarabaeidae	Root Feeder	TWD, MH, GBK, PK	(D), (H)
44.	White grub (Sugarcane Beetle)	*Holotrichia consanguinea*	Coleoptera	Scarabaeidae	Root Feeder	PK	(D), (H)
45.	Dung beetle	*Heliocopris bucephalus*	Coleoptera	Scarabaeidae	Root Feeder	TWD	(D), (H)
46.	Root borer	*Phassus signife*r Walk.	Lepidoptera	Hepialidae	Root and stem borer	MH, PK	(D), (F), (L)
47.	Coconut Rhinoceros beetle	*Oryctes rhinoceros* (L.)	Coleoptera	Scarabaeidae	Crown border	MH, NPT	(C), (D), (F)
48.	Rhinoceros beetle	*Xylotrupes* sp.	Coleoptera	Scarabaeidae	-	MH, NPT	(C), (D), (F)

Mechanical control

(A) Hand Picking of pest' developmental stages/ Remove leaves
(B) Yellow Sticky Trap
(C) Molasses Trap/ jaggery trap
(D) Light Trap
(E) Insect Net/ Sweet Net

Cultural Control

(F) Weeding/ collect debris and burn/ bury
(G) Water Management
(H) Ploughing/ hoe

Biological Control

(I) Covering Nylon Mesh over the collected leaves for wasp parasitoid
(J) Painting/ spraying sweet and sticky liquid for ant population

Chemical control

(K) Contact Insecticide
(L) Systemic insecticide

Plant Extract

(M) Neem Oil

Townships

Tharyarwaddy : TWD
Minhla : MH
Gyobingauk : GBK
Paukkhaung : PK
Padaung : PD
Nay Pyi Taw : NPT

Appendix 2: List of Natural Enemies which are useful in Control and Prevention of Insect Pests in Teak Plantations of Pyay and Tharyarwaddy Districts, Bago Region

No.	Common Name	Species	Order	Family	Type of nature
1.	Wasp	*Apanteles* sp.	Hymenoptera	Braconidae	Parasite
2.	Wasp	*Bracon* sp.	Hymenoptera	Braconidae	Parasite
3.	European paper wasp	*Polistes* sp.	Hymenoptera	Polistinae	Parasite
4.	Black ant	*Camponotus* sp.	Hymenoptera	Formicidae	Predator
5.	Red ant	*Solenopsis* sp.	Hymenoptera	Formicidae	Predator
6.	Lady beetle	*Coccinella undecimpunctata*	Coleoptera	Coccinellidae	Predator
7.	Lady beetle	*Coccinella transversalis*	Coleoptera	Coccinellidae	Predator
8.	Lady beetle	*Cycloneda munda*	Coleoptera	Coccinellidae	Predator
9.	Spider	*Lycosa pseudoanulata*	Araneae	Lycosidae	Predator
10.	Green lynx spider	*Peucetia* sp.	Araneae	Oxyopidae	Predator
11.	Spider	*Oxyopes* sp.	Araneae	Oxyopidae	Predator
12.	Spider	*Argiope* sp.	Araneae	Papaveraceae	Predator
13.	Huntsman spider	*Olios* sp.	Araneae	Sparassidae	Predator
14.	Praying mantis	Mantisa religiosa	Orthoptera	Mantidae	Predator
15.	Green lace wing	*Chrysoperla* sp.	Neuroptera	Chrysopidae	Predator
16.	Red dragonfly	*Sympetrum fonscolombiii*	Odonata	Libellulidae	Predator
17.	Damsel fly	Unidentified	Odonata	-	Predator
18.	Ground beetle	*Nebria brevicollis*	Coleoptera	Carabidae	Predator
19.	Assassin bug	*Zelus renardii*	Hemiptera	Reduviidae	Predator

Appendix 3: Pest Survey Form (Insect Net)

တည်နေရာ .....မြို့နယ်၊ .....ကြိုးဝိုင်း၊ အကွက်အမှတ်.....

