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Analysis of Insect Communities in *Gmelina arborea* Plantation of Different Stand Ages in Cibugel, West Java

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Abstract: Community timber plantation has an essential role as a source for the wood industry. One of the community timber plantations is located in Cibugel, Sumedang Regency, West Java. Lots of *Gmelina arborea* are planted in this community timber plantation because it does not need specific care and have a short cutting time. However, planting Gmelina in a community timber plantation leads to insect attacks on trees from different age groups, which could decrease wood production. Sustainable insect pest control efforts can be carried out by first understanding the structure of insect communities at different plant ages. Therefore, a study was conducted to compare the diversity of insect communities in plant age groups of 2, 4, and 15 years using the pitfall trap and sticky trap methods, supported by the hand searching method and microclimate data collection. In addition, plant damage caused by insects was also determined by analyzing the absolute and relative damage intensity. The results show that the dominant insect community in Gmelina age groups 2 and 15 years is Formicidae, which are generally classified as predators. Meanwhile, in the 4-year age group, the insect community was dominated by insects classified as herbivores, pests of *G. arborea* plants. These results align with the highest level of plant damage, namely in the 4-year age group.

Keywords: Feeding guild analysis, forest stand age, *Gmelina arborea* plantation, insect community structure.

Introduction

Community forest can be defined as land outside the state forest area that is overgrown with trees in such a way that it is a living community of biological nature and the environment and the land is owned by the people (Department of Forestry and Plantations, 1999). Community forests in Indonesia are essential because they contribute to the timber supply needed for the timber industry. The average contribution of community forests per year is 16-20 million m3 (Department of Agriculture and Forestry, 2014).

West Java is an area with considerable potential in community forest development efforts. Based on data obtained from BPS, log production by province shows that West Java produced 1,649,986.14 m^3 in 2021, 1,574,008.94 m^3 in 2022, and 1,319,829.13 m^3 in 2023. One of the timber production areas in West Java is the Cibugel community forest, Sumedang district. The production of community forest products in Sumedang Regency in 2023 was recorded at 6,200 m^3. The widely planted trees are teak, mahogany, and pine (BPS Sumedang Regency, 2023). Sengon, suren, mangli, and white teak are other options planted in the Cibugel community forest. Although not native to Indonesia, white teak (*G. arborea*) is a favorite in the community forest.

Gmelina arborea is adaptable to a wide range of forest habitats, including semi-evergreen tropical forests, moist teak forests, deciduous forests, and dry teak forests. It can grow at altitudes ranging from sea level to 1,200 meters, with an annual rainfall range of 750–4,500 mm (Agroforestry Database, 2009). Native to Bangladesh, *G. arborea* is known for its fast growth, with a rotation period of 7–10 years, and can thrive without intensive care (Roshetko et al., 2004). However, without proper management, the harvesting period may be more extended than under silvicultural systems, where rotation can be reduced to 4–6 years with optimal results (Tewari, 1995).

The biodiversity of the Cibugel community forest can affect plant growth and production, namely nutrient circulation, microclimate changes, and detoxification of chemical compounds (Altieri, 1999). Insects, as one component of biodiversity, have an essential role in the food web, namely as herbivores, carnivores, and detritivores (Strong et al., 1984). Herbivorous insects are the leading cause of yield loss, either by eating the plants directly or as vectors of pathogens (Kirk-Spriggs, 1990). In addition, insect diversity has another function, namely as a bioindicator.

This type of insect has begun to be widely studied because it is useful for understanding the condition of an ecosystem. Some insects that have the potential to be bioindicators include Lepidoptera as indicators of habitat change (Holloway & Stork, 1991), Carbidae beetles as bioindicators of agricultural land management (Kromp, 1990), and ant species as indicators of the presence of predators in an agroecosystem (Peck et al., 1998). In natural habitats such as forests, damage from herbivorous insects is rare. This is because the number of carnivorous insects in natural forest habitats is greater and the diversity of insect species is much higher and more complex than in community forests (Janzen, 1987).

