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# Study on insects in China-Myanmar Friendship Multi-Species Plantation, Ngamin Reserved Forest, Taungdwingyi Township

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## Abstract

Insect pests, their damages, and natural enemies were investigated in a multi-species plantation within the Ngamin Reserved Forest to evaluate its resistance to insect pests. Light traps, insect nets, and visual surveys were employed, and the damage level was assessed using a scoring system ranging from 0 (no damage) to 5 (severe damage). The survey documented a total of 30 insect species (insect pests: 23 spp. and beneficial insects: 7 spp.), including a natural enemy spider species. Among the pests, leaf feeders were dominant, accounting for up to 65% of the total pest species found, followed by sap feeders (22%), bark feeders (9 %), and stem borers (4%). Beneficial insects were mostly predator and parasitoid species from the orders Hymenoptera and Coleoptera. Of the 30 insect species recorded, light trap surveys identified 16 insect pests and six beneficial species. According to the classification of insect pest damage used in the study, the plant damage level was very low(1=1-20%). In addition, no outbreak of a particular insect pest was observed during the study period. These findings align with the fact that the multi-species system enhances ecosystem resilience, a phenomenon likely driven by associational resistance. Growing multi-species in plantations, conserving native biocontrol agents in forest plantations, and integrating targeted interventions, such as light traps, when pest damage is more serious than low-level, can support forest plantation health and reduce reliance on chemical controls.

**Keywords:** *Insect pests, Beneficial insects, Multi-species plantation, Pest management*

# တရုတ်-မြန်မာ ချစ်ကြည်ရေးသစ်မျိုးစုံစိုက်ခင်းတွင် အင်းဆက်ပိုးမွှားကျရောက်မှုအား လေ့လာခြင်း

ဇော်မင်းအေး၊ ဦးစီးအရာရှိ

## စာတမ်းအကျဉ်း

ဤလေ့လာမှုအား ငမင်သစ်မျိုးစုံရောနှောစိုက်ခင်းအတွင်း အင်းဆက်ဖျက်ပိုး ကျရောက်မှု အခြေအနေနှင့် စိုက်ခင်း၏ ဖျက်ပိုးဒဏ်ခံနိုင်ရည်ရှိမှုတို့ကို အကဲဖြတ်နိုင်ရန် ဆောင်ရွက်ခဲ့ပါသည်။ အလင်းရောင်ထောင်ချောက်၊ ပိုးဖမ်းပိုက်နှင့် မျက်မြင်စာရင်း ကောက်ခြင်းနည်းလမ်းများဖြင့် ပိုးမွှားကျရောက်မှုကို စာရင်းကောက်ယူခဲ့ပြီး ပိုးမွှားဖျက်ဆီးမှု အခြေအနေကို ပျက်စီးမှုအလိုက် (ပျက်စီးမှုမရှိ = ၀၊ ပျက်စီးမှုအလွန်ပြင်းထန် = ၅) အဆင့်များ သတ်မှတ်၍ ဆန်းစစ်ခဲ့ပါသည်။ အင်းဆက်ပိုးမွှားမျိုးစိတ် စုစုပေါင်း ၃၀ မျိုး (ဖျက်ပိုး ၂၃မျိုး၊ အကျိုးပြုပိုး ၇မျိုး)နှင့် ဖျက်ပိုးများ၏ သဘာဝရန်သူပင့်ကူ ၁ မျိုး မှတ်တမ်းတင်နိုင်ခဲ့ပါသည်။ အင်းဆက်ဖျက်ပိုးများတွင် ရွက်စားပိုးပါဝင်မှု ၆၅% အများဆုံး ဖြစ်ပြီး၊ စုပ်စားပိုး၂၂ %၊ အခေါက်ထိုးပိုး ၉ % နှင့် ပင်စည်ဖောက်ပိုး ၄ % များ ဖြစ်ကြောင်း တွေ့ရှိခဲ့ရပါသည်။ အကျိုးပြုအင်းဆက်ပိုးမျိုးစိတ် ၇ မျိုးသည် Hymenoptera နှင့် Coleoptera မျိုးစဉ်များမှ ဖျက်ပိုးစားအင်းဆက်များနှင့် ကပ်ပါးအင်းဆက်များကို အများဆုံး တွေ့ရှိခဲ့ပါသည်။ မှတ်တမ်းတင်နိုင်ခဲ့သည့် အင်းဆက်ပိုးမွှား ၃၀ မျိုးအနက် အင်းဆက်ဖျက်ပိုး ၁၆ မျိုးနှင့် အကျိုးပြုအင်းဆက်ပိုး ၆ မျိုးကို အလင်းရောင်ထောင်ချောက် (Light Trap)ဖြင့် ဖမ်းယူစာရင်းကောက်ခြင်းဖြင့် တွေ့ရှိခဲ့ခြင်းဖြစ်ပါသည်။ ပိုးမွှားကျရောက်ဖျက်ဆီးမှုသည် ပျက်စီးမှုအဆင့်သတ်မှတ်ချက်အရ အဆင့် (၁=၁-၂၀%) အလွန် နည်းပါးကြောင်းတွေ့ရှိခဲ့ပါသည်။ထို့အပြင်ဖျက်ပိုးတစ်မျိုးမျိုးဆိုးရွားစွာ ကျရောက်ခြင်းမရှိကြောင်းလည်း တွေ့ရှိခဲ့ပါသည်။ ယခုလေ့လာတွေ့ရှိချက်များသည် သစ်မျိုးများ ရောနှော စိုက်ပျိုးခြင်းဖြင့် “ဆက်စပ်မှုဆိုင်ရာခံနိုင်ရည်” (Associational Resistance)ကို တိုးမြှင့် ပေးနိုင်၍ စိုက်ခင်း၏ ဂေဟစနစ်ဆိုင်ရာခံနိုင်ရည်ရှိမှုအား ကောင်းမွန်စေသည် ဟူသည့် အချက်နှင့် ကိုက်ညီမှုရှိပါသည်။ အကျိုးပြုအင်းဆက်များကိုထိန်းသိမ်းကာကွယ်ခြင်း နှင့် လိုအပ်ပါက အလင်းရောင်ထောင်ချောက် အသုံးပြုနိုမ်နင်းခြင်းကဲ့သို့သော ကာကွယ်နှိမ်နင်းရေးနည်းလမ်းများကို ပေါင်းစပ်အသုံးပြုမည်ဆိုပါက သစ်တောစိုက်ခင်းများ၏ ကျန်းမာကြံ့ခိုင်မှုကို ပံ့ပိုးပေးရုံသာမက ဓာတုပိုးသတ်ဆေးများအပေါ် မှီခိုရမှုကိုလည်း လျှော့ချနိုင်မည် ဖြစ်ပါသည်။