စိုက်ခင်းအမှတ်..... ရက်စွဲ..... စာရင်းကောက်ယူသူ .....

အပူချိန်.....စိုထိုင်းဆ .....

စဉ်	အင်းဆက်အမည်	အင်းဆက်အရေအတွက်	စုစုပေါင်း
	စုစုပေါင်း		

Appendix 4: Pest Survey Form (Light Trap)

တည်နေရာ ………………….မြို့နယ်၊ …………………..ကြိုးဝိုင်း၊ အကွက်အမှတ်…………….

စိုက်ခင်းအမှတ်……………. ရက်စွဲ…………… စာရင်းကောက်ယူသူ ………………..

အပူချိန်……………………..စိုထိုင်းဆ …………………………….

စဉ်	အင်းဆက်အမည်	၂၀ ကေကွက်များအလိုက် အင်းဆက်အရေအတွက်					စုစုပေါင်း
		၁	၂	၃	၄	၅	
	စုစုပေါင်း						

Appendix 5: Pest Survey Form (Sticky Trap)

တည်နေရာ .....မြို့နယ်၊ .....ကြိုးဝိုင်း၊ အကွက်အမှတ်.....

စိုက်ခင်းအမှတ်..... ရက်စွဲ..... စာရင်းကောက်ယူသူ .....

အပူချိန်.....စိုထိုင်းဆ .....

စဉ်	အင်းဆက်အမည်	Sticky Trap ၁ ခုချင်းရှိ အင်းဆက်အရေအတွက်					စုစုပေါင်း
		၁	၂	၃	၄	၅	
	စုစုပေါင်း						

Appendix 6: Pest Survey Form (Visual Survey)

တည်နေရာ .....မြို့နယ်၊ .....ကြိုးဝိုင်း၊ အကွက်အမှတ်..... စိုက်ခင်းအမှတ်..... ရက်စွဲ.....

စာရင်းကောက်ယူသူ ..... အပူချိန်.....စိုထိုင်းဆ .....

အင်းဆက်အမည်	အပင်နံပါတ်								စုစုပေါင်း
	၁	၂	၃	၄	၅	၆	၇	၈	
မှတ်ချက်									

Appendix 7: Disease Survey Form

အပင်ရောဂါစာရင်း

တည်နေရာ .....မြို့နယ်၊ .....ကြိုးဝိုင်း၊ အကွက်အမှတ်.....၊ စိုက်ခင်းအမှတ်.....

GPS Point ..... အကွက်အမှတ်စဉ်.....

ရက်စွဲ ..... စာရင်းကောက်ယူသူ .....

အပင်အမှတ်စဉ်	အရွက်		ပင်စည်		အမြစ်		မှတ်ချက်
	ရောဂါ	ပြင်းထန်မှု	ရောဂါ	ပြင်းထန်မှု	ရောဂါ	ပြင်းထန်မှု	
၁							
၂							
၃							
၄							
၅							
၆							
၇							
၈							