According to local reports from the Cibugel subdistrict office, the diversity of tree species in community forests has occasionally attracted insect outbreaks across different tree age groups, leading to decreased timber productivity. Therefore, this study was conducted to compare the diversity of insect communities among plantation stands of 2, 4, and 15 years of age, and to determine the damage caused by herbivorous insects by analyzing the intensity of absolute and relative damage. This study is the first step in finding sustainable insect pest management efforts by maintaining the balance of the *Gmelina arborea* agroecosystem.

Material and Method

Research area description

This research was conducted in the community forest area of Cibugel Village, Cibugel District, Sumedang, West Java. Cibugel District has an area of 48.86 km2. Geographically, Cibugel District is located in the southeast of the capital city of Sumedang Regency (BPS Sumedang Regency, 2023a). Cibugel District consists of 7 villages, one of which is Cibugel Village. Cibugel Village borders Tamansari Village to the north, Sukaraja Village and Jayamandiri Village to the east, Buanamekar Village to the south and Jayamekar Village to the west. Cibugel Village is located at an altitude of 921 meters above sea level and has an area of 4.5 km2 (BPS Sumedang Regency, 2023b). The imagery of the Cibugel Village community forest is shown in Figure 1.

Figure 1. Imagery of Cibugel Village community forest and environmental tone in three sites (Google Earth, 2024)

Data Collection

Insect sampling was conducted in three areas with different ages of white teak trees, namely trees aged 2, 4, and 15 years. The sampling area was a 40m x 20m plot, with 8 subplots measuring 10m x 10m. The data collection method was carried out actively and passively. The active method used was the Hand Searching method with several modifications. The Hand Searching method was carried out in two ways, namely looking up and looking down. Hand searching and looking up was carried out by collecting and recording the number of insects encountered along the 40m x 20m path shown in Figure 2, with a search height above the knee. While the hand searching looking down method was carried out by collecting and recording insects encountered at a height below the knee (The Province of British Columbia, 1998). This method was carried out by two people, each standing at the starting point (orange circle in Figure 2), then each observer walked in the direction of the red and blue arrows for 1 hour. The modifications made to this method are by not using an aspirator, and there is a waiting time of 5 minutes at every 10-meter distance.

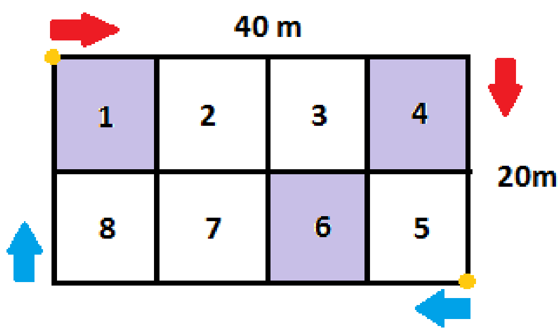


Figure 2. Hand collecting method and pitfall trap device installation (The Province of British Columbia, 1998)

Passive methods include pitfall traps and sticky traps. Soil insect sampling was conducted using the pitfall trap method. In each age group, pitfall trap devices were installed in three different subplots that were determined semi-randomly. Determination of the sampling site was carried out by sorting the subplots measuring 10m x 10m from 1 to 8. Furthermore, three random numbers were determined by drawing lots. The three subplots used in this study are subplots 1, 4, and 6. The scheme of the sampling area is shown in Figure 2. In each 10 x 10 meter subplot sampling area, five traps were installed systematically with a distance of 1 meter between each trap. The traps were filled with detergent dissolved in water, which acts as a killing agent (Gibbs & Oseto, 2006). Traps were set at 09.00 am and allowed to stand for 24 hours (Uetz, 1976). Next, preservation was carried out with the addition of 70% alcohol. Insect samples were then identified in the laboratory.