# Study on insects in China-Myanmar Friendship Multi-Species Plantation, Ngamin Reserved Forest, Taungdwingyi Township

## 1. Introduction

Forest plantations are established for various products and services: timber, fuelwood, fiber, soil, water, biodiversity conservation, carbon sequestration, regulating, and cultural services. The rotation age of forest plantations takes years, even for the short-rotation system with fast-growing species. During this period, disturbances such as drought, fire, pests, and disease outbreaks can occur. For some reasons, including economic and ease of doing silvicultural operations, the majority of plantations established were monocultures. Forest plantations are increasingly critical for meeting global timber demands, yet their monoculture structure often renders them vulnerable to insect pest outbreaks, leading to significant economic and ecological losses (Jactel et al., 2021). The simplification of forest ecosystems can reduce natural balances, allowing pest populations to exceed damaging thresholds with greater frequency (Pureswaran et al., 2018). In response, there is a growing interest in the development of multi-species plantations, which are theorized to promote greater ecological resilience.

With climate change, biodiversity conservation, landscape restoration, and nature-based solutions, demands from forest plantations extend beyond just timber and forest products. In the case of pest management, a foundational principle is the concept of associational resistance, where increased plant species diversity can directly impede the ability of herbivorous insects to locate and exploit their host plants (Barbosa et al., 2009). Furthermore, diverse plant communities often support more complex food webs, including a richer array of natural enemies such as predators and parasitoids, which provide top-down regulation of pest populations (Gurr et al., 2017). The presence and abundance of these beneficial arthropods are key indicators of an ecosystem's biological control potential (Sollai et al., 2024).

Despite the theoretical benefits, empirical studies documenting the specific insect pest and natural enemy assemblages in emerging multi-species plantations are essential for validating and refining management strategies. This study was conducted taking advantage of an existing mixed forest plantation established through the China-Myanmar Friendship Program in Ngamin Reserved Forest Compartment No. (218) from August 2024 to March 2025.

## 2. Objectives

The main objective of this research is to study the insect pests infesting the multi-species forest plantation in Ngamin Reserved Forest. The specific objectives are as follows:

1. To inventory the spectrum of insect pest species and their natural enemies, classifying them by taxonomic order and feeding guild.
2. To assess the plant damage and evaluate the role of tree diversity in promoting resistance.
3. To suggest suitable pest management guidelines for the plantation's long-term sustainability.

## 3. Materials and Methods

The study was conducted within the multi-species forest plantation established under the China-Myanmar Friendship Program in the Ngamin Reserved Forest, Taungdwingyi Township. The involvement of the tree species is provided in Appendix 1.

The plantation site is situated across two compartments: Compartment No. 218, adjacent to Milepost (26/6) on the Nay Pyi Taw–Magway Highway, and Compartment No. 216, near Milepost (28/1) within the reserved forest (Figure 1). Initial establishment activities, including

planting, were carried out throughout the 2017 calendar year. Current management focuses on the maintenance and preservation of the plantation and the implementation of research and development programs.

In conducting the insect survey, nine sample plots (labeled from A to I) were systematically established within the 55-acre plantation area (in Compartment No. 218) using a zig-zag sampling pattern to ensure representative coverage. The following methods were used to record insect observations in the field:

- Visual Observation: Direct visual surveys were carried out by selecting 9 sample plots in the study area of 55 acres. In each sample plot, 17 sample plants were marked permanently by "X" pattern. Visual observations of pests, natural enemies, and plant damage were conducted on 153 plants in the sample plots.
- Light Trap: One light trap was set up in each sample plot one night before recording. The light trap was on from 6 pm to 6 am. The pests and natural enemies trapped in six light traps were observed.
- Insect Net: An insect net survey was conducted, cross-walking the sample plots before nine o'clock in the morning. The pests and natural enemies captured in the insect net were observed.
- Identification of insect pests was carried out in the Forest Research Institute (FRI), Protection Section, Entomology laboratory, with the help of identified specimens in the museum (FRI) and available literature; Dawwrueng et al. (2017), Wood SL & Bright DE (1992), Wood SL (2007), published literature, and websites.