(a) ရွက်ပြောက် (a) ခေါင်ခြောက်သေ (a) ပင်ညှိုး

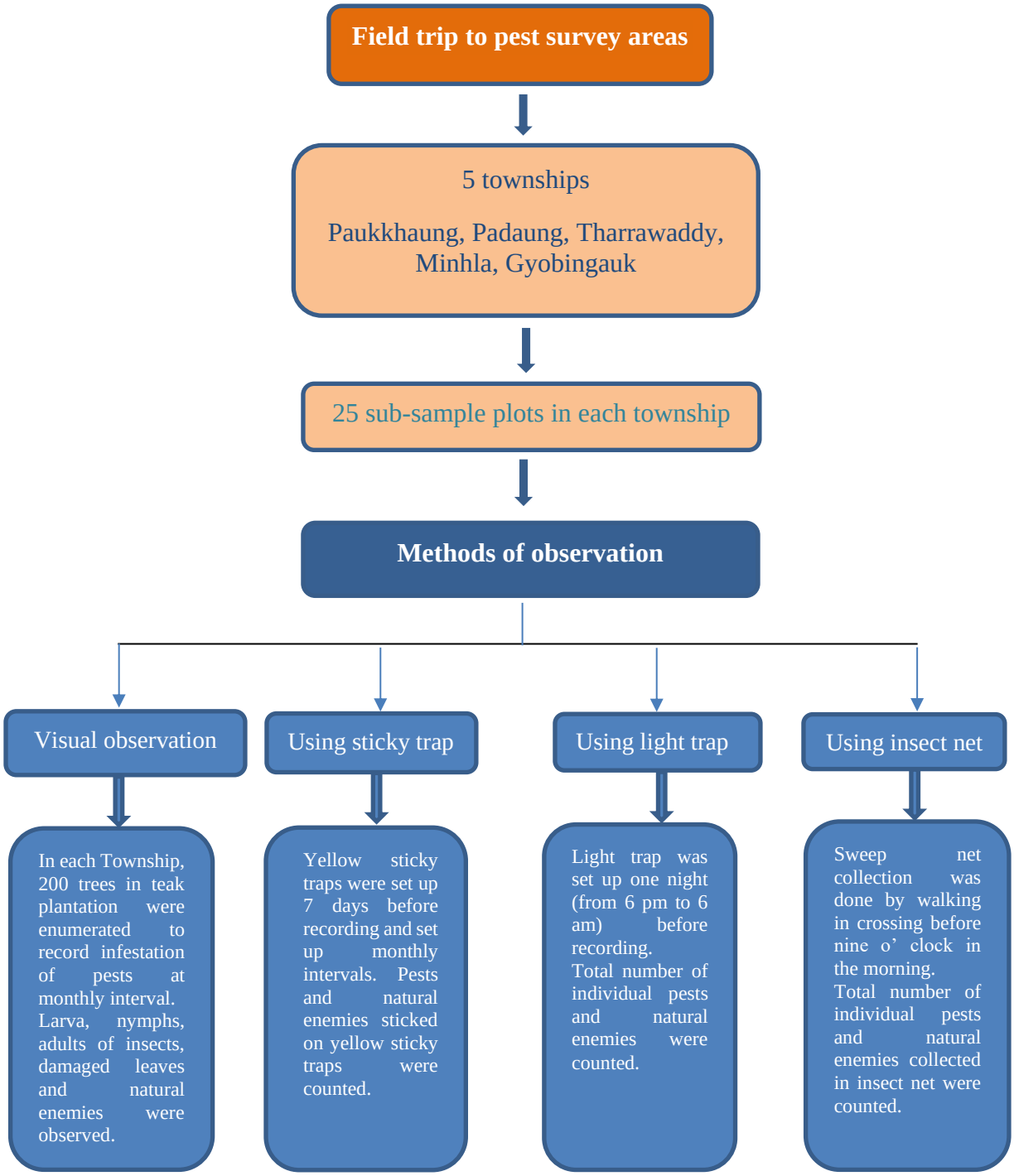
(b) သံချေးမှို (b) ကိုင်းခြောက် (b) အမြစ်ပုပ်