In addition to soil insects, flying insects were also sampled using sticky traps. Sticky traps are traps in the form of brightly colored boards treated with adhesive liquid (Gibbs & Oseto, 2006). The colors commonly used are yellow, white, and red, which are attractive to insects that consider the color resembles a flower (Shipman, 2011). In this study, sticky traps were made using yellow and white infraboard measuring 7.5 x 12cm, each of which was installed on one white teak tree at each different age. The trap was placed on the tree trunk and kept for 24 hours. Captured insects were then preserved with alcohol and identified in the laboratory.

The following method is to visually observe the intensity of damage against the absolute and relative intensity of damage. The absolute intensity of damage is calculated by determining the absolute number of individuals attacked by pests, namely at the growing point. The relative damage intensity was calculated by determining the percentage of damage per plant based on the level of leaf damage shown in Table 1. Both observations were carried out on the same three subplots using the pitfall trap method. (Unterstenhofer 1963 in Surachman et al., 2011).

Table 1. The percentage of damage intensity

Damage intensity	Percentage of Leaves Damage	Damage Classification
Healthy plant	≤ 5%	0
Light damage	6% - 25%	1
Moderate damage	26% - 50%	2
Heavy damage	51% - 75%	3
Hefty damage	≥ 75%	4

In addition to insect data collection, microclimatic and edaphic measurements were taken. Microclimate data on air temperature and humidity were measured using a sling psychrometer. Light intensity and air temperature were measured using a data logger.

Data processing

This study analyzes insect data, including abundance, species richness, Shanon diversity index, evenness, dominance, and Sorensen similarity index. Diversity, evenness, and dominance parameters were calculated using the following formulas.

Shannon-Wiener Biodiversity Index

$$H' = -\Sigma pi \ln pi \quad (1)$$

$$Evennerss\ (E) = \frac{H'}{\ln(s)} \quad (2)$$

$$Dominance\ (D) = \Sigma pi^2 \quad (3)$$

$$Sorensen\ index\ (Is) = \frac{2C}{(A+B)}\ x\ 100\% \quad (4)$$

Analysis of absolute and relative leaf damage intensity was calculated using the following formula (Unterstenhofer 1963 in Surachman et al., 2011).

$$Absolute\ damage\ index = \frac{a}{(a+b)}\ x\ 100\% \quad (5)$$

$$Relative\ damage\ index = \frac{\Sigma(n\ x\ v)}{Z\ x\ N}\ x\ 100\% \quad (6)$$

Note:
s = species richness
a = number of damaged sample plants (absolute)
b = Number of undamaged sample plants
n = number of affected plants with certain damage classification
v = damage classification value
z = highest damage classification value
N = total number of tree samples observed

Result and Discussion

Pitfall trap

Pitfall traps are one method that can be used to inventory soil insects. Overall, 19 insect species were found belonging to 11 families. Formicidae generally dominated the catches with a total of 95, followed by Tenthredinidae with 17 and Tettigoniidae with 7 catches. Formicidae, the dominant family, generally act as predators and detritivores in the ecosystem. The Formicidae family has an ecological role in controlling pests, maintaining soil aeration, and seed dispersal (Susilawati & Indriati, 2020; Peng, 2009). On the other hand, Tenthredinidae, the second largest insect family, are insects that are generally herbivores. Several Tenthredinidae species are pests of *Gmelina arborea* plants (Wingfield & Robinson, 2004). Comparison of insect composition based on feeding guilds at different plant ages is shown in Figure 3.

