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Morphological Traits of Maluku Native Forest Clove (*Syzygium aromaticum* L. Merr & Perry.)

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Abstract

A study was conducted to study the morphology of the forest cloves groups based on their sizes of their leaves, flowers, fruits and seeds, and to determine their potential yield and optimize their production system. The research was conducted for six months from January until June 2018 in Ambon, Maluku Province, Indonesia. The research used a random sampling technique to > 15-year-old trees in productive clove forest maintained by the local farmer in Ambon. The observation and recording was conducted at several stages of clover growth, namely bud sprouting, flower bud, blooming, perianths and anthers senescence, unripe green and ripe fruits. Different size groups of forest cloves have significant differences in the duration of flower and fruit formation. Forest cloves with large leaves, flowers, fruits and seeds had quicker ripening process than the othersize groups, but their fruits were longer to ripen. Flower from the medium size group had the shortest duration to develop its flower and form its fruit, whereas the smallest type took the longest time in fruit formation process but the duration of fruit ripening was similar to those from large morphology. Among the three different sizes of forest cloves in Maluku, the trees with large leaves, flowers, fruits and seeds group are the best to be commercially developed due to its earliest time to harvest and large flower sizes. Forest cloves are best harvested when the flowers are fully matured, indicated by one or two flower buds from one inflorescence have bloomed.

Keywords: Ambon, morphology, flower development, fruit formation, wild-type clove

Introduction

Cloves are aromatic flower buds of a tree in the family Myrtaceae. Forest cloves (*Syzygium aromaticum*) is one of the popular spices in Indonesia. Forest clove is a native and endemic species to Moluccas or Maluku, North Maluku and some areas in Papua. Based on identification at Bogoriense herbarium, Bogor-Indonesia LIPI-Cibinong Research Center the scientific name of forest clove from Maluku is *Syzygium aromaticum L. Merr & Perry*. In Maluku, the broadest distribution is found on Ambon Island (Hitulama, Hitumessing, Mamala, Morella) and Seram Island (Latu and Hualoy villages). Cloves grow well in areas that are rich in organic matter, optimum pH 5.5-6.5 (Rukmana and Yudirachman, 2016). Ideal rainfall ranges from 500-3500 mm per year which is spread evenly, optimum temperature 22-32°C, with optimum humidity of 60-80% (Ruhnayat and Wahid, 2007). On Ambon Island, this species is found at an altitude of 100-250 m while on Seram Island at an altitude of 100-500 m. Just like any other Syzigium plants, forest cloves can grow in the tropical and subtropical area (Hadipoentyanti, 1997).

Forest cloves are wild cloves with their flower as the main product commonly used for making cigarette, spices, medicine, and food preservatives (Syukur et al., 2016). Other products made from cloves are oil and oleoresin which are distilled from cloves flowers or leaves (Bermawie and Wahyuni, 2008). Clove is an important economic spice as it is the main source of income for local farmers in Malacca (Rukmana and Yudirachman, 2016). The income from cloves contributes to the province income, particularly through cigarette production (Kemala and Yuhono, 2007). In 2015, cigarette from cloves, along with those from tobacco, reached 95% of total tax of the

province. The area of clove plantations has increased from 501,378 ha in 2012 to 542,281 ha in 2016; however, clover production has not met the national demand. Clove imports in 2016 were about 24 tons and will continue to increase with the development of clove cigarette factories and other industries that use cloves as raw materials (Ditjenbun, 2016).

One of the ways to develop commercial clove varieties is through exploring and preserving the clove germplasms. Forest cloves trees have round and an oval canopy, low branching in its main stem, and are large and sturdy trees with less pointed canopy than other cloves varieties (Koemiati, 1997). Forest clove leaves are oval with a rather flat leaf edge and a slightly rounded (obtuse), thicker, dark green, ± 15.17-20.36 cm long, and ± 6.99-9.86-cm wide. Flowers are deep yellowish green, light yellow-green when the picking time, terminal flowering and hermaphrodite, ± 2.35-2.41 cm long, ± 0.57-0.64 cm wide, and ± 0.58-0.82 g weight. Fruits are ± 2.75-3.32 cm length, ± 1.40-2.00 cm diameter, ± 3.61-8.01 g weight, light green when immature and dark red when ripe. Seeds are firm purple-red, recalcitrant and have two cotyledons with radicules at the base, ± 1.97-2.31 cm long, ± 0.90-1.16 cm diameter, ± 1.26-2.21 g weight.