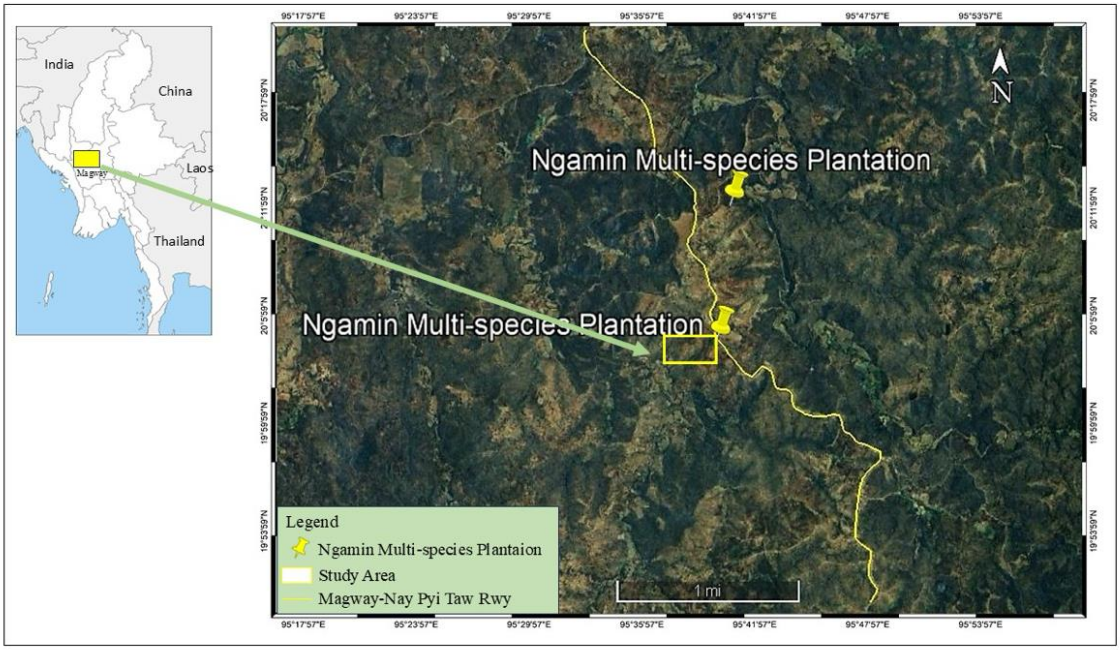


**Figure 1**. Location map of Ngamin multi-species plantation.

## 4. Results

### 4.1 Visual observation

Monthly visual observation was conducted to characterize key insect pests and their natural enemies within the plantation ecosystem. As detailed in Table 1, two pest species were identified: a termite (Isoptera: Rhinotermitidae), classified as a bark feeder, and an ambrosia beetle, *Platypus* sp. (Coleoptera: Platypodinae), a wood borer. Furthermore, a single species of natural enemy, an ant (Hymenoptera: Formicidae) acting as a generalist predator, was recorded (Table 2).

**Table 1**. Insect pest species recorded by visual observation within the multi-species forest plantation in Ngamin Reserved Forest.

| No. | Pest category | Common Name | Scientific Name | Family | Order |
|---|---|---|---|---|---|
| 1 | Bark feeder | Termite | - | Rhinotermitidae | Isoptera |
| 2 | Stem borer | Ambrosia beetle | *Platypus* sp. | Platypodinae | Coleoptera |

**Table 2**. Different species of natural enemies recorded by visual observation within the multi-species forest plantation in Ngamin Reserved Forest.

| No. | Type of nature | Common Name | Scientific Name | Family | Order |
|---|---|---|---|---|---|
| 1 | Predator | Ant | - | Formicidae | Hymenoptera |

### 4.2 Visual assessment of plant damage

Plant damages were assessed through scoring from 0 (no damage) to 5 (severe) to quantify the severity of damage. Direct observations were made to estimate the percentage of foliage damage as a percentage of total foliage, and the number of holes caused by insects in the stem was counted to assign the damage scores. The scoring was applied to individual trees in the sample plots, and the average damage score was calculated. The details of the scoring system are as follows:

0 = no damage,
1= very low (1-20%),
2 = low (21-40),
3 = moderate (41-60%),
4= high (61-80%), and
5= severe (81-100%).

Borer attacks, which pose a significant threat to the health and survival of trees, were observed on four *Lagerstroemia speciosa* trees and two *Pterocarpus macrocarpus* trees in two sample plots(B and C). However, the overall plant damage, including leaf feeders and borers, remained very low (1=1-20%). In *Tectona grandis* trees, only foliage feeders' damage was observed, and the symptoms of borers and sup-sacking insects were not found.

### 4.3 Light trap survey

Light trap surveys conducted within the Nga Minn Reserved Forest yielded a diverse arthropod assemblage, comprising 16 species of pests (Table 3) and 6 species of natural enemies (Table 4). The light trap survey successfully documented a taxonomically diverse assemblage of phytophagous (plant-feeding) arthropods within the plantation ecosystem. In particular, the inventory comprised 16 distinct pest species spanning four insect orders and representing three primary feeding guilds. The recorded pests were dominated by the orders Orthoptera (grasshoppers and katydids; 6 species) and Hemiptera (true bugs; 5 species), followed by Coleoptera (beetles; 4 species) and single representatives from Lepidoptera (butterflies/moths) and Phasmatodea (stick insects).

Analysis of feeding strategies revealed a clear predominance of foliage feeders, which constituted the majority of the recorded species (11 out of 16). This guild included all Orthopterans, the Lepidopteran larva, the Coleopteran weevil and scarab, and the stick insect. The sap feeder guild was the second most represented, comprising five Hemipteran species (froghoppers, stink bugs, and leaf-footed bugs). A single species, the longhorn beetle (*Derobrachus* sp.), was identified as a bark feeder.