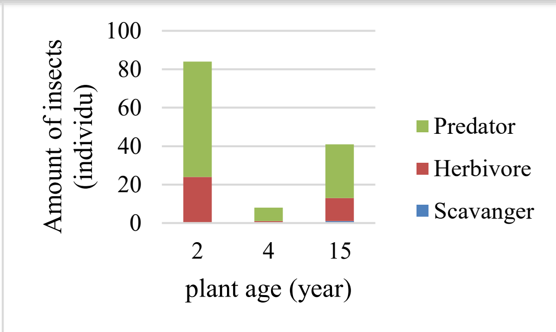


Figure 3. Insect abundance based on feeding guilds in *G. arborea* plants aged 2, 4, and 15 years

Insect catches from pitfall traps indicate that insect abundance is highest in 2-year-old tree stands (site 1) and lowest in 4-year-old stands (site 2). Despite having the highest insect abundance, site 1 is dominated by predators. This indicates a healthy agroecosystem. The Shannon-Wiener diversity index value is 2.254. This value indicates that the diversity of soil insect species is in a moderate transition (Molles, 2008). The evenness of species in the three sites is relatively high because the evenness index (E) is close to 1 (Mulder, 2004). Based on environmental baseline observations, this indicates that the evenness of species in each site generally tends to be the same; no site was found to have a very different structural composition compared to the other sites. This is supported by the Sorensen similarity index value of 22%. This means that the variation of insect species found in the three sites tends to be the same.

Sticky trap

Based on the results of the study using the sticky trap method, the highest Species Richness was obtained at site 1, which was 13 species. At site 2, the species richness obtained was 8 species, and the lowest was at site 3, which was 5 species. Insect traps with sticky traps aim to describe the structure of the flying insect community, and the abundance of these insects is closely related to the canopy cover at the site. The canopy area at site 1 tends to be closed, while sites 2 and 3 have a more open canopy (Magurran, 1988). In addition, the density at site 1 is higher, which makes the canopy at site 1 more closed. The closed canopy causes light penetration to be unable to enter, lowering the temperature. This is in line with the temperature and light intensity data at site 1, which are relatively low compared to other sites (Marra, 2005).

The highest abundance of individuals was also found at site 1, at 41 individuals. Meanwhile, the abundance at site 2 was 16 individuals, and at site 3 was 31. This is also related to the closed canopy condition of site 1, which makes site 1 a suitable habitat for insects (Marra, 2005). Evenness on the three sites is relatively high because the evenness index value is close to 1 (Mulder, 2004). The evenness index on site 1 has the lowest evenness index, namely 0.781. The evenness index at site 3 is 0.814, and the highest is at site 2 at 0.82467. Each species in site 1 has several individuals that tend to be the same, but two species have a considerable number of individuals compared to the other species. On site 1, the most commonly found insects were Culicidae and Formicidae. The presence of these insects, especially Formicidae, can control the abundance of other insects. This is because Formicidae act as predators for other pests of Gmelina plants, such as insects from the Tingidae family. The presence of Formicidae, which causes many pests on site 1, was not obtained using the sticky trap method (Peng, 2009). Meanwhile, evenness in sites 2 and 3 is higher because the number of individuals in each species is not too different (Elzinga, 1978).

The diversity index value at site 1 has the highest diversity index of 2,004, which means that diversity at site 1 is moderate or relatively stable. Meanwhile, site 2 and site 3 have lower diversity index values than site 1, namely 1,715 and 1,311. This is because the species richness at site 1 is the highest. The higher the species richness of a place, the higher the index value. The Sorensen index on sites 1 and 2 is 28.57%, the Sorensen index on sites 1 and 3 is 44%, and the Sorensen index on sites 2 and 3 is 46.2%. This data found that the Sorensen index at site 2 and site 3 had the most outstanding value, but had not yet reached the value of 50%. The index value at sites 2 and 3 is 46.2%, which means close to 50%, indicating that sites 2 and 3 are almost similar communities because of the similar number of species found in both sites, and is supported by a similar environmental tone regarding the canopy.

The canopy on both sites tends to be open, which allows light to enter the site, making the microclimate conditions, such as temperature, on both sites tend to be similar, resulting in the insects found tending to have similarities (Elzinga, 1978). On sites 2 and 3, many insects such as Culicidae, Muscidae, and Acrididae were found. These insects generally need sunlight because it can help them identify flower colors, such as yellow or white so that they can obtain appropriate food sources based on the coloring of the light (Natawigena, 1990). The Sorensen index on sites 1 and 3 also has a relatively high value of 44%.