Morphologically, forest cloves are classified into three major groups based on the size of the leaf, flower, fruit, and seed, namely large, medium and small. Forest cloves in Maluku are distinctly different from the current description of cloves in general. Maluku's forest clove has thick leaves, and low leaf eugenol content so the leaf aroma is not as strong. The forest clove flowering season in Maluku begins at the end of December or in early January to early March each year. Clove flowers are usually harvested in March, and the following three months until June is the period for fruit formation. Ambon forest cloves phenology has never been systematically investigated. The current study was aimed studying the morphology of the forest cloves groups based on their sizes of their leaves, flowers, fruits and seeds, to determine their potential yields in order to optimizing their production system management.

Flowering phenology is phases that occur naturally in the flowering process (Harmiatun et al., 2016). Flowering phenology is very important for planning breeding programs, particularly to identify the superior varieties (Jamsari et al., 2007), to determine the optimum harvest time, post-harvest handling, harvesting seeds for planting, and production management. Plant species can have different flowering and fertilization patterns (Tabla and Fargas, 2004), which can be identified by looking at changes in the vegetative period to generative and generative durations, particularly of time to flower, seed formation and time to harvest (Sitompul and Guritno, 1995).

The climate in Ambon where forest cloves are grown is influenced by the monsoon wind circulation which flows to the equator during April to September (Laimeheriwa, 2012). The air circulation in this region is dominated by cool and relatively dry southeast trade winds or easterly wind from Australia and will turn into southwest trade winds after going to the equator and the northern equator. During this period Maluku experience dry conditions. More specifically, rainy season with local rain pattern occurs from May – August while dry season occurs from November – February. September – October is transition season from rainy season to dry season while March – April is transition season from dry to rainy season.

The aim of this research was to investigate the phenological stages of three groups of forest cloves based on the size of the leaves, flowers, fruits, and seeds, and to determine the potential yields of each group.

Material and Methods

The research was carried out in Ambon, Maluku, Indonesia (2° 30'-9° 00'S, 124°– 136°E). Phenological observation on flower development and fruit formation was conducted from January to March 2018.

The study was an exploratory method conducted at nine productive forest cloves maintained by the local farmers. The age of the forest cloves trees were > 15 years. Three trees with large, medium and small leaf, flower, fruits and seeds were selected from each size group. From each tree ten leaves and ten flower clusters were collected purposively from 1 m^2 quadrants according to the method employed by Tresniawati and Randriani (2011). The criteria for the selected leaves are healthy, 4th leaf from the shoot apex (Ruhnayat, 2007). Measurement of flowers was conducted according to the method described by Tresniawati and Randriani (2011), i.e. on one or two flowers from one inflorescence. Fruit and seed samples were selected based on changes in size and color when ripened.

The morphological characters recorded were the length of leaves, flowers, fruit, and seeds which were determined using a ruler. Stem diameter was measured using a Vernier caliper. A digital balance was used to measure the weight of flowers, fruits, and seeds and the color was determined using a scale of the RHS color chart 2015. The method employed by

Mudiana and Ariyanti (2011) was used as a guide for the duration of the observation (in weeks) with some modifications, on bud sprouting, flower bud, blooming, perianths and anthers fall, unripe green fruit, and ripe fruit. Although cloves harvesting occurred at the flowering stage, the observation was conducted until the completion of the fruit formation. Three different characteristics of forest cloves were recorded based on the size of the leaf, flower, fruits and seeds i.e. small, average, and large morphology.

Results

Morphological Character

Forest cloves with large morphology had the longest leaves which is about 20.36 cm in length and 9.86 cm wide (Figure 1 A-a). The flower color was deep yellowish green (141A) (Figure 1 D-a). The average length of mature flowers was around 2.41 cm, a width of 0.64 cm and weighed 0.82 g. The color was light yellow green (154D). The average length of ripe fruit was around 3.30 cm with a diameter of 1.90 cm weighed about 7.65 g. The color was dark red (59A) (Figure 1 B-a). The seed length was around 2.31 cm with a diameter of 1.10 cm and a weight of 1.99 g. The color was strong purplish red (59D) (Figure 1 C-a).

The forest cloves with medium size leaves had a leaf length of 18.15 cm and a width of 8.70 cm. The color was strong yellow green (144A) (Figure 1 A-b). The flower length was around 2.23 cm with a flower tube that was 0.54 cm wide and 0.67 g in weight. The color was light yellow-green (154D) (Figure 1 D-b). The fruit had a length of 3.32 cm with a diameter of 2.00 cm and weighed 8.01 g. The color was dark red (59A) (Figure 1 B-b). The seed length was 2.30 cm with a diameter of 1.16 cm and a weight of 2.21 g with a dark purplish red (59D) (Figure 1 C-b).