**Table 3**. Different species of pests recorded by light traps within the multi-species forest plantation in Ngamin Reserved Forest.

| No. | Pest category | Common Name | Scientific Name | Family | Order |
|---|---|---|---|---|---|
| 1 | Leaf Feeder | Angle winged katydid | *Microcentrum* sp. | Tettigoniidae | Orthoptera |
| 2 | | Common grass yellow butterfly | *Eurema hecabe* | Pieridae | Lepidoptera |
| 3 | | Curve-tailed Bush Katydid | *Scudderia curvicauda* | Tettigoniidae | Orthoptera |
| 4 | | Katydids or bush crickets | *Ducetia* sp. | Tettigoniidae | Orthoptera |
| 5 | | Large pine weevil | *Hylobius* sp. | Curculionidae | Coleoptera |
| 6 | | May beetle | *Phyllophaga* sp. | Melolonthinae | Coleoptera |
| 7 | | Rufous - legged Grasshopper | *Xenocatantops* sp. | Acrididae | Orthoptera |
| 8 | | Scarab beetle | *Diplotaxis* sp. | Scarabidae | Coleoptera |
| 9 | | Short horned grasshopper | unidentified | Acrididae | Orthoptera |
| 10 | | Short horned Grasshopper | *Xenocatantops humilis* | Acrididae | Orthoptera |
| 11 | | Stick insect | unidentified | Diapheromeridae | Phasmatodea |
| 12 | Sap Feeder | Black froghopper | *Callitettix versicolor* | Cercopidae | Hemiptera |
| 13 | | Brown marmorated stink bug | *Halyomorpha halys* | Pentatomidae | Hemiptera |
| 14 | | Giant leaf footed bug | unidentified | Coreidae | Hemiptera |
| 15 | | Green stink Bug | *Chinavia hilaris*. | Pentatomidae | Hemiptera |
| 16 | Bark Feeder | Longhorn beetle | *Derobrachus sp.* | Cerambycidae | Coleoptera |

On the other hand, the survey identified six arthropod natural enemies, representing a range of predatory and parasitoid taxa crucial for biological control within the ecosystem. This guild comprised species from four insect orders and exemplified two primary modes of entomophagy: predation and parasitism (Table 4).

**Table 4**. Different species of natural enemies recorded by light traps within the multi-species forest plantation in Ngamin Reserved Forest.

| No. | Type of nature | Common Name | Scientific Name | Family | Order |
|---|---|---|---|---|---|
| 1 | Predator | Net-winged beetle | unidentified | Lycidae | Coleoptera |
| 2 | | Yellow-spotted Ground Beetle | *Craspedophorus* sp. | Carabidae | Coleoptera |
| 3 | | Mantid | *Tenodera sinensis* | Mantidae | *Mantodea* |
| 4 | | Assassin Bug | *Peirates* sp. | Reduviidae | Hemiptera |
| 5 | | Dragon fly | unidentified | Libellulidae | Odonata |
| 6 | Parasite | Wasp | *Bracon* sp. | Braconidae | Hymenoptera |

The natural enemy complex was dominated by Coleoptera (beetles; 2 species), with single representatives from Mantodea (mantids), Hemiptera (true bugs), Hymenoptera (wasps), and Odonata (dragonflies). The collected specimens are categorized into distinct functional groups: (1) Predators and (2) Parasitoids. Predators were the most prevalent group, including the mantid (*Tenodera sinensis*), assassin bug (*Peirates* sp.), ground beetle (*Craspedophorus* sp.), and dragonfly. These species are free-living hunters that actively consume a wide range of prey, providing broad-spectrum suppression of pest populations. The braconid wasp (*Bracon* sp.) represents a parasitoid group. Female wasps lay eggs on or within host insects, and the developing wasp larvae consume the host, providing effective control of specific pest species.

**4.4 Insect net survey**

The application of sweep-netting methodology facilitated the inventory of diurnal and low-canopy arthropods, resulting in the collection of nine pest species and two natural enemy species (Tables 5 and 6, respectively). Sweep-netting surveys within the understory vegetation of the study area documented a pest assemblage of nine herbivorous insect species, representing three major orders. The collected pests were predominantly from the order Orthoptera (grasshoppers and katydids), which constituted the most diverse group with four species, all within the family Acrididae (short-horned grasshoppers) and Tettigoniidae (katydids). This was followed by Hemiptera (true bugs) with two species, and single representatives from Coleoptera (beetles) and Lepidoptera (butterflies).

**Table 5**. Different species of pests recorded by the insect net within the multi-species forest plantation in Ngamin Reserved Forest.

| No. | Pest category | Common Name | Scientific Name | Family | Order |
|---|---|---|---|---|---|
| 1 | Leaf Feeder | Shorthorned grasshopper | *Xenocatantops humilis* | Acrididae | Orthoptera |
| 2 | | Pumpkin beetle | *Aulacophora* sp. | Chrysomelidae | Coleoptera |
| 3 | | katydids or bush crickets | *Ducetia antiopda* | Tettigonidae | Orthoptera |
| 4 | | Shorthorned grasshopper | *Pseudochorthippus* sp. | Acrididae | Orthoptera |
| 5 | | Shorthorned grasshopper | unidentified | Acrididae | Orthoptera |
| 6 | | lemon emigrant butterfly | *Catopsilia crocale* | Pieridae | Lepidoptera |
| 7 | | katydids or bush crickets | *Ducetia* sp. | Tettigoniidae | Orthoptera |
| 8 | Sap Feeder | Black froghopper | *Callitettix versicolor* | Cercopidae | Hemiptera |
| 9 | | Rice ear bug | *Leptocorisa* sp. | Alydidae | Hemiptera |

In contrast, sweep-netting collections yielded two distinct and ecologically significant natural enemy species, representing two major arthropod groups. The natural enemies comprised one species from the order Hymenoptera (a parasitoid wasp) and one from the order Araneae (an orb-weaving spider).