(c) ရွက်ခြောက် (c) ကျီးပေါင်း (c) ခါးရိသေ

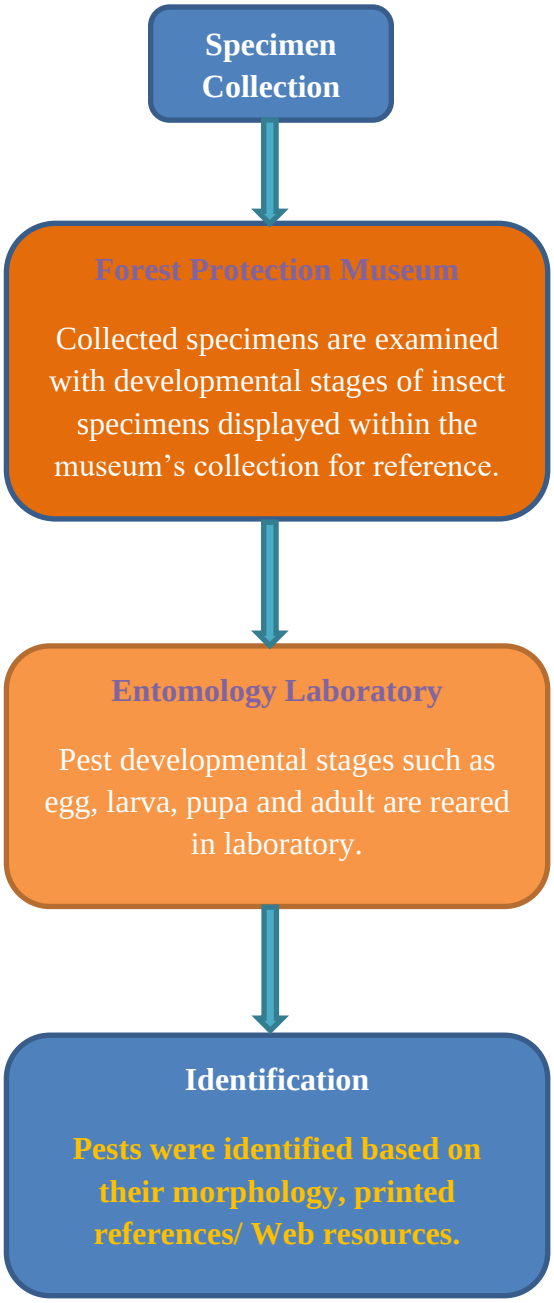
(d) ဖားဥမှို (d) ကျီးပေါင်းကပ်ပါးပင်

ရောဂါပြင်းထန်မှုအဆင့်: L - အနိမ့်ဆုံး; M - အလယ်အလတ်; S - အမြင့်ဆုံး

