Study of *Cananga odorata* (Lam.) Hook. f. & Thoms. Flower Development: Morphological Variations in an Urban Environment

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**Abstract:** *Cananga odorata* is a native plant in the Indonesian archipelago. The flowers are often used to produce essential oils with many uses and a distinct fragrance. This study aims to observe each stage of the *Cananga odorata* flower development. The flowers were obtained from a home garden in Pasar Minggu, South Jakarta, from November 2020 until January 2021. Further observations of the stamen and pistil developments were conducted using *Dino-Lite Edge Digital Microscope* AM4115 Series. The results show that *Cananga odorata* flower development can be categorized into bud, display-petal, initial-flowering, full-flowering, end-flowering, and senescence stages. The flowers require 35 days to develop from bud stage to flower senescence. Stamens and pistils also develop primarily during the bud stages and mature after flower anthesis. Flower mutants were also found and may be caused by a mutation in the flower's homeotic genes. Each different stages of flower development show a different morphological change in the flower perianth and reproductive organs. A discrepancy of flower morphology within each stage, especially those seen during the anthesis stages, might imply a variation in the flower's internal factors.

1. **Introduction**

*Cananga odorata* (Lam.) Hook. f. & Thoms is an evergreen flowering tree from the Annonaceae family native to the Indonesian archipelago. *Cananga odorata* typically grow up to 10-20 m in height [1]. The flowers of *Cananga odorata* are often used to produce essential oils because of their many uses and distinctive aromatic scent. The oils found in *Cananga odorata* flowers can help with anxiety, tension, shock, fear, and panic because of the calming effects it has on the nervous system. The oils of the flowers are often used in soap, cosmetics, and other hygienic by-products. *Cananga odorata* flowers can also be used as medicine to treat hepatitis and other ailments [2].

Volatile compounds produced by *Cananga odorata* flowers differ in each development stage. The maturity of the flowers determines the volatile compounds that are produced. Flowers in the intermediate stages of development contain a high level of volatile compounds. Meanwhile, flowers in the mature stages of development contain compounds that contribute to the flowers' aromatic scents, such as hydrocarbon, esters, and alcohol compounds [3]. Previous studies have observed the anatomy and
morphology of a few different stages in the *Cananga odorata* flower development [7]. Another study has also observed the volatile organic compound emissions of different *Cananga odorata* flower development stages [3]. However, no study has successfully identified the different morphological changes that occur in different stages of the *Cananga odorata* flower development from the bud stage until the end of flower anthesis and flower senescence. A study of the development stages of *Cananga odorata* will be beneficial to understanding the species’ reproductive biology. Furthermore, understanding the development stages of *Cananga odorata* flower development can provide vital information for future studies. Therefore, this study aims to observe the full development stages of *Cananga odorata* flowers from the bud stage to its mature stage to better understand the reproductive biology of *Cananga odorata*.

2. **Method**

2.1. **Sample collection**

*Cananga odorata* flowers from bud to mature stages were collected and observed from November 2020 to January 2021 at a home garden in Pasar Minggu, South Jakarta. The time of collection and observation was from 16:00 to 17:00. The flowers were collected from a tree that is approximately 2 m in height.

2.2. **Flower development observation**

*Cananga odorata* flower samples were arranged on millimeter block paper from the earliest bud to the latest mature flower. Classification of each flower development stage was based on Qin et al. [3]. Additional observations of the stamen and pistil development from bud to the end-flower stage were conducted using Dino-Lite Edge Digital Microscope AM4115 Series at a magnification of 20x and 50x. Sepals and petals were removed from flowers in the bud stage to observe the development of the flowers’ reproductive organs.

3. **Results and discussion**

Observation results show that *Cananga odorata* flower development can be divided into several stages (Figure 1-4). Flowers begin at bud stage where it first emerges from bracts on the stem axillar of mature trees. Flowers in bud stage would continue to develop until it reaches anthesis (flower opening). Flower anthesis proceeds in different stages until flowers reach maturity. Mature yellow flowers would then progress to flower senescence after one day. *Cananga odorata* flowers require 35 days to develop from bud stage to flower senescence stage (Table 1).

![Figure 1. Flower development stage from bud stage to initial-flowering stage. b= bud; a=anthesis.](image)
Figure 2. Flower development stage from display-petal stage to full flowering stage. a = anthesis.

Figure 3. Flower development stage of full-flowering stage (a8) and end-flowering stage (a9).

Figure 4. Flower senescence.