**Table 6**. Different species of natural enemies recorded by the insect net within the multi-species forest plantation in Ngamin Reserved Forest.

| No. | Type of nature | Common Name | Scientific Name | Family | Order |
|---|---|---|---|---|---|
| 1 | Parasite | Wasp | *Bracon* sp. | Braconidae | Hymenoptera |
| 2 | Predator | Decorative silver orb spider | *Leucauge decorata* | Tetragnathidae | Araneae |

### 4.5 Summary and Synthesis of Results

Surveys within the multi-species forest plantation in Ngamin Reserved Forest yielded a total of 23 pest species and 8 natural enemy species, as summarized in Tables 7 and 8, respectively. Of these species identified, the majority (15 species, 65 %) were classified as foliage feeders, representing the most prevalent pest category. Sap feeders constituted the next largest group (5 species, 22 %), followed by wood borers and bark feeders (3 species, 13.0%), as shown in Figure 3. Moreover, the pie chart (Figure 2) illustrates the relative abundance of six different insect orders, showing what percentage each order contributes to the total population being studied. The order Orthoptera is the most dominant group, making up more than a third of the sample.

**Table 7**. Total number of different species of pests recorded within the multi-species forest plantation in Ngamin Reserved Forest.

| No. | Pest category | Common Name | Scientific Name | Family | Order |
|---|---|---|---|---|---|
| 1 | Leaf Feeder | Angle winged katydid | *Microcentrum* sp. | Tettigoniidae | Orthoptera |
| 2 | | Curve-tailed Bush Katydid | *Scudderia curvicauda* | Tettigoniidae | Orthoptera |
| 3 | | Katydids or bush cricket | *Ducetia* sp. | Tettigoniidae | Orthoptera |
| 4 | | Katydids or bush cricket | *Ducetia antiopda* | Tettigonidae | Orthoptera |
| 5 | | Rufous - legged Grasshopper | *Xenocatantops* sp. | Acrididae | Orthoptera |
| 6 | | Short horned grasshopper | unidentified | Acrididae | Orthoptera |
| 7 | | Short horned Grasshopper | *Xenocatantops humilis* | Acrididae | Orthoptera |
| 8 | | Short horned grasshopper | unidentified | Acrididae | Orthoptera |
| 9 | | Large pine weevil | *Hylobius* sp. | Curculionidae | Coleoptera |
| 10 | | May beetle | *Phyllophaga* sp. | Melolonthinae | Coleoptera |
| 11 | | Pumpkin beetle | *Aulacophora* sp. | Chrysomelidae | Coleoptera |
| 12 | | Scarab beetle | *Diplotaxis* sp. | Scarabidae | Coleoptera |
| 13 | | lemon emigrant butterfly | *Catopsilia crocale* | Pieridae | Lepidoptera |
| 14 | | Common grass yellow butterfly | *Eurema hecabe* | Pieridae | Lepidoptera |
| 15 | | Stick insect | unidentified | Diapheromeridae | Phasmatodea |

| No. | Pest category | Common Name | Scientific Name | Family | Order |
|---|---|---|---|---|---|
| 16 | Sap Feeder | Black froghopper | *Callitettix versicolor* | Cercopidae | Hemiptera |
| 17 | | Brown marmorated stink bug | *Halyomorpha halys* | Pentatomidae | Hemiptera |
| 18 | | Green stink Bug | *Chinavia hilaris* | Pentatomidae | Hemiptera |
| 19 | | Giant leaf footed bug | unidentified | Coreidae | Hemiptera |
| 20 | | Rice ear bug | *Leptocorisa* sp. | Alydidae | Hemiptera |
| 21 | Bark feeder | Termite | unidentified | Rhinotermitidae | Isoptera |
| 22 | | Longhorn beetle | *Derobrachus* sp. | Cerambycidae | Coleoptera |
| 23 | Stem borer | Ambrosia Beetles | *Platypus* sp. | Platypodinae | Coleoptera |

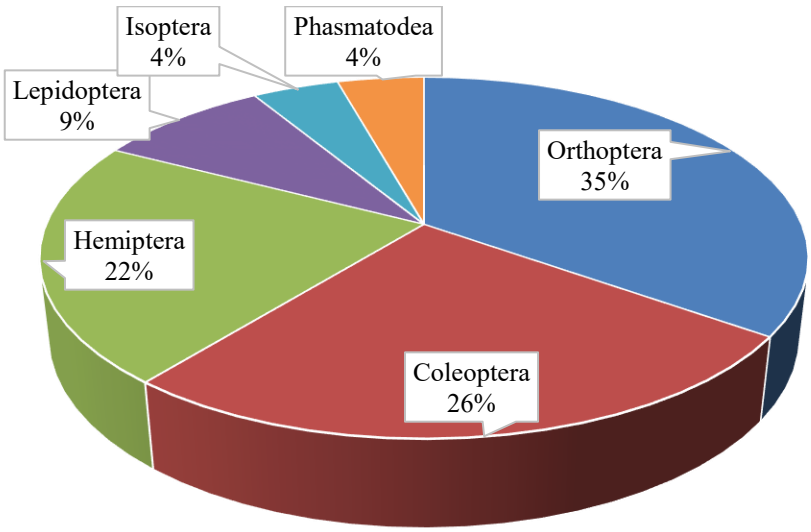


**Figure 2**. Percentage of different orders of insect pests infesting multi-species forest plantation in Ngamin Reserved Forest.