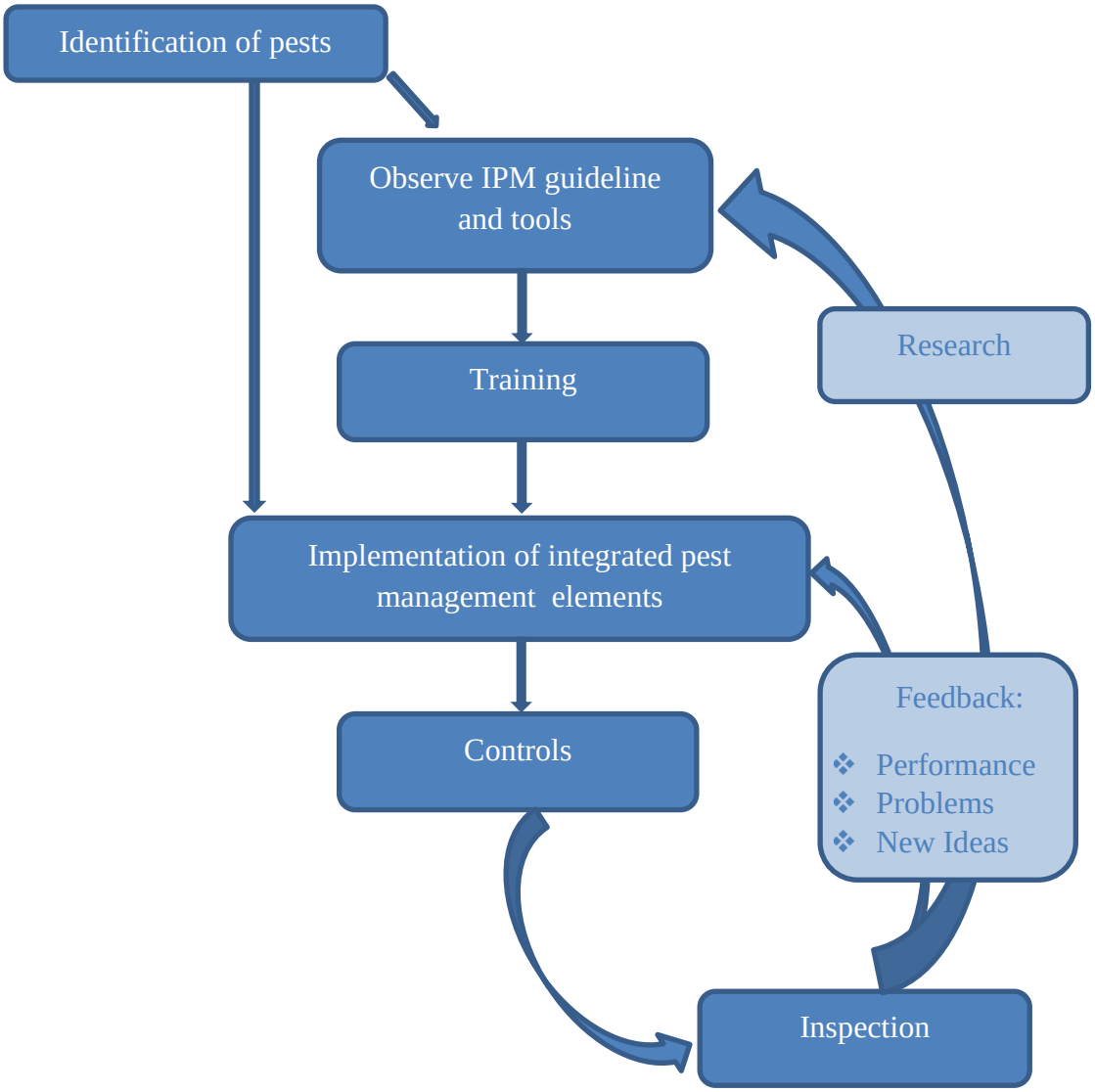
Appendix 8: Flow Chart for Pest Survey



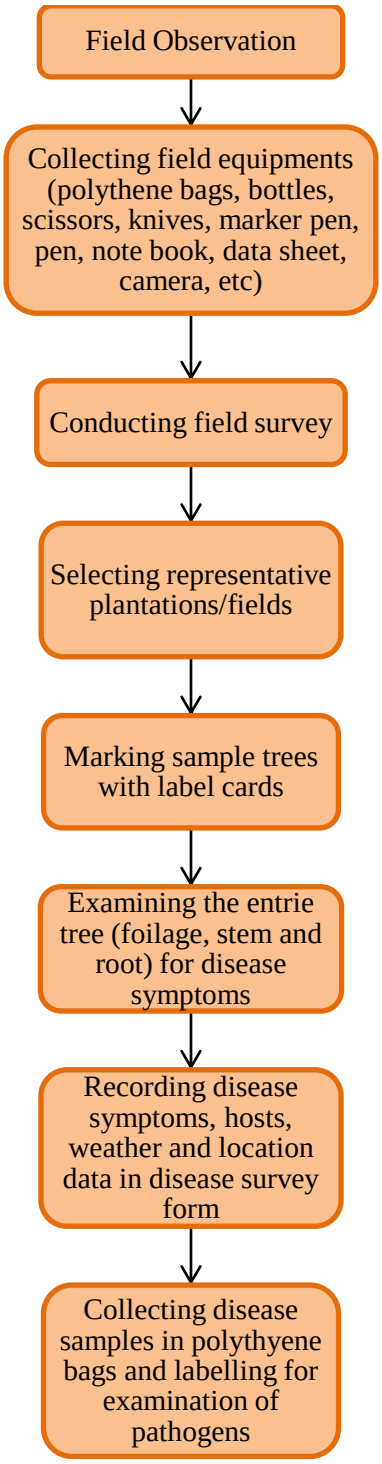
Appendix 9: Flow Chart for Pest Identification



