Flower and fruit development and flower-visiting insects of gmelina (Gmelina arborea roxb.)

A A Pramono, E Rustam, D Syamsuwida, K P Putri, D F Djam’an and E Pujiastuti

Forest Tree Seed Technology Research and Development Center, Jalan Pakuan Ciheuleut, Bogor, Indonesia 16001

E-mail: eva_yr@yahoo.co.id

Abstract. The purpose of the research was to identify flower development and fruit formation as well as identification of flower-visiting insects as potential pollinators. Observations carried out in three sample trees, and five flowering branches at each sample tree were marked. We also carried out the identification of flower-visiting insects, foraging behavior, visiting rate, number of visiting insects, and time of flower visit. The results showed that in one year, 2-3 reproductive cycles might occur, which one cycle lasted about 1-2 months. In a panicle of flowers, flower buds, flower bursts and fruitlets are found simultaneously. The panicle has 5-34 flower buds. The development of buds to panicle formation takes 5-7 days, while the time required for flower and fruit development from generative buds up to yellow fruit was in a range between 38 to 67 days or 1 to 2 months. The total reproductive success of sample trees was varying from 12% to 17%. The most dominant flowers-visiting insects and alleged as pollinators of G. arborea is a carpenter bee (Xylocopa latipes) that actively visiting flowers at 8:00 until 11:00 am. Insect visited about 5 to 20 flower panicles with an average of 11 flower panicles per minute.

1. Introduction

Gmelina arborea is a fast-growing deciduous tree species. Supported by proper soil conditions, trees at aged of three years old can produce timber of 5.8 m - 8.3 m in length with 10 cm - 15 cm in diameter and wood production of more than 30 m³ per year [1]. Generally, the wood is moderately durable and resistant to various termite attacks [2]. It is used for pulpwood, general carpentry, joinery, furniture components, and other household fixtures [1]. Gmelina has a good prospect for the plantation that the potential to be improved. The weaknesses of gmelina plantation are susceptible to diseases and pests [3] that can be solved and managed through persistent and integrated efforts [4].

The success of the reproduction process of a plant depends on its ability to complete the stages of development of reproductive organs, starting from the initiation of flower buds to mature fruit. Failure in one of the stages of this development can lead to seed lower productivity [5]. Studying flower morphology is essential, especially for understanding the structure of reproductive organs and the characteristic of its flower and fruit development. Each inflorescence and flower has its characteristics that closely related to pollination systems, include the characteristics of the flower color, flower position, whether upright or hanging, anthers and stigma position, stylus size, and flower odor. White flowers are usually favored by bees or moths [6]. According to [7], the flowers are found to bloom at
08.00 up to 11.00 am. [7] also found that bees and birds are regular flower visitors. They are found in flowers as soon as the sun rises, and their foraging activity lasts until sunset. The bee species of *Xylocopa latipes* only collects nectars. Meanwhile, *Amegilla* sp and *Apis cerana* collect nectar and pollen [7]. This research aim was to identify the biological processes of reproduction involving flower development and fruit formation as well as identification of flower-visiting insects as potential pollinators.

2. Methodology

2.1. Time and location

The study was conducted at the Experimental Garden of Nagrak, Bogor Regency in February until December 2015 to 14-year-old of *G. arborea* stand.

2.2. Procedure

The development of flowers and fruit were observed individually, on three sample trees and five branches of each tagged sample tree. Observations included the structure of flowers and fruit, as well as flowers and fruit development process starting from flower buds, flowers bloom, anthesis, young fruit, until ripe fruit. A stepladder was mounted in each sample tree to facilitate the observation.

Any changes in the structure of flower and fruit were recorded (date and period required for each change), dimension, shape, and color. The observation was carried out at 7.30 am until 12:00 am. Data on flower-visiting insects were determined by:

a) foraging rate is recorded as the number of flowers visited per minute [8],

b) visiting duration was recorded as the time spent by insects to visit the flowers,

c) foraging movement was observed by watching closely how the insects are approaching the flowers, including the time of insect landed and moved to the next flowers.

2.3. Data analysis

Observation of morphological changes that occur during the development of flowers and fruits were analyzed descriptively.

3. Result and discussion

3.1. Flower and fruit development

The generative phase in *G. arborea* begins when the trees shed their leaves. About a week after the fall of the leaves, flower buds appear. Period of flowering can occur 2-3 times in a year. The generative phase begins with the emergence of the axillary buds on the site of the fallen petiole. Generative buds appear like a bulge brown color and a bract covers the buds. During its development, the bract will fall, and flower bud grew to form a panicle (Figure 1). The length of the panicle was around 68.47 cm - 123.82 cm. The development form the generative shoots to become panicles take about 5-7 days.