Table 1. The days required for each stage of Cananga odorata flower development

| Flower development stage | Days from flower opening (anthesis) |
|--------------------------|-------------------------------------|
| Bud                      | -16                                 |
| Display-petal            | 0                                   |
| Initial-flowering        | +6                                  |
| Full-flowering           | +13                                 |
| End-flowering            | +18                                 |
| Flower senescence        | +19                                 |
Sepals remain closed during the bud stage of flower development, enclosing the petals, stamens, and pistils within. Sepals open to display the flower’s petals during the display-petal stage; meanwhile, the stamens and pistils remain enclosed by the petals. Petals open and lengthen until their maximum length during the initial-flowering stage. Petals reach their maximum length at the full-flowering stage. Mature flowers will change colors from green to yellow as it enters into the end-flowering stage. A reddish-brown blotch can also be seen on the inner petals’ base of the flowers as they mature (marked by a black arrow in Figure 6C). Flowers are most fragrant during the end-flowering stage. According to Jin et al. [4], the vibrant yellow color and strong fragrance of mature flowers are utilized to attract pollinators. The drooping inner and outer petals of the flower create a type II pollination chamber based on Saunders’ categorization [5], in which the pollination chamber is formed by petals that constrict the stamens and pistils. Pollinators of *Cananga odorata* flowers include small beetles relevant to the size of the flowers’ pollination chamber. The pollinators were presumably rewarded with food from stigmatic exudates and pollen [6]. Flowers would enter into senescence without developing into fruit after the end-flowering stage (Figure 4).

The mature flowers of *Cananga odorata* are highly fragrant and grow in groups of 6-8 flowers on the stem axillar. The flower morphology consists of a pedicel, three broad and pointed sepals, six straplike and pointed petals arranged in two circles, with three petals in each. Numerous pointed stamens surround a group of separate pistils in the middle of the flower apex. This observation is consistent with the *Cananga odorata* flower morphology described by Parrotta and Nurhayani et al. [1][7].

The development of the stamens and pistils was also observed (Figure 5-6). According to Rutishauser [8], stamen development begins acropetally in the flower apex. Pistil formation then occurs in a continuous transition after more than 200 stamens have occupied the flower apex. The results obtained follow Rutishauser [8], in which stamens in the early bud stage appear to be rounded and not yet pointed as in the later bud stages; meanwhile, pistils have yet to be developed. Stamens begin to develop pointed ends during the intermediate bud stage and a concave forms in the middle of the flower apex (marked with a black arrow in Figure 5C). This concave marks the transition from stamen development to the inception of free carpels. Stamens have developed pointed ends at the late bud stage, and free carpel primordia, each with a ventral cleft, can be observed on the flower apex. The stamens and pistils continue to mature during the initial flowering stage until the end-flowering stage (Figure 6). Mature stamens have a reddish-brown tint at the tips.

Endress [9] describes the stamens of *Cananga odorata* flowers as having cuneate forms with a large apex and short filaments. A single *Cananga odorata* flower has numerous stamens that are densely arranged spherically on the flower apex. This architecture of the stamens provides a protective function for the thecae and ovaries as the reproductive organs of the flowers become exposed in the mature flowers. This architecture may also protect the reproductive organs from pollinators with biting-mouth parts and other herbivorous insects. Endress also describes the pistils (androecia) of *Cananga odorata* as hemispherical in shape. Observation results of mature stamens and pistils were consistent with Endress’ description (Figure 7).

Several flower mutations were found during the observation (Figure 8). Mutant flowers show a different morphology from the typical flowers described by Parrotta and Nurhayani et al. Mutant flower morphologies show an increase or decrease in the number of sepals and/or petals. Furthermore, stamens and pistils were observed to form petaloids in the third and fourth whorls of some mutant flowers. A few mutant flowers also show an irregular flower shape, forming a half-circle instead of a whole flower circle. An irregular flower apex shape can also be seen in mutant flowers with an increased number of petals (Figure 8H), where a typical flower should have a hexagonal flower apex shape [8]. Mutations in the flowers can be observed from the display petal stage, when sepals open and petals are displayed, until the end-flowering stage.
Figure 5. Stamen and pistil development during bud stage (before anthesis). (A, B) Bud stage 3; (C) Bud stage 6, black arrow shows the concave formed in the centre of the flower apex; (D, E) Bud stage 9.

Figure 6. Stamen and pistil development after anthesis. (A) Display-petal stage; (B) Initial-flowering stage; (C) Full-flowering stage, black arrow shows the reddish-brown blotch found on the base of inner petals of mature flowers.