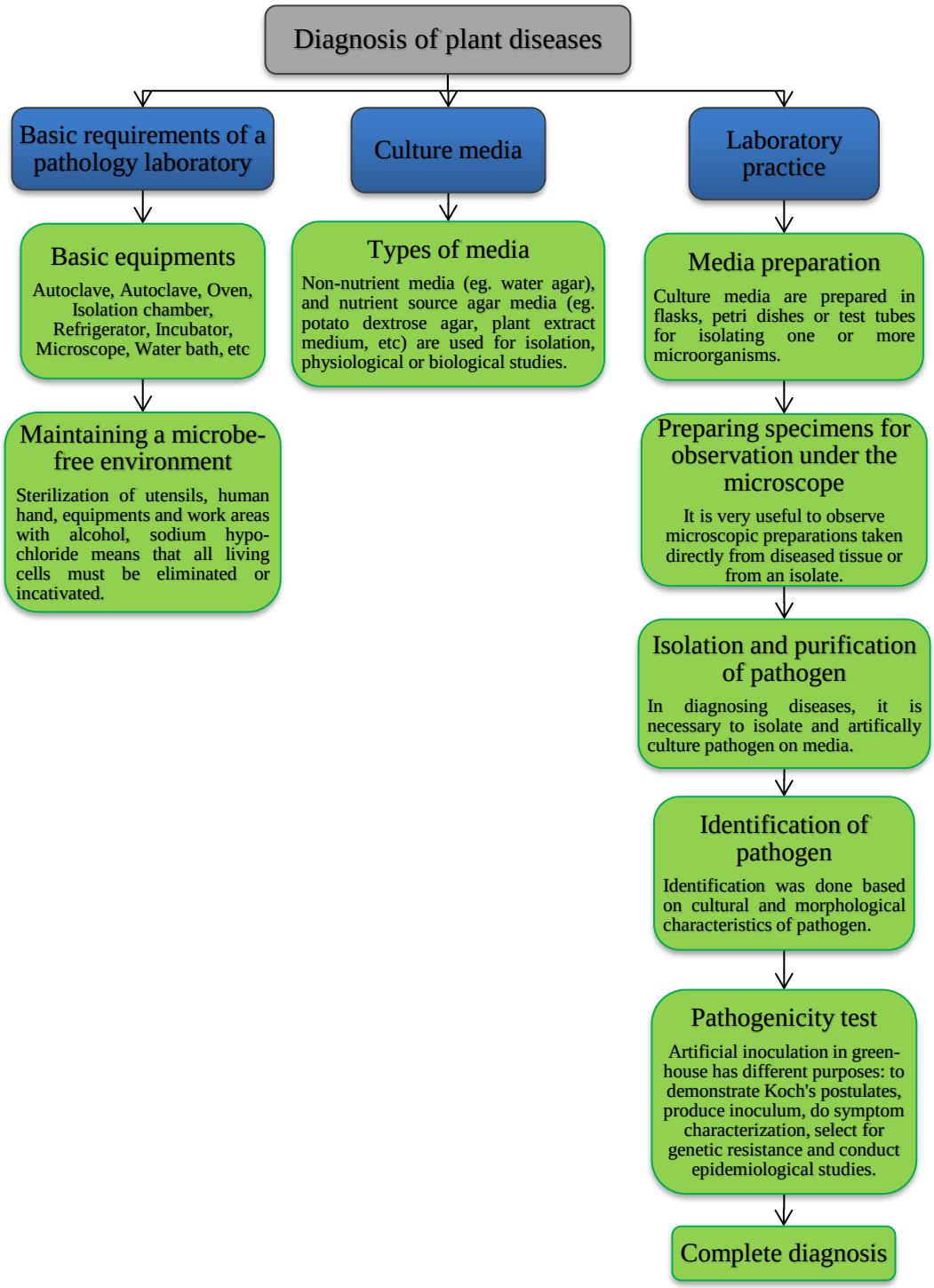
Appendix 10: Flow Chart for Pest Control Measures