Along with the growth of the panicle, the development of flowers has also occurred. The number of flower stalk in a panicle was around 5-34, and each stalk consisted of three to four flowers. The flower number per stalk decreased towards the tip. The stalks at the panicle grew alternately. Each flower stalk was covered with a pair of bract that will remain until the flowers bloom.

Flower buds were covered with green petals that will open in a few days, and purple crown grew, elongated and enlarged. The flowers positioned in the middle of the stalk will develop first, followed by the flowers grow beside it (Figure 1c). The time duration required from the flower buds toward bloom is 2 to 13 days.

When the flowers bloom, the flower crown opens downward. The position of filaments is lower than the style; therefore, it is less likely that pollens will fall into the stigma, which is against earth gravity. Thus the pollination in gmelina needs to be assisted by pollen vectors. The blooming of flowers lasts for 2 to 5 days.

The development of the fruit was marked by the swelling of the flower base that is a developing ovary. The color of the fruit can characterize the stages of fruit development. In the early stages, the
fruit was white on the base and red-purple at the tip. White fruit lasted about 2 - 4 days, and the fruit gradually turns green. During the fruit development from white to green, the size increases rapidly until the maximum size was reached. The average size of green fruit was 20.60 - 33.62 mm. The development of white fruit to green fruit with a maximum size took about 18-25 days (Figure 1f).

The yellow fruit stage was the last stage of fruit development before shedding. Yellow-colored fruit was a feature of mature fruit. At this time, the fruits have soft and juicy flesh. Fruits were light green to yellow attached to the tree for 7-10 days. Most of the fruits after reaching the maximum size would be fallen immediately. Therefore, only a few yellow fruits found on the tree.

The duration of flower buds to grow into yellow fruits ranges from 38 to 67 days or 1-2 months. The overall development of the flower buds to the matured fruit is shown in figure 1.

Figure 1. The development of flower buds to become mature fruit. (a) Generative bud 5-7 days, (b) flower shoots 2-13 days, (c) flower burst 2-5 days, (d) wilted flower and developing ovarium 2-3 days, (e) fruitlets 2-4 days, (f) purple-green fruits 18-25 days, (g) light green-(h) yellow fruits 2-4 days.

3.2. Reproductive success

The ratio of flower to fruit (fruit set) of gmelina in Nagrak - Bogor research plot is relatively high, i.e., between 42% to 64%. However, the ratio of ovules to seeds (seed set), on average, was 27% to 30%. The reproductive success value was obtained from the calculation of fruits set and seed set values, which was 12% to 17% (Table 1).

| Tree number | Flowers/panicle | Fruits/panicle | Seeds/fruit | Ovules/flower | Fruit Set | Seed Set | Reproductive success |
|-------------|-----------------|----------------|-------------|---------------|-----------|----------|---------------------|
| Tree 1      | 20.7            | 13.3           | 1           | 3.7           | 0.643     | 0.270    | 0.17                |
| Tree 2      | 23.8            | 11.1           | 1           | 3.3           | 0.466     | 0.303    | 0.14                |
| Tree 3      | 25.1            | 10.5           | 1           | 3.5           | 0.418     | 0.286    | 0.12                |
3.3. Flower visitor insects

Insects found actively visiting flowers and touching anther and stigma are carpenter bees (*Xylocopa latipes* and *Xylocopa confusa*) who belong to Family Apidae, Orde Hymenoptera, *Amegilla* sp and *Trigona* sp. (Figure 2). The most active and dominant insect visiting the flower is *X. latipes*. This result is similar to the report [7] that suggested the visitors of the flowers of gmelina include birds and bees (*X. latipes*, *Amegilla* sp. and *Apis cerana indica*); however, in this study we did not observed birds visiting flowers.

*Figure 2. Flower visitor insect, Carpenter bees: (a) (*Xylocopa latipes*) and (b) *Amegilla* sp.*

*Xylocopa* sp was the most dominant flower visitor that actively visited the flowers between 08.00 am and 11.00 am. Observation of flower-visiting behavior showed that when the insects were entering the canopy area of the tree for one minute, they unable to visit about 5 to 20 panicles or about 11 panicles on average. The visiting duration at each flower panicle ranged from 0.6 seconds to 16.4 seconds or 3.6 seconds on average (Table 2).

| Parameter                                | Minimum | Maximum | Average ± St. Deviation |
|------------------------------------------|---------|---------|-------------------------|
| Number of panicles visited/minute (panicles) | 5       | 20      | 11 ± 3                  |
| Visiting duration/panicle (seconds)       | 0.6     | 16.4    | 3.6 ± 3.2               |
| Number of flowers visited/minute (flowers)| 10      | 35      | 23 ± 8                  |
| Visiting duration/flower (seconds)        | 0.5     | 8.8     | 1.8 ± 1.5               |

The carpenter's bee (*Xylocopa* sp) is considered as the primary pollinator of gmelina. It is the most common insect entering the gmelina canopy area to visit flowers. The size of *Xylocopa*’s body corresponds to the corolla’s size, of which the base of the corolla is funnel-shaped. The insect is landed on the flower and entered into the crown funnel to pick up nectar. When the bee was entering the crown, the anthers were touching the fine-haired back of the bee. At that time, the pollens were most likely to stick to the bee's back. When the bees were moving to another flower, then the pollination process would be expected to occur as the stigma was touching the back of the bee that containing pollens from previous flowers.