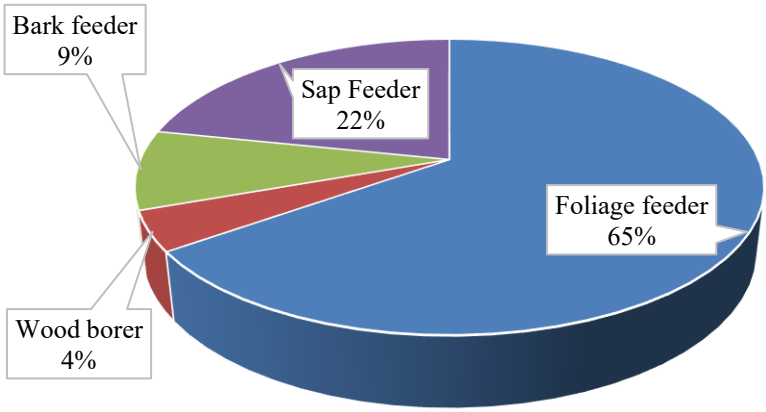


**Figure 3**. Percentage of different categories of insect pests infesting multi-species forest plantation in Ngamin Reserved Forest.

The order Orthoptera was the most diverse, with eight species of foliage-feeding katydids (Tettigoniidae) and grasshoppers (Acrididae). This was followed by Coleoptera, represented by six species across various families, including foliage-feeding weevils (Curculionidae), scarabs (Scarabaeidae), and chrysomelids (Chrysomelidae), as well as the wood-boring ambrosia beetle (Platypodinae). The order Hemiptera was represented by five sap-feeding species, including stink bugs (Pentatomidae), a froghopper (Cercopidae), and a rice ear bug (Alydidae). Lepidoptera included two foliage-feeding pierid butterflies, while Isoptera and Phasmatodea were each represented by a single species. In summary, the results indicate a community dominated by herbivorous insects, with foliage feeders being the most common functional guild, followed by sap feeders and wood borers.

A systematic survey of the local arthropod fauna revealed a community dominated by predatory species, as detailed in Table 8. The inventory cataloged eight distinct specimens, encompassing a range of orders including Coleoptera, Hymenoptera, and Araneae, etc. (Figure 4). Notably, seven of the eight species identified—including ants, beetles, a mantid, an assassin bug, a dragonfly, and a spider—were classified as predators, underscoring their critical role in trophic regulation and natural pest control within the ecosystem. A single parasitic wasp (Bracon sp.) was also recorded, highlighting the diversity of ecological functions present. The prevalence of these natural enemies suggests a robust and dynamic food web at the study site.

**Table 8**. Total number of different natural enemies recorded within multi-species forest plantation in Ngamin Reserved Forest.

| No. | Type of nature | Common Name | Scientific Name | Family | Order |
|---|---|---|---|---|---|
| 1 | Predator | Ant | unidentified | Formicidae | Hymenoptera |
| 2 | | Net-winged beetle | unidentified | Lycidae | Coleoptera |
| 3 | | Yellow-spotted Ground Beetle | *Craspedophorus* sp. | Carabidae | Coleoptera |
| 4 | | Mantid | *Tenodera sinensis* | Mantidae | Mantodea |
| 5 | | Assassin Bug | *Peirates* sp. | Reduviidae | Hemiptera |
| 6 | | Dragon fly | unidentified | Libellulidae | Odonata |
| 7 | | Decorative silver orb spider | *Leucauge decorate* | Tetragnathidae | Araneae |
| 8 | Parasite | Wasp | *Bracon* sp. | Braconidae | Hymenoptera |

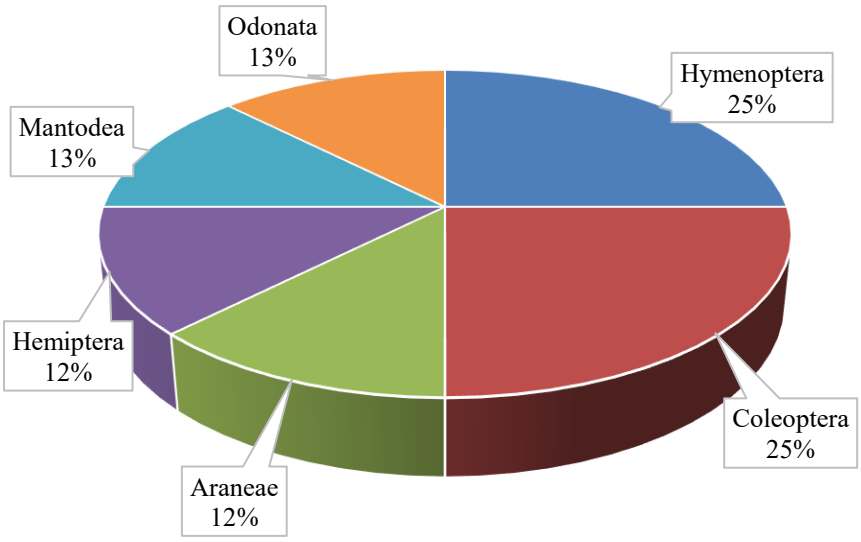


**Figure 4**. Percentage of different natural enemies attacking pests of multi-species forest plantation in Ngamin Reserved Forest.

## 5. Discussion

### 5.1 Identified pests in the multi-species plantation

The insect pest survey conducted in the multi-species plantation at Nga Minn Reserved Forest revealed a diverse community of 23 species, providing a critical baseline for understanding the ecosystem's biotic pressures. The assemblage was dominated by foliage-feeding Orthoptera (35%), followed by Coleoptera (26%) and Hemiptera (22%). When classified by feeding guild, the complex was primarily composed of foliage feeders (65%) and sap feeders (22%). The high prevalence of foliage feeders, particularly orthopterans like grasshoppers and locusts (Acrididae), is indicative of a resident pest community adapted to a broad range of host plants, which is a characteristic feature of mixed-species environments (Jactel & Brockerhoff, 2007).