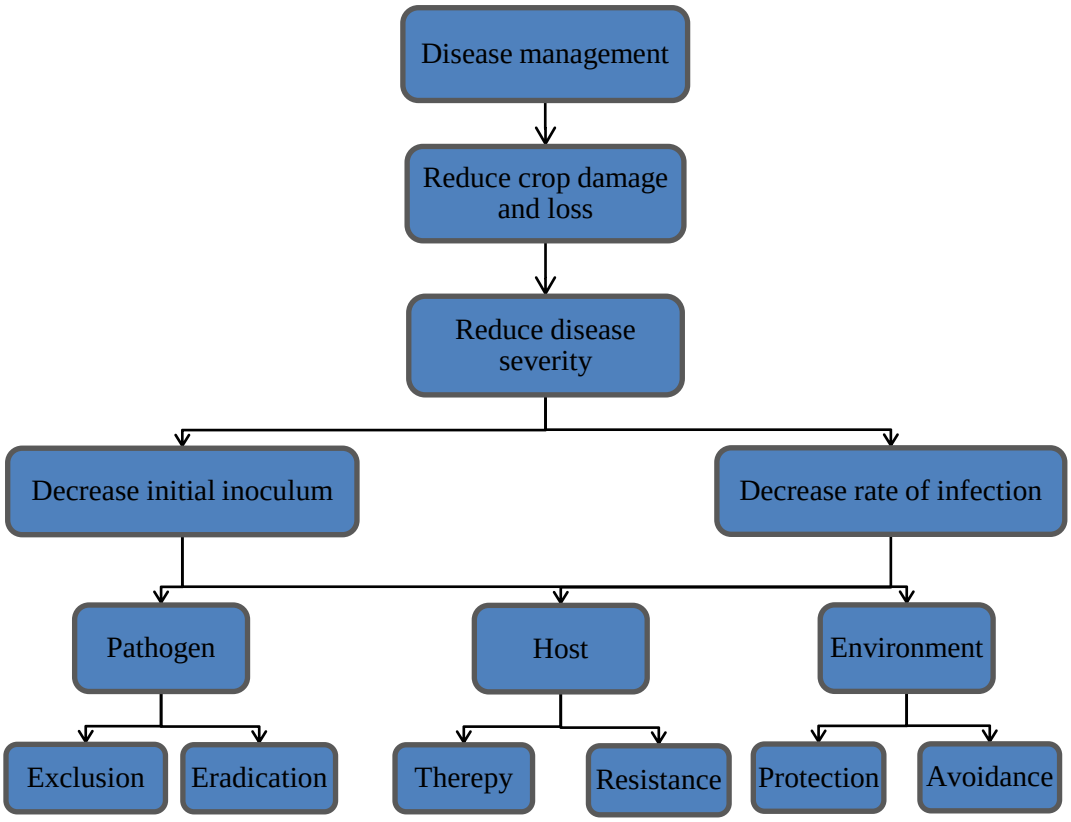
Appendix 11: Flow Chart for Plant Disease Survey



Appendix 12: Flow Chart for Plant Diseases Diagnosis



Appendix 13: Flow Chart for Plant Disease Management



Exclusion – means preventing the inoculums from entering or establishing in a field or area where it does not exist.

Eradication – is the process of reducing, inactivating, eliminating or destroying inoculums at the source, either from a region or from an individual plant in which it is already established.

Therepy – is a curative procedure and is applied to individuals (infected host plant) after infection has taken place.

Resistance – can be induced by use of certain biotic and abiotic factors. Use of biotechnological tools (tissue culture, genetic engineering and protoplast fusion) are being used to develop resistant cultivars.

Protection – can be achieved by creating toxic barrier (chemical sprays, dusts, modification of environment and host nutrition) between plant surface and the inoculums.

Aviodance – involves avoiding disease by planting at time when, or in areas where inoculums is absent or ineffective due to environmental conditions. The main practices are choice of geographical area, slection of field and planting time, selection of seed/planting materials, modification of cultural practices.