Forest cloves with small leaves had 15.17 cm leaf length and about 6.99 cm leaf width with a deep yellowish green in color (141A) (Figure 1 A-c). The length of the mature flowers was around 2.35 cm with light yellow green color (154D) (Figure 1 D-c), the width of the flower tube of 0.57 cm, and it weighed around 0.58 g. The ripe fruit has The around 2.75 cm length, 1.40 cm diameter, weight of 3.61 g; the fruit shape is concave with dark red color (59A) (Figure 1 B-c). The seeds were small and shiny with a length of about 1.97 cm with a diameter of 0.90 cm and weighed around 1.26 g; the seeds have a dark

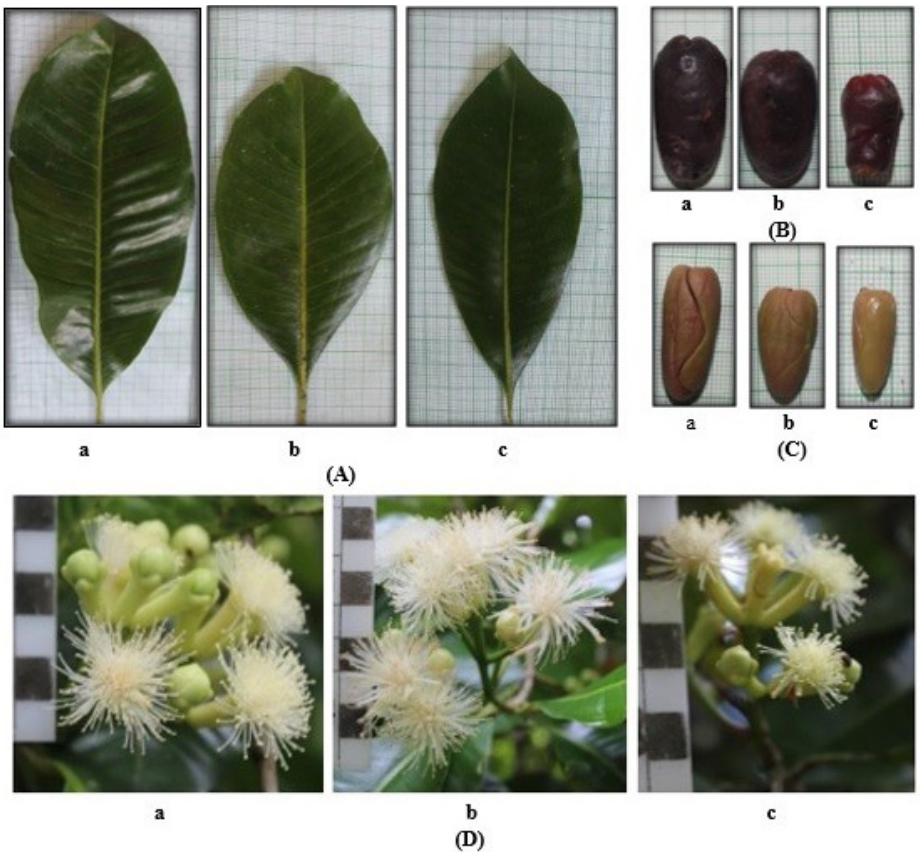

Figure 1. The leaf morphology of Maluku's forest clove leaves (A), fruits (B), seeds (C), and flowers (D); a: forest cloves with large, b: medium, and c: small leaves, fruits, seeds and flowers

purplish red color 59D (Figure 1 C-c). Most fruits were found to be seedless.

Forest Clove Fruit Development

Forest cloves has complete flowers; the flowers have calyx, corolla, stamen, and pistil. The flowers are hermaphrodite as the male and female flowers are borne in one flower organ. Flower development and fruit formation stages of forest cloves (Figure 2) are similar to any other Syzygium genus. For example, *S. pycnanthum* which is divided into 6 phases that involves flower induction, flower initiation, pre-anthesis, anthesis, pollination and fertilization and formation, fruit ripening and seed formation (Mudiana and Ariyanti, 2010).

Duration of Phenological Stages

The different sizes of forest clove morphology demonstrated different flower development and fruit formation, even though they share similar bud sprouting duration. Forest cloves with large morphology bloomed more quickly, i.e. at about 8 weeks after bud sprouting, but their fruits take longer to ripen (Figure 3A). Forest cloves with medium morphology had the earliest fruit formation of 19 weeks after bud sprouting but the flower bloomed a week slower compared to those with large morphology (Figure 3B). The duration of flower development and fruit formation of the small forest cloves are similar to those of the medium size, but the flowers took longer to bloom, e.g. around 12 weeks (Figure 3C). The difference in the morphology does not only affect the phenology, but also the reproduction success (Ollerton and Lack, 1998; Schmidt, 1983). The difference in duration due to the size of morphology can be a guide in revising or supplementing the botanical description of *S. aromaticum* species. For example, Snow (2010) reported a new Syzygium species with small leaves and winged branchlets.