The sticky trap method is a method commonly used to see insect diversity. In this research, sticky traps were made with two color variants: white and yellow. This color was chosen because it is bright, so it attracts the attention of insects sensitive to light, such as Muscidae, Culicidae, and so on. Other insects that can be identified as pests, such as Cynipidae and Formicidae, which are predators of these pests, were also obtained. In this study, 88 individuals were obtained. This shows that this method is quite effective in identifying the presence of insects, especially flying insects that like bright colors, so using this method is appropriate (Bashir et al., 2014).

Hand Searching

The observations using the hand searching method on three sites with different land ages showed 127 insect individuals from nine orders, with the highest abundance found in Lepidoptera (44 individuals) and Orthoptera (42 individuals). These two orders reflect groups of herbivorous insects and pollinators that are generally very responsive to changes in vegetation composition and habitat structure (Triplehorn & Johnson, 2005). In two-year-old sites, Lepidoptera's dominance and Hymenoptera's presence indicate the availability of young host plants and increased ecosystem interactions such as pollination, parasitoid, and predator activity. This is in line with the findings of Campos et al. (2008), which state that the diversity of herbivorous insects and parasitoids can be used as an indicator of the productivity of a developing ecosystem. The composition of insects on the three sites based on hand searching results is shown in Figure 4.

The four-year-old site showed the highest abundance of Orthoptera, especially the leaf-eating herbivores that correlated positively with vegetation density and plant structure complexity (Samways, 1994). The presence of Odonata, Lepidoptera, and several other orders in relatively balanced numbers on this site indicates an agroecosystem in a semi-stable condition, where various insect feeding guilds—such as herbivores, pollinators, predators, and detritivores—can coexist. Such functional diversity contributes to increased ecosystem resilience and is an important indicator of a healthy agroecosystem (Altieri, 1999).

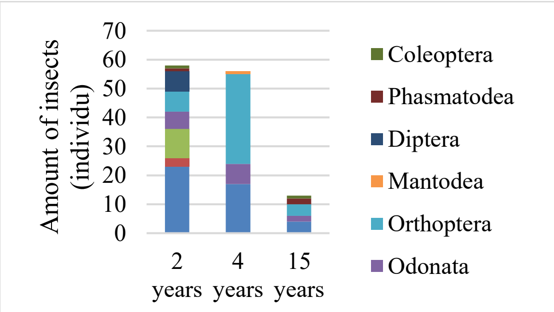


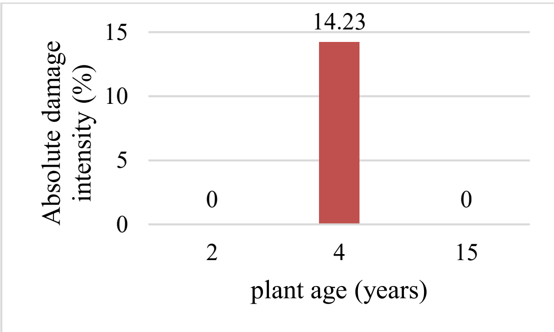
Figure 4. Insect composition based on the hand searching method at different plant ages

In contrast, on the fifteen-year-old site, the number of individuals decreased drastically to only 13, although several orders such as Lepidoptera, Orthoptera, and Phasmatodea were still found. This decline can be associated with the ecological succession process that causes vegetation cover to become denser, thereby reducing open habitats that are important for many types of insects (Begon et al., 2006). The presence of specialist orders such as Phasmatodea may indicate the presence of complex microhabitats, even if their abundance is low (Schowalter, 2016).