Appendix 14: Insect Orders and their Feeding Habit

Order - Coleoptera (beetles and weevils)

Coleoptera (beetles and weevils) is the largest order in the class Insecta. Both larva and adult have strong mandibulate and chewing mouth parts. Many species are herbivores and they feed on the roots, stems, leaves or reproductive structures of their host plants. They can attack all parts of living plants of processed fibers, grains and wood products. Beetles can live on fungi or burrow into plant tissues or excavate tunnels in wood or under bark. Predatory species (lady beetles) feed by praying aphids and scale insects.

Order - Lepidoptera (butterflies and moths)

Lepidoptera is the second largest order in the class Insecta. Most larvae (caterpillars) have a well-developed head with chewing mouthparts. Most lepidopteran larvae are herbivores: some species eat foliage, some burrow into stems or roots, and some are leaf- miners. The adult's mouthparts form a coiled tube (proboscis) beneath the head and it is used to imbibe floral nectar and other liquid substances.

Order - Hemiptera, suborder Heteroptera (true bugs)

Plant feeding bug are important pests of many crop plants. They can injury to plant tissues and weaken plants by removing sap or can transmit plant pathogens.

Order - Hemiptera, suborder Homoptera
(leafhoppers, planthoppers, treehoppers, cicadas, aphids, psyllids, whiteflies, scale insects)

Many species are pests of cultivated plants. These species have piercing/sucking mouthparts and feed by withdrawing sap from vascular plants. Aphids and leafhoppers are important carriers of plant diseases. Cicadas (nymphs) live underground where feed on the roots of trees and shrubs.

Order - Hymenoptera (bees, wasps, ants and sawflies)

Order Hymenoptera is the third largest order of Insect. Bees and wasps (immatures) have well developed head and chewing mouthparts. Adults have chewing mouthparts except in bees where mouthparts form a proboscis for collecting nectar. Most of the Hymenoptera are beneficial as natural enemies

of insect pests (parasitic wasps) or as pollinators of flowering plants (bee and wasps)

Order - Isoptera (termites and white ants)

They have chewing mouthparts and sometimes with large mandibles. Termites become economic pests when their appetite for wood and wood products extends to homes, buildings materials, forests and other commercial products.

References

Agrawal, M. V. S. and K. Chaukikar (2021). Seasonal activity of insect fauna collected through light trap in polyhouse. Journal of Entomology and Zoology Studies 2021; 9(1): 52-60.

Chhetri, V. T., G. C. R., Chaudhary, S., Timilsina, S., and Gautam, S. (2021) Pests, pathogens, pathogenic diseases, and diseases control strategies of sal (Shorea robusta) in Nepal. Archives of Agriculture and Environmental Science, 6(2), 210-217.

Deepak, k.M., J. Komal and S. S. T. Katta (2022). Different Types of Insect Traps for Different Insects.

Gilchrist-Saavedra, L., Fuentes-Davila, G., and Martinez-Cano, C. (1997) Practical guide to the identification of selected diseases of Wheat and Barley, D.F.: CIMMYT.

Parthasarathy, S., Thiribhuvanamala, G., Muthulakshmi, P., and Angappan, K. (2021) Diseases of foreest trees and their management. New Delhi-110085 (India).

Sharma, J. K., Mohanan, C., and Maria Florence, E. J. (1985) Disease survey in nursery and plantations of forest tree species grown in KERALA. KFRI Research Report 36, 16-49.

https://genent.cals.ncsu.edu/insect-identification/order-coleoptera/family-elateridae/

Acknowledgements

Authors are sincerely thankful to Ministry of Natural Resources and Environmental Conservation (MONREC) for giving permission. Authors gratefully acknowledge Asian Forest Cooperation Organization (AFoCO) for giving this opportunity and financial support. Authors would like to acknowledge the Directors, Deputy Directors, Assistant Directors, Officers and Staffs for their continuous encouragement and support during disease survey. The present study was supported by FD-AFoCO IPDM Project (AFoCO/014/2020).