Figure 7. Mature flower reproductive organs. (A) Stamens; (B) Pistils with stamens and petals removed from the flower.
Figure 8. Flower mutations found in *Cananga odorata*. (A) Flower with two sepals; (B) Flower with four sepals; (C) Flower with four petals; (D) Flower with five petals; (E, F) Flowers with an irregular flower shape; (G) Flower with more than six petals, as well as stamens and pistils developed into petaloids; (H) Flower with an irregular apex shape.

Flower mutants can occur because of a mutation in the flower's homeotic genes. Based on the ABC model of flower development proposed by Bowman et al. [10], each floral whorl has a unique combination of homeotic A, B, and C gene expressions that determine each floral's identities. The C function genes' repression will cause the A function genes to appear in the flower's third and fourth
whorls, which causes the stamens and pistils to develop into petaloids. According to Saunders [5], flowers of the Annonaceae family commonly have an increase or decrease in the number of sepals and/or petals. However, this variation is limited to a few groups, including the ‘ambavioid’ clade of the Annonaceae family, including *Cananga odorata* var. *fruticosa*. Saunders also observed other mutations within the Annonaceae family.

*Cananga odorata* var. *fruticosa* (Craib) J. Sincl. is a variety of *Cananga odorata* dwarfed, with a height reaching up to only 2 m. The petals of the flowers from the *fruticosa* variety are often more numerous and curlier. Furthermore, the flowers of this variety never develop into fruit [11]. This description is consistent with the *Cananga odorata* flowers observed; thus, the *Cananga odorata* var. *fruticosa* flowers were also found to contain a different essential oil composition from *Cananga odorata* of the standard variety. This distinction may be caused by differences in genetics and growing conditions of the two varieties of flowers [4].

4. Conclusion

*Cananga odorata* flower development can be categorized into several stages, from bud to flower senescence, which takes about 35 days. Stamens and pistils develop during the bud stages and mature after the display-petal stage. Flower mutations can be observed during flower development, resulting from mutations in the flower’s homeotic genes.

This study has limited quantitative data that could objectively distinguish the different flower stages, especially in the bud and initial-flowering stages. Suggestions for further studies would be to include measurements of the different flower stages to categorize the different development stages based on quantitative data objectively. Better equipment may also be used to enhance the observation of the different flower development stages, such as Scanning Electron Microscopy. Genetic analysis may also need to be done to verify the involvement of flower homeotic genes that causes mutations in flower.

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References

[1] Parrotta 2009 Cananga odorata Enzyklopädie der Holzgewächse 54 1-8 (doi.org/10.1002/9783527678518.ehg2010004)
[2] Orwa C, Mutua A, Kindt R, Jamnadass R, and Anthony S 2009 Agroforestry Database 4.0 1-5 (http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp)
[3] Qin X-W, Hao C-Y, He S-Z, Wu G, Tan L-H, Xu F and Hu R-S 2014 Volatile organic compound emissions from different stages of *Cananga odorata* flower development *Molecules* 19 8965-8980
[4] Jin J, Kim M J, Dhandapani S, Tjhang J G, Yin J-L, Wong L, Sarojam R, Chua N-H and Jang I-C 2015 The floral transcriptome of ylang ylang (*Cananga odorata* var. *fruticosa*) uncovers biosynthetic pathways for volatile organic compounds and a multifunctional and novel sesquiterpene synthase *J. Exp. Bot.* 66 3959-3975
[5] Saunders R M K 2010 Floral evolution in the Annonaceae: hypotheses of homeotic mutations and functional convergence *Biol. Rev.* 85 571-591
[6] Saunders R M K 2012 The diversity and evolution of pollination systems in Annonaceae *Bot. J. Linn. Soc.* 169 222-244
[7] Nurhayani F O, Wulandari A S and Suharsi T K 2019 The floral morphology and anatomy of kenanga (*Cananga odorata* (Lam.) Hook.f. & Thomson) *IOP Conf. Ser.: Earth Environ. Sci.* 394 1-6
[8] Rutishauser R 2016 Acacia (wattle) and Cananga (ylang-ylang): from spiral to whorled and irregular (chaotic) phyllotactic patterns – a pictorial report Acta Soc. Bot. Pol. 85 1-15
[9] Endress P K 2008 The whole and the parts: Relationships between floral architecture and floral organ shape, and their repercussions on the interpretation of fragmentary floral fossils Ann. Mo. Bot. Gard. 95 101-120
[10] Bowman J L, Smyth D R and Meyerowitz E M 1991 Genetic interactions among floral homeotic genes of Arabidopsis Development 112 1-20 (PMID: 1685111)
[11] Manner H L and Elevitch C R 2006 Cananga odorata (ylang-ylang) Species Profiles for Pacific Island Agroforestry pp 1-10 (www.traditionaltree.org)