Discussion

Fruit development stages on forest cloves start with the induction phase, which anatomically involves tissue expansion, followed by the initiation of floral buds (Rai et al., 2006; Damaiyani and Metusala 2011). During the induction phases, a chemical and hormonal change occurs, including the reduction of gibberellin and the rise of total glucose (Rai et al., 2006). The flower bud formation (Figure 2a and 2b) occurred during is started with the visible expansion of the meristem, followed by the emergence of the flower bud, and ended when the calyx and the corolla had formed and visible. Pre-anthesis phase, i.e. the stage when flower bud is ready to bloom, is an important phase in growing forest cloves as this stage determines the correct time to harvest. Forest cloves can be harvested when one or two flowers from one inflorescence have bloomed. It is not necessary to wait until all the buds have bloomed, as harvesting later than this stage reduces the quality of the clove oil. This harvesting period only occur on a short period of time before the flowers within the inflorescence fully bloomed (Figure 2C). Fully bloomed flower involves turgor pressure changes (Liang and Mahadaran,

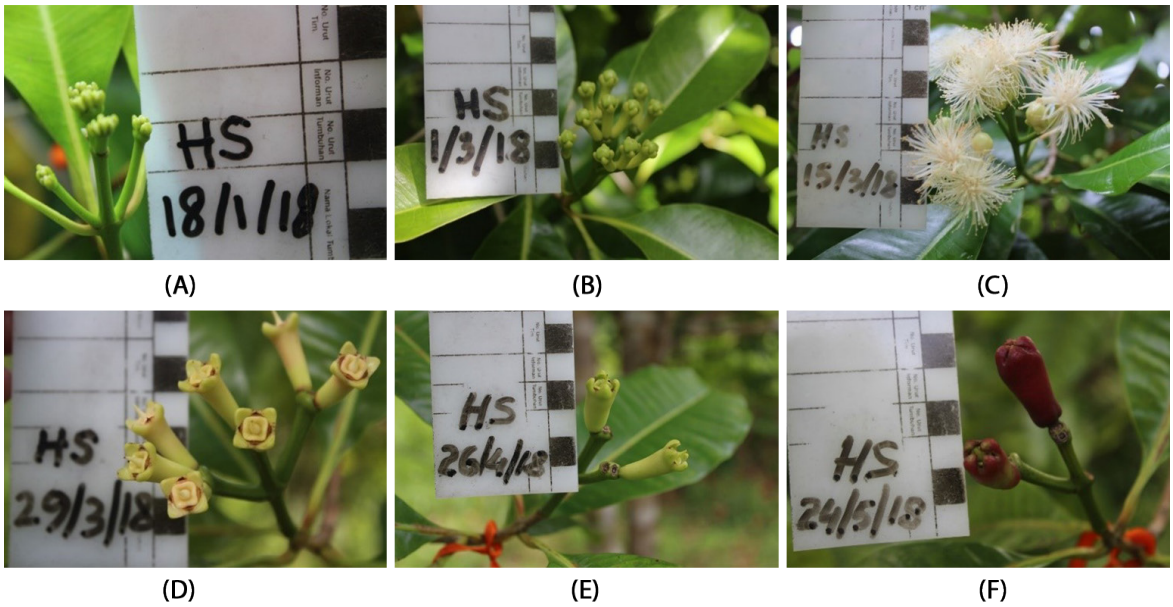

Figure 2. Phenological stages of fruit development of forest clove: (A) bud sprouting, (B) flower buds in an inflorescence, (C) fully opened flowers, (D) Maluku's forest clove: the stage where perianths and anthers already dropped, (E) unripe green fruits and (F) ripe fruits.