The result of this study was in line with the report of [9], who suggested that *Xylocopa* is one of the insects known to act as a pollinator for cultivated plants in Southeast Asia. *Xylocopa* is an insect that visits gmelina flowers [10]. Our research site was surrounded by garden yards and settlements. Our
finding on *X. latipes* in our research seems to be similar to the research finding of [11]. They claimed that *X. confusa* and *X. latipes* were discovered in artificial habitats such as community forest, gardens and agricultural areas because they have a habit of nestling on the wall. Both species are not found out in natural forests, teak forests, pine Forests, and agathis forests [11]. Meanwhile, [10] found that *Xylocopa* foraging in various forest types: deciduous forests, deciduous dipterocarp forests, evergreen forests, dipterocarp-pine forests, and mixed evergreen-deciduous forests. *X. latipes* and *X. confusa* in oil palm plantations, but did not find in rubber plantations or wild jungle rubbers [12].

4. Conclusion
Reproductive cycles of *Gmelina* can occur 2-3 times during the year, and one cycle lasting about 1-2 months. The development of generative buds to be yellow fruits takes 38 to 67 days. Total reproductive success of sample trees varied from 12% to 17%. Insects found visiting flowers actively were *Xylocopa latipes*, *Xylocopa confusa*, *Amegilla* sp, and *Trigona* sp. The most dominant flower visitor, and suspected as a pollinator of gmelina at the research site was *X. latipes*, who actively visit the flowers at 8:00 until 11:00 am. In one minute, the insects visit about 10 to 35 flowers per minute. The duration taken for *X. latipes* to visit each flower ranges from 0.5 seconds to 8.8 seconds, with an average of 1.8 seconds.

Acknowledgment
This study was supported by the Forest Tree Seed Technology and Development Center-Bogor, Forest Research, Development and Innovation, Ministry of Environment, and Forestry of Republic Indonesia. Hasan Royani deserves our special thanks for assisting in technical detail.

References
[1] Florido L V and Cornejo A T 2002 Yemane *Gmelina arborea* (Roxb.) Research Information Series on Ecosystems 14 (3) 3-8
[2] Palaypayon C M and Batalon J M 2002 Issues and Facts on Yemane Research Information Series on Ecosystems 14 (3) 9-11
[3] Dvorak W S 2004 World view of *Gmelina arborea*: opportunities and challenges New Forest 28 111-126
[4] Wingfield M J and Robinson D J 2004 Diseases and insect pests of gmelina arborea: real threats and real opportunities New Forest 28 227-243
[5] Owens J N 1991 Flowering and Seed Ontogeny Technical Publication No. 5, ASEAN-Canada Forest Tree Seed Centre Project Muak-Lek Saraburi Thailand
[6] Faegri K and van der Pijl L 1979 *The principles of pollination ecology* Third edition Pergamon Press Oxford
[7] Raju A J S and Rao S P 2006 Pollination by bees and passerine birds and seed dispersal by monkeys in the white teak *Gmelina arborea* Roxb., a commercially important timber tree species in the Eastern Ghats Current Science 90 (2) 232 - 236
[8] Dafni 1992 *Pollination Ecology - a Practical Approach*. Oxford University Press.
[9] Kevan P G 1995 *Pollinator behavior & plant Phenology*. In Pollination of cultivated plants in the tropics. D. W. Roubik ed. FAO Rome Italy p 136-142
[10] Jongjitvimol T and Petchsri S 2015 Native bee pollinators and pollen sources of Apidae (Hymenoptera) in four forest type of lower northern Thailand Sains Malaysiana 44 (4) 529-536
[11] Widhiono I and Sudiana E 2015 Diversity of insect pollinators and its relationship with flowers colors on Agricultural crops in the Northern slopes of Mount Slamet, Central Java Biospecies 8 (2) 43-50
[12] Siregar E H, Atmowidi T and Kahono S 2016 Diversity and abundance of insect pollinators in different agricultural land in Jambi, Sumatera *Hayati Journal of Biosciences* 23 13-17