Reproductive activity patterns of four species of *Cinnamomum* in Purwodadi Botanic Garden

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Abstract. The aims of this study were to know flowering and fruiting pattern of the four *Cinnamomum* and their response in relation to seasonal change in rainfall, temperature and air humidity in Purwodadi Botanic Garden. The vegetative and reproductive activities were observed once per week based on the abundance of leaves, flowers and fruits using a scoring method from 0-4, for 6-8 years of observations. The rainfall per month, temperature, and humidity were simultaneously recorded. Data were analysed by Principal Component Analyses to determine the microclimate variables that have correlation to the reproductive activity patterns of all four species. Most species started flowering and fruiting during June – August, except *C. burmanii* which produced flowers 2-3 times per year in small quantity. Flowering of *C. burmanii* showed positively correlations with rainfall intensity, while flowering the other three species did not relate to microclimate in PBG. Six dry months preceding a long dry season in 2015 caused *C. burmanii* did not produce flowers and fruits.

1. Introduction

*Cinnamomum* is a genus of evergreen aromatic trees belonging to the Lauracea family. The species of *Cinnamomum* have aromatic oils in their leaves and bark. The genus includes a great number of economically important trees. Many *Cinnamomum* species are well known as spice and medicine. Main characteristic of the *Cinnamomum* genus is their leaves are mostly trilinerved or sometimes inconspicuously five-nerved, with conspicuous midrib on both surfaces. Mature leaves are dark green, while young leaves are reddish brown to yellowish-red. *Cinnamomum* is a genus of monoecious species, have hermaphrodite flowers, small, greenish white, white to yellow. The purplish-black fruit is an ovate, ellipsoidal or subglobose drupe. There are about 250 species of the genus *Cinnamomum* of the family Lauraceae in the world and they are spread out mostly in tropical and subtropical Asia [1].

Phenology can be defined as scientific study of the seasonal timing of life events. In plants, it is related to dates of plant growth phenomenon, such as flowering, leaf flushing or ripening of fruit [2]. Plant phenological patterns are influenced by environmental and biotic processes. In tropical regions, there is less seasonality with regard to temperature and day length; indeed, there is often greater diurnal than seasonal temperature variation. However, many tropical regions experience seasonality of rainfall, and phenological patterns are often related to this seasonality with peaks in fruit production occurring at the beginning of the rainy season [3,4]. Climate elements affect the phenology of plants such as the vegetative phase and reproductive components. This effect can be minor or major. It is suggested that
climatic factors not be directly responsible for triggering and synchronization of phono
gical events [5]. The production of flowering trees depends on the regularity of vegetative and reproductive activity. In the tropics, plant phenology is influenced by hydro period variation. The beginning and the end of rainy season cause the changes of plant vegetative and reproductive activities. Flowering, fruiting and seed set are very sensitive to water deficit [6].

Purwodadi Botanic Garden (PBG) is an ex situ conservation institution that has a main task to conserve plant species diversity. The garden has a collection of 2055 plants species including some Cinnamomum species (Registration data of Purwodadi Botanic Garden until December 2018). There are six species of Cinnamomum in the garden, namely Cinnamomum burmanii, C. iners, C. verum, C. sintoc, C. camphora, and C. celebicium. The first four species are periodically flowering and fruiting in the garden, but C. camphora and C. celebicium have never bloomed (preliminary research). Each plant species has a different pattern of flowering and fruiting time as influenced genetic and environmental properties [2]. Purwodadi Botanical Garden is included in a slightly wet tropical climate (Group C) with a dry climate (Group E) which occurs regularly, seasonal variations often occur [7]. The seasonal variations in the Purwodadi Botanic Garden appeared to affect phenological of species plant collections. Some fruit tree species showed different reproductive activities in response to hydro period variation in the Purwodadi Botanic Garden [8]. Environmental factors are related to the flowering of four Annona species that grow on Purwodadi Botanic Garden. Rainfall intensity (0-550 mm) affected to the flowering of Annona muricata, temperature (25,56-28,33°C) and humidity (66,83-85,02%) to A. squamosa, and humidity to A. glabra (71,62-85,02%) and A. montana (71,62 to 82,94 %) as well [9]. The aim of this research are to determine the reproductive activity pattern of all four Cinnamomum species and to know their respon in relation to seasonal change in rainfall, temperature and air humidity in Purwodadi Botanic Garden.