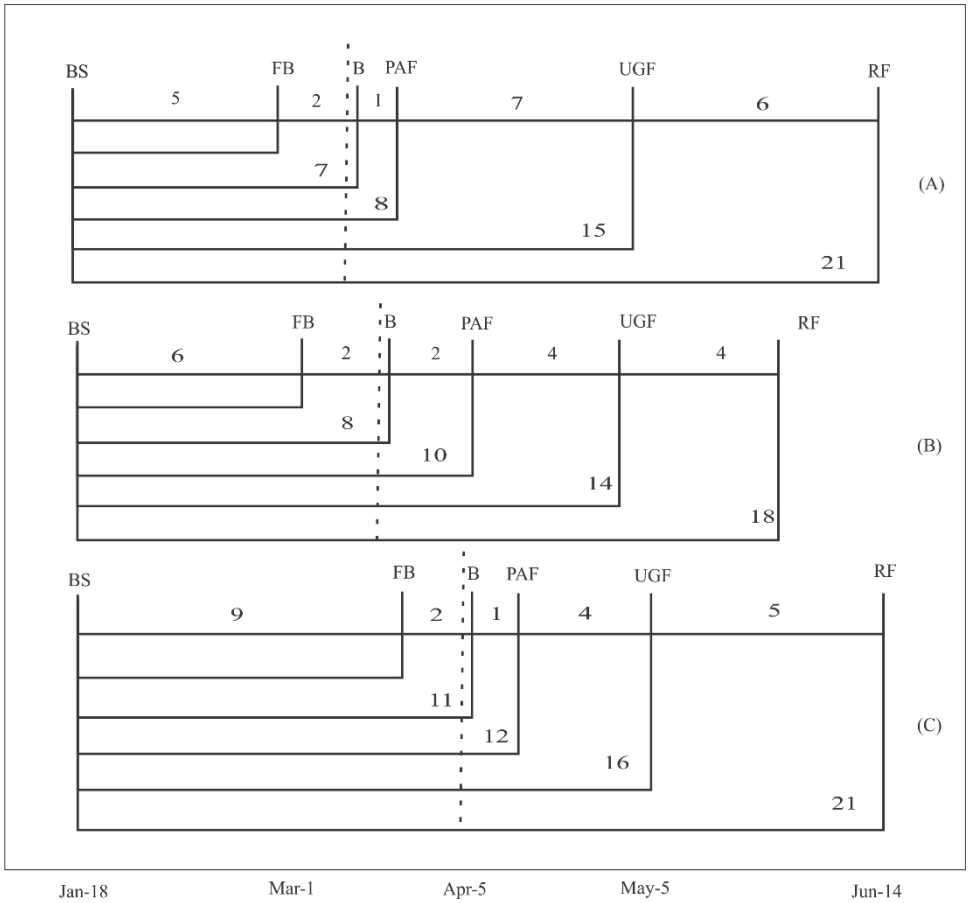

Figure 3. Duration (in weeks) of phenological stages of forest clove with (A) large; (B) average; (C) small leaf, fruit, seed and flower, where BS: the onset of bud sprouting; FB: formation of floral buds; B: blooming; PAF: perianths and anthers fall; UGF: unripe green fruits and the onset of fruit maturation; RF: fruit started to ripen. Dotted line indicates the appropriate time to harvest flowers.

2011). The fall of the perianths and anthers (Figure 2D) was a sign that the flower had undergone pollination and fertilization. Forest cloves flower had a common and simple pollination system, i.e. exposing their perianths and anthers to attract insect pollinators (Shivanna, 2016), despite forest cloves flowers do not have a strong aroma like the other types of clove. The last stage was the fruit ripening process. Green fruit (Figure 2e) turned to red (Figure 2f). Forest cloves fruits have the shape of an enlarged bottle on the apex with visible calyx just like on the other Syzygium fruits (Mudiana and Ariyanti, 2010).

Forest cloves fruit formation occurs during the rainy and the dry seasons. Flower development occurs at the end of the dry season (January - March) whereas fruit formation occurs at the beginning of the rainy season (March - June).

The flower bud is the part of the clove which is picked during the harvest. The dotted line in Figure 3 shows the harvest time before the flower fully bloomed. Therefore, the difference in phenology duration can be a guide in developing forest cloves as a commodity. Forest clove with large morphology is more advantageous due to its rapid blooming flower and significant weight due to its larger size flowers than any other forest cloves.

The phenological duration is also influenced by the climate and temperature, different year of observation could also expose the difference in its stages of phenology (Hussain et al., 2016); and the different patterns can be utilized as a reference for conservation efforts (Morellato et al., 2016) and their potential development. The stages of phenology also contribute to chemical elements contained in forest cloves such as eugenol, eugenyl acetate, caryophyllene oxide and β-caryophyllene (Razafimamonjison, 2013).

Conclusion

Our study has revealed that differences in the size of forest cloves leaf, flower, fruit and seeds determine the phenological durations of bud sprouting, flower bud formation, blooming, perianths and anthers

drops, and the process of fruit ripening. Forest cloves with large leaves, flowers, fruits and seeds have the earliest blooming period and the most potential forest cloves to be commercially developed.

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