The dominance of orthopterans is of significant ecological and economic concern. Locusts and grasshoppers are voracious, polyphagous pests capable of inflicting severe defoliation across various ecosystems, including forestry plantations (Lomer et al., 2001; Usmani & Usmani, 2018). Their capacity for rapid population growth allows them to reach destructive outbreak levels quickly, with nymphs capable of causing substantial biomass loss in short periods (Peng et al., 2020; Qayyum et al., 2024). In young or newly established forest stands, such as this plantation, this feeding directly reduces photosynthetic capacity, impedes tree growth, and can threaten silvicultural investments and regeneration success (Smith & Jones, 2010).

Beyond orthopterans, the significant presence of Coleoptera (26%) includes two particularly damaging groups. The first is leaf beetles (Chrysomelidae), which are destructive folivores in both larval and adult stages. Their feeding damage—ranging from shot-hole perforation to complete skeletonization of leaves—severely compromises plant health and can stunt the growth of young trees (Wang & Lee, 2018). The second, and potentially more insidious, group are ambrosia beetles (Curculionidae: Scolytinae and Platypodinae). These pests represent a distinct mechanical and biological threat; by boring into the xylem to create galleries, they introduce symbiotic ambrosia fungi. The subsequent fungal colonization can clog vascular tissues, leading to wilting, tree decline, or mortality (Eskalen et al., 2013). A key concern is that many ambrosia beetles are known to attack apparently healthy trees in addition to stressed individuals, posing a continuous risk to plantation health (Hulcr & Stelinski, 2017).

### 5.2 Corresponding Natural Enemies and Biocontrol Potential

The recorded assemblage of eight natural enemy species, predominantly from the Orders Hymenoptera and Coleoptera, is a positive indicator of the plantation's ecological integrity and its capacity for top-down pest regulation. The presence of generalist predators such as carabid ground beetles (Carabidae) and mantids is particularly significant. Carabids are well-documented as key regulators of soil-dwelling pests and insect eggs in agroforestry systems (Lövei & Sunderland, 1996), while mantids are formidable generalist predators capable of suppressing populations of various foliage-feeding insects (Prete et al., 1999).

The identification of a parasitoid wasp from the family Braconidae holds considerable importance for biological control potential. This group is renowned for its role in suppressing numerous Lepidopteran and Coleopteran pests through larval parasitism (Shaw & Huddleston, 1991). Although the inability to identify the dragonfly to species level highlights a common taxonomic challenge in rapid biodiversity assessments, it does not diminish its ecological role as a major aerial predator of dipteran and homopteran pests (Corbet, 1999).

### 5.3 Plant Damage, Mixture, and Associational Resistance

Although plant damage caused by borers, particularly ambrosia beetle, was observed only on a few trees during the study period, regular monitoring and targeted control measures will help ensure the long-term sustainability of the plantation.

Kaitaniemi et al. (2007) found that mixing Scots pine (Pinus sylvestris) with 50% silver birch (*Betula pendula*) shows associational resistance against sawfly *Neodiprion sertifer*. Jactel et al. (2021) indicated that mixtures experienced reduced damage from specialist herbivore insects, especially when trees of distant relatives are mixed-planted.

*Gmelina arborea* was interplanted with *Checkrasia tabularis* and *Leucaena Leucocephlar*, at 4 ft x 4 ft spacing and planted in blocks with 12 other species as silvicultural controls against *Tingis beesoni*. Aung Zeya (1983) reported that *Gmelina arborea* survival was only achieved in plots interplanted with *Leucaena Leucocephlar and* the other two mixed plantings resulted in complete failure due to insect attacks, while chemical controls (application of insecticide mixture at first detection and before complete defoliation) also achieved survival of *Gmelina arborea.*

Therefore, differing results of resistance to pest damage for a focal species may often be obtained through mixed plantings. Jactel et al. (2021) suggested that tree species having functionally different characteristics should be chosen in a mixed plantation to increase associational resistance.

The number of insect groups attacking the teak trees of the studied mixed plantation was lower than in the pure teak plantation in Ngaliak Reserved Forest, adjacent to milepost 13/6 on Naypyitaw-Magwe Road, where our survey from June 2025 to November 2025 revealed higher foliage damage and symptoms of sap-sucking Tingids insects, which were not observed in teak trees within the study plantation. The lower level of insect herbivory observed in this study is consistent with a meta-analysis of over 624 study cases by Jactel et al. (2021), which indicated that, on average, insect herbivory damage is reduced in mixtures than in pure plantations.

The absence of pest outbreaks suggests that the mixture may enhance associational resistance against pest epidemics. This aligns with the previous studies, where increased plant diversity can create barriers to pest movement and provide superior habitat for natural enemies, thereby supporting biological control (Jactel & Brockerhoff, 2007). To bolster this inherent resistance, we recommend integrating light traps for managing adult foliar pests and targeted interventions for borers, especially ambrosia beetle, and actively conserving the prevalent

biocontrol agents (e.g., Reduviidae, Carabidae, spiders, and mantids), which are cornerstone species for sustainable pest regulation (Gurr et al., 2017).

## 6. Conclusion

The very low level of plant damage caused by insect pests and the absence of pest outbreaks during the study period could indicate that the multi-species composition enhances the ecosystem's resilience to pest epidemics. Therefore, the promotion of multi-species plantations can serve as a sustainable and effective strategy for pest management in forestry. Regular monitoring and assessments of multiple benefits provided by this mixed plantation, such as insect pest regulation, biodiversity conservation, growth and economic potential, and carbon sequestration, etc., will provide valuable information for future plantation development programs.