2. Methods
Four Cinnamomum species growing in PBG i.e: Cinnamomum iners, C. sintoc C. burmanii, and C. verum were observed their vegetative and reproductive activities once per week for 6-8 years of observation. Vegetative activities were the activity of plants in the formation of young leaves, mature leaves and senescence leaves. Whereas reproductive activities consist of flowering and fruiting activity that was found flowers (buds and blooms) and fruits (immature and ripe fruit) on plants [12]. Observations were conduct on 2 tree sample per species. The phenology of Cinnamomum iners and C. burmanii were observed from 2007-2010, then continued in 2015-2016. Cinnamomum verum were observed from 2007-2012. While C. sintoc were observed from 2007-2012 continued in 2015-2016. The observation was based on phenological characteristic such as the abundance of leaves (young, mature, senescence), flowers (bud, bloom) and fruits (immature, ripe) by scoring 0-4 in Table 1 [7,11]. Reproductive activities pattern was determined by frequency of flowering and fruiting of plant species in one year. There are continual (flowering or fruiting with sporadic brief break), sub annual (flowering or fruiting in more than one cycle per year), annual (only one major cycle per year), and supraannual (one cycle over more than one year) [12,13]. The rainfall per month (mm), temperature (°C), and humidity (%) were simultaneously recorded. All data were analyzed by Principal Component Analyses (PCA) to determine the microclimate variables that have correlation to the reproductive activity patterns of all four species.

| Table 1. Scoring estimation of the abundance of leaves, flowers and fruits. |
|---------------------------|---------------------------------|
| Score | Phenological characteristic |
| 0 | Trees without leaves, flowers or fruits |
| 1 | Trees show ≤ 25% of the character (leaves, flowers, fruits) |
| 2 | Trees show ≤ 26-50 % of the character (leaves, flowers, fruits) |
| 3 | Trees show ≤ 51-75 % of the character (leaves, flowers, fruits) |
| 4 | Trees show ≤ 76-100 % of the character (leaves, flowers, fruits) |
3. Results and Discussion

3.1. Reproductive activity patterns of four Cinnamomum species

Growth of young leaves of *C. iners* showed similar pattern to two other species of Cinnamomum i.e. *C. burmanii* and *C. verum* (Table 2). This species produced young leaves throughout the year. Whereas *C. sintoc*, had sub-annual patterns, young leaves grew two/three times in a year. In 2015, *C. burmanii* did not produce young leaves for 6 dry months (rainfall <100 mm) (Figure 1). While the mature leaves and old leaves of the four Cinnamomum species showed the same continual patterns, because the four species are known as evergreen trees.

| Phenological categories | C. iners | C. sintoc | C. burmanii | C. verum |
|-------------------------|----------|-----------|-------------|----------|
| **Vegetative Activity** |          |           |             |          |
| young leaves            | continual| sub-annual| continual, except in 2015 no young leaves until 6 months | continual |
| mature leaves           | continual| continual | continual   | Continual |
| senescence leaves       | continual| continual | continual   | Continual |
| **Reproductive Activity** |          |           |             |          |
| flowering frequency     | 1 times  | 1 times   | 2-3 times   | 2-3 times |
| flowering time / seasonal flowering | Annual | annual | January/Feb/March (minor), June/July (major); seasonal | Feb/March (minor), August, Sept, Oct (major); seasonal |
| flowering peak           | July/August | July | June/July | August, Sept, Oct |
| flowering period         | dry season | dry season | end of the rainy to dry season | end of the rainy to dry season |
| fruiting pattern         | annual    | annual   | sub annual | sub annual |
| fruiting                | ripe fruit present, except in 2012, 2015, 2016 | ripe fruit present, but in 2009, 2015, 2016 | ripe fruit present | ripe fruit present |

Flowering of *C. iners* and *C. sintoc* showed the same patterns, their flowering occurred once a year (annual). *Cinnamomum iners* produced flowers in July-August, when rainfall decreased (Table 2). Similarly, *C. sintoc* flowered in June-July, when rainfall decreased. While *C. burmanii* and *C. verum* had different patterns from *C. iners* and *C. sintoc*, namely subannuals (Table 2). This trees which categorized as subannual flowered 2-3 times yearly. *C. burmanii* flowered with minor period in January-March. Whereas *C. verum* flowered with minor period in April-May and major period in July/August (Figure 2). This condition is possible in the tropics because the sun passes overhead twice each year, influencing insulation rates and weather patterns. Biotic and abiotic factors have entrained a cyclic rhythm in the plants, at over evolutionary time. When conditions are not favorable for flowering, plants will be reduced of flowering intensity until this condition favorable for flowering [14]. This is thought
to occur in flowering of *C. burmanii*, which a long dry season in 2015 (6 dry months) apparently caused *C. burmanii* did not flower (Figure 2).