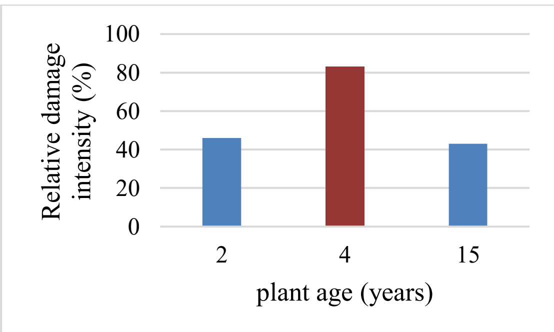
These data suggest that field age influences insect community structure, where young fields (2 years old) tend to have higher diversity and abundance. In contrast, older fields show a trend toward specialization. The existence of orders such as Hymenoptera (parasitoids), Odonata (predators), and Orthoptera (herbivores) also supports the role of insects as bioindicators, which have been widely recognized in the literature as markers of ecological conditions and agroecosystem health (Brown, 1997; Andersen, 1997). Thus, variations in insect composition can be used as a basis for evaluating the effectiveness of land management in the long term and as a reference in sustainable agricultural strategies.

Absolute and Relative Damage

The intensity of pest damage to *G. arborea* plants was calculated, and the absolute and relative percentage of damage was obtained (see Figure 5). Based on the graph in Figure 5, the three age groups of *G. arborea* have an absolute damage intensity (IKM) below 25%, which indicates a low pest attack intensity based on the categories made by the Directorate of Food Crop Protection. The highest absolute damage intensity is in the 4-year age group, while the lowest is in the 15-year age group. *G. arborea* in the 2-year and 15-year age groups have a relative damage intensity that can be categorized as a moderate attack intensity because the relative damage intensity (IKN) value is 25-50%. Meanwhile, *G. arborea* in the 4-year age group has the highest relative damage intensity and is categorized as a very severe attack intensity because it has an IKN value greater than 75%.



(a)



(b)

Figure 5. (a) Absolute damage percentage, and (b) relative damage to *G. arborea* plants in the 2, 4, and 15-year age groups

As seen in Figure 5, damage to *G. arborea* plants occurred more in the 4-year age group compared to other age groups. The high damage to *G. arborea* in the 4-year age group is supported by the small number of Formicidae found because this family acts as a biocontrol agent against *G. arborea* insect pests (Peng, 2009). Different planting systems can also cause different pest attack intensities. In the 4-year age group, *G. arborea* was planted as a monoculture, while the other two age groups were planted as silviculture. Plants cultivated as a monoculture are more susceptible to pest attacks. The increase in pest attacks is caused by the availability of food continuously, all the time, and in every place for the pest (Altieri & Nicholls, 1999). Thus, the condition of the monoculture forest becomes a habitat with abundant resources for pests so that the intensity of damage becomes higher.

The planting system must also consider the distance between plants because it can influence the intensity of pest attacks. According to Arif (2006), pest populations decrease proportionally to increasing planting distance. *G. arborea* in the 4-year-old age group had tighter distances between plants compared to the distance between plants in the 2-year and 15-year-old age groups. Therefore, the intensity of pest attacks is highest in the 4-year-old age group.

Damage to *G. arborea* plants can stunt tree height and diameter growth, ultimately reducing the volume of plant stands (Nair, 2001). Actions that can be taken to reduce damage due to pest attacks include utilizing natural enemies of insects and increasing plant diversity, such as implementing intercropping systems, crop rotation, or open field planting to increase ecosystem stability and reduce the risk of pest disturbances (Altieri & Nicholls, 1999).

Conclusion

Based on research conducted, the most dominant insect in *G. arborea* in the 2- and 15-year age groups is Formicidae, which have an ecological role as predators. In contrast, in the 4 age group, the insect community structure is dominated by herbivorous insects, generally pests on *ge* plants. These results align with the highest level of tree damage, namely in the 4-year-old group of *G. arborea*. The structural characteristics of the insect community and the composition of the feeding guilds within it provide an overview of the health condition of the agroecosystem, which can be the basis for efforts to manage insect pests sustainably by maintaining the presence of predators in it.

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