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**Appendix 1. Tree Species Involved in the Multi-Species Plantation, Ngamin Reserved Forest, Taungdwingyi Township**

| No. | Myanmar Name | Common Name | Scientific Name |
|---|---|---|---|
| 1 | ကျွန်း | Teak | *Tectona grandis* |
| 2 | မြန်မာပိတောက် | Myanmar Rosewood | *Pterocarpus macrocarpus* |
| 3 | ပျဉ်းကတိုး | Myanmar Ironwood | *Xylia xylocarpa* |
| 4 | အင်ကြင်း | Dark Red Merant, Light Red Merant | *Shorea siamensis* |
| 5 | ရွေးကြီး | Red Bead Tree | *Adenanthera pavonine* |
| 6 | သင်းဝင် | Khacho, Sortom | *Millettia pendula* |
| 7 | ယင်းမာ | Chickrassy | *Chukrasia velutina* |
| 8 | မြန်မာကုက္ကိုလ် | Lebbeck, Frywood | *Albizia lebbeck* |
| 9 | သစ်မကျည်း | Black Siris, Fragrant Albizia | *Albizia odoratissima* |
| 10 | လျှော်ဖြူ | - | *Sterculia versicolor* |
| 11 | ပျဉ်းမ | Pride Of India, Queen Crape Myrtle | *Lagerstroemia speciosa* |
| 12 | ဘင်္ဂ် | - | *Mitragyan rotundifolia* |
| 13 | တမာ | Neem Tree | *Azadirachta indica* |
| 14 | ဥရွေဝါ | Indian Laburnum | *Cassia fistula* |
| 15 | မလွ | Katsagon | *Markhamia stipulata* |
| 16 | ဇီးဖြူ | Goose Berry | *Phyllanthus emblica* |
| 17 | မယ်ဇလီ | Siamese Cassia | *Senna siamea* |
| 18 | လိန် | Indian Laurel | *Terminalia pyrifolia* |
| 19 | ကံ့ကော် | Indian Rose Chestnut | *Mesua ferrea* |
| 20 | ခရေ | Spanish Cherry | *Mimusops elengi* |
| 21 | စိန်ပန်းကြီး | Flamboyant, Royal Pionciana | *Belonix regia* |
| 22 | သပြေကြီး | Sea Apple | *Syzygium grande* |
| 23 | ဆီသပြေ | Paradise-Tree, Bitterwood | *Simarouba glauca* |
| 24 | အုန်းနှဲ | Toothbrush Tree, Sand Paper Tree | *Streblus asper* |
| 25 | နကျယ် | - | *Pterospermum semisagittatum* |
| 26 | မယ်ဓယ် | Mabua Butter Tree | *Madhuca longifolia* |
| 27 | မြန်မာရှား | Cutch Tree | *Acacai catechu* |
| 28 | လက်ပံ | Red Silk Cotton Tree | *Bambax ceiba* |
| 29 | ဖျောက်ဆိပ် | Indian Elm | *Holoptelea integrifolia* |
| 30 | နဘဲ | Indian Ash Tree | *Lannea coromandelica* |

**Appendix 2. Recorded photos of insect observations in the field**

(a)

(b)

(c)

(d)

(e)

Figure denotes (a) visual observation, (b) light trap, (c) yellow sticky trap, and (d) sweeping insect net

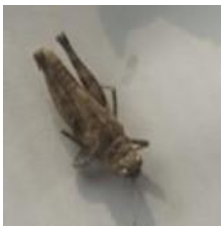
## Appendix 3. Recorded photos of insect pests


Angle winged katydid
*Microcentrum* sp.


Curve-tailed Bush Katydid
*Scudderia curvicauda*

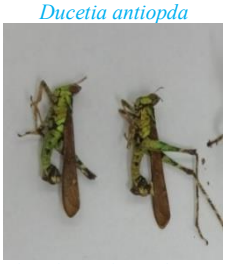

Katydid
*Ducetia* sp

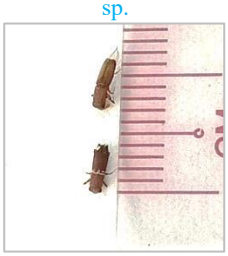

Katydid
*Ducetia antiopda*


Rufous - legged Grasshopper *Xenocatantops* sp.


Short horned grasshopper
*X. humilis*


Short horned grasshopper unidentified

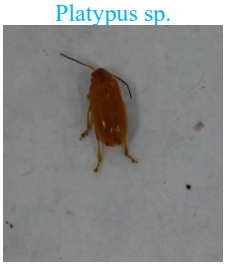

Short horned grasshopper unidentified


Ambrosia beetle
Platypus sp.


Large pine weevil
*Hylobius* sp.


Longhorn beetle
*Derobrachus* sp.


May Beetle
*Phyllophaga* sp.


Pumpkin beetle
*Aulacophora* sp.


Scarab beetle
*Diplotaxis* sp.


Black froghoppers
*Callitettix versicolor*


Brown marmorated stink bug
*Halyomorpha halys*


Green stink Bug
*Chinavia hilaris*

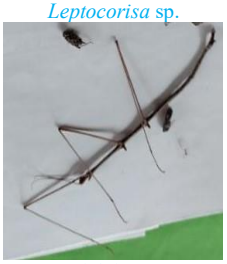

leaf footed bug
unidentified


Rice ear bug
*Leptocorisa* sp.


lemon emigrant butterfly
*Catopsilia crocale*


Common grass yellow butterfly
*Eurema hecabe*

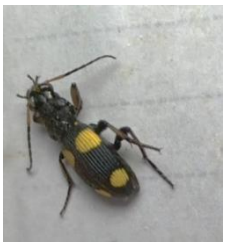

Termite
unidentified


Stick insect
unidentified

## Appendix 4. Recorded photos of beneficial insects and natural enemy of insect pests

Ant
Unidentified

Net-winged beetle
Unidentified



Yellow-spotted ground beetle
*Craspedophorus* sp.

Mantid
*Tenodera sinensis*

Assassin bug
*Peirates* sp.

Wasp
*Bracon* sp.

Dragon fly
Unidentified

Decorative silver orb spider
*Leucauge decorata*