![Vegetative activities patterns of C. iners, C. sintoc, C. burmanii and C. verum](image)

*Figure 1. Vegetative activities patterns of C. iners, C. sintoc, C. burmanii and C. verum*

- □ = young leaves; □ = mature leaves; □ = senescence leaves; blank= missing data

![Flowering patterns of C. iners, C. sintoc, C. burmanii and C. verum](image)

*Figure 2. Flowering patterns of C. iners, C. sintoc, C. burmanii and C. verum* ; □ = bud; □ = bloom
From four Cinnamomum species observed, C. burmanii showed reproductive activity that was different from the others. Cinnamomum burmanii produced flowers and fruits only slightly abundance (score <1). While fruiting times of C. burmanii occurred in June/July. Cinnamomum verum produced fruits twice yearly. Fruiting major period occurred in August, September, and October. Cinnamomum verum showed more regularity in flowering and fruiting seasons compared to the other three species (Table 2).

Fruiting times of C. iners and C. sintoc showed the same annual patterns, those plants produced fruit once a year. Cinnamomum iners started to fruit in August and the fruiting peak was attained in September/October (Figure 3). Cinnamomum sintoc onset to fruit in July/August and the peak of fruiting times attained in September/October. In 2010, like C. iners, C. sintoc produced fruits with minor period.

![Figure 3. Fruiting patterns of C. iners, C. sintoc, C. burmanii and C. verum; □ = immature; ■ = ripe](image)

3.2. The relationship between climate factors and vegetative and reproductive activities of four Cinnamomum species

During eight years’ observation (2007-2012 and 2015-2016), climate in Purwodadi Botanic Garden showed average temperature and humidity that are almost the same pattern from year to year (Figure 4). Average rainfall shows a slight change in patterns, namely the change in the duration of the dry and wet months. Usually, there are 4-5 dry months (rainfall< 100 mm) takes place in Purwodadi Botanic Garden. In 2012 and 2015, long dry months occurred for 6-7 months. The opposite condition occurred in 2010 and 2016 which happened a long wet months (10-11 months) (Figure 4).

Based on the results of the PCA analysis, there were a relationship between climate factors and vegetative activity of C. sintoc, C. burmanii and C. verum. Whereas the vegetative activity of C. iners did not relate to climate (Figure 5). The abundance of mature leaves of C. burmanii showed a negative relationship to rainfall intensity, while the abundance of deciduous leaves was positively associated with humidity. Abundance of C. sintoc young leaves decreased, but senescence leaves will be more

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numerous with increasing temperature. Likewise the abundance of *C. verum* young leaves also decreased with increasing temperature (Figure 5).

**Figure 4.** Rainfall intensity per month during observation and average temperature (above) and humidity (below).

Flowering of *C. iners*, *C. sintoc*, and *C. verum* was not related to climate, but flowering of *C. burmanii* showed a positively associated with rainfall intensity. Decreasing rainfall caused *C. burmanii* produced little flowers. The low *C. burmanii* flower produced was related to adaptability of this species. *Cinnamomum burmanii* grows best at an elevation between 500-1,500 metres, whereas Purwodadi Botanic Garden is located at 350 meter above sea level (masl). In addition, this species prefers a mean annual rainfall in the range 2,000 - 2,500 mm, but tolerates 1,800 - 3,500 m. During observation, when along dry season, rainfall intensity in the garden was less 2000 mm.

Flowering of *C. iners*, *C. sintoc*, and *C. verum* which were not influenced by microclimate showed that the three species of plants carry out flowering activities regularly, not affected by the increasing and decreasing of rainfall, temperature and humidity. This indicates that these species are more adaptable to the changes of environment, so there is no change in flowering and fruiting patterns [13].

Figure 5 showed that the fruiting process of *C. burmanii* did not relate to climatic factors. This was because during the 4 years of observation this species did not produce fruit (its flowers were very little). However, fruiting of others *Cinnamomum* were related to air temperature and humidity. The fruiting of *C. sintoc* was negatively correlated to humidity. The increasing humidity caused decreasing of *C. sintoc* fruits. The fruiting of *C. verum* was related to temperature, increasing the temperature would increase its fruiting. The fruiting of *C. iners* was positively correlated to temperature and negatively to humidity. Figure 5 showed that the fruiting of *C. iners* would increase with the increasing temperature and decreasing humidity. *Cinnamomum iners* never produced ripe fruit, when longer wet months or longer dry months.
4. Conclusions
Flowering of C. iners and C. sintoc occurred once a year (annual), while C. burmanii and C. verum flowered twice yearly. Flowering and fruiting time for Cinnamomum species was almost similar, when rainfall decreased until the beginning of the dry season. Flowering of C. iners, C. sintoc, and C. verum was not related to climate, but flowering of C. burmanii showed a positively associated with rainfall intensity. Whereas the fruiting of C. iners, C. sintoc, and C. verum were associated with temperature and humidity.

Acknowledgement
We would like to thank Mr. Matrani for collecting data during observation. I am thankful to Abban Putri Fiqa for data processing.

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