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FLOWERING AND FRUITING CYCLE OF Cinnamomum sintoc Blume IN LOWLAND FOREST OF CIREMAI MOUNTAIN NATIONAL PARK, WEST JAVA AND THE IMPLICATION FOR CONSERVATION

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ABSTRACT

Cinnamomum sintoc Blume is an endangered species experiencing an ongoing decline due to overharvesting; in- and ex-situ conservation efforts are urgently needed to ensure its survival. We performed a detailed assessment of the flowering and fruiting phenology of C. sintoc in a lowland forest in West Java, Indonesia. We aimed to relate the duration of each phenological phase to environmental factors including elevation, humidity, temperature, and slope, as well as the orientation of the flowers. A total of 30 trees were sampled from three elevation ranges (500–700, 700–900, and 900–1,100 m). We found that C. sintoc requires approximately 40 days to complete flowering and an additional 82 days to produce mature fruit. The period from flower initiation to fruit ripening spans 4 months, from late July to early November. Flowers that are east-facing developed mature fruit more rapidly than those facing other directions, and the shortest flowering and fruiting phenological period was observed for east-facing flowers at 700–900 m. These results provide a baseline for studying phenological shifts in C. sintoc, and could inform seed harvesting efforts for conservation projects in the study area of Gunung Cermai National Park.

Key words: *Bintangkot, declining population, Endangered species, Lauraceae, phenology*

INTRODUCTION

Cinnamomum sintoc is a critically endangered species experiencing ongoing population decline due to overexploitation. The species is sought after and harvested for perceived health benefits (de Kok, 2019). Handayani (2018) reported ongoing population declines in several conservation areas, as well as an imbalanced population structure; seedlings were scarce relative to later growth stages, suggesting poor recruitment. Similar findings were reported from Bromo Tengger Semeru (Hidayat and Risna, 2007) and Ciremia Mountain National Parks (Ismail et al., 2019), located in East and West Java, Indonesia, respectively. The total population of *C. sintoc* is currently less than 50 individuals. Given the ongoing decline, *in*- and *ex-situ* conservation efforts are urgently needed, many of which rely on successful seed harvesting and propagation.

Obtaining high-quality seeds requires an understanding of plant phenology, including seasonal phenomena such as flowering, fruiting, and leaf drop (Yulistyarini 2020). Aside from factors related to internal biological processes, plant phenology is strongly influenced by the environment, especially air temperature and humidity, as well as the timing and length of rainy and dry seasons. These factors influence phenological timing because they are directly related to soil moisture and thus water stress (Moore &Laurenroth, 2017, Krishnan et al., 2020). The flowering process includes several phases that are influenced by different intrinsic and extrinsic factors. Although each flower produced by a plant has the potential to produce a seed, production rates can be extremely low, such that few seeds are available for harvesting or propagation. Thus, understanding flowering phenology is pivotal to plant conservation (Jamsari et al., 2007)

In a study of the flowering and fruiting times of four *Cinnamomum* species in Puwodadi Botanical Garden, East Java, Yulistyarini (2020) showed that *C. sintoc* typically flowers once per year, during the dry season in June and July, with peak flowering occurring in July. In a phenological assessment of the related *C. cullilawan* in Papua New Guinea, Herlina et al. (2022) found that flowering phenology was strongly influenced by air temperature and humidity, rainfall, light intensity, and wind direction. The flowering cycles of *Cinnamomum* in Sri Lanka are strongly affected by environmental factors, but the effects thereof can differ among species (Razad et al., 2018, Kubov et al., 2022).

We aimed to comprehensively assess the flowering and fruiting cycles of *C. sintoc*, to assist with conservation efforts. These data are critical for determining the optimal timing of seed collection for *in*- and *ex-situ* projects. Collectively, studies of *Cinnamomum* indicate that fruiting and flowering phases are influenced by local environmental factors. We aimed to assess each phase within the phenological cycle across an elevation gradient in Gunung Cermai National Park, West Java.

RESEARCH METHOD

We performed sampling in the Bintangot Block of Gunung Ciremai Mountain National Park, with sampling locations spanning an elevation range of 500–1,100 m above sea level (Figure 1). Sampling occurred from January to December of 2020.

We sampled 30 *C. sintoc* trees; 10 trees were selected within each of three elevation ranges (500–700, 700–900, and 900–1,100 m). We assessed the duration of five flowering and fruiting phases for each sample tree: flower initiation (F_0), small bud (F_1), big bud (F_2), flower opening (F_3), and fruit development (F_4). These categories were based on those described by Dafni (1992) (Table 1). In addition, we assessed the orientation (relative to cardinal directions) of the flowers. Some fruit and flower observations were made using binoculars, and photographs were taken of sample trees. Trees were marked using tree paint and/or tags. At the time of flower and fruit observations, we measured temperature (°C) and humidity using a thermometer and hygrometer, respectively. Slope was assessed for each sample tree using a clinometer. We assessed the relationships among the duration of each phase, flower orientation, and environmental factors (temperature, humidity, and slope) using ANOVA, and the Kruskal-Wallis and Mann-Whitney U tests. Analyses were performed using SPSS software (version 32.0; IBM Corp., Armonk, NY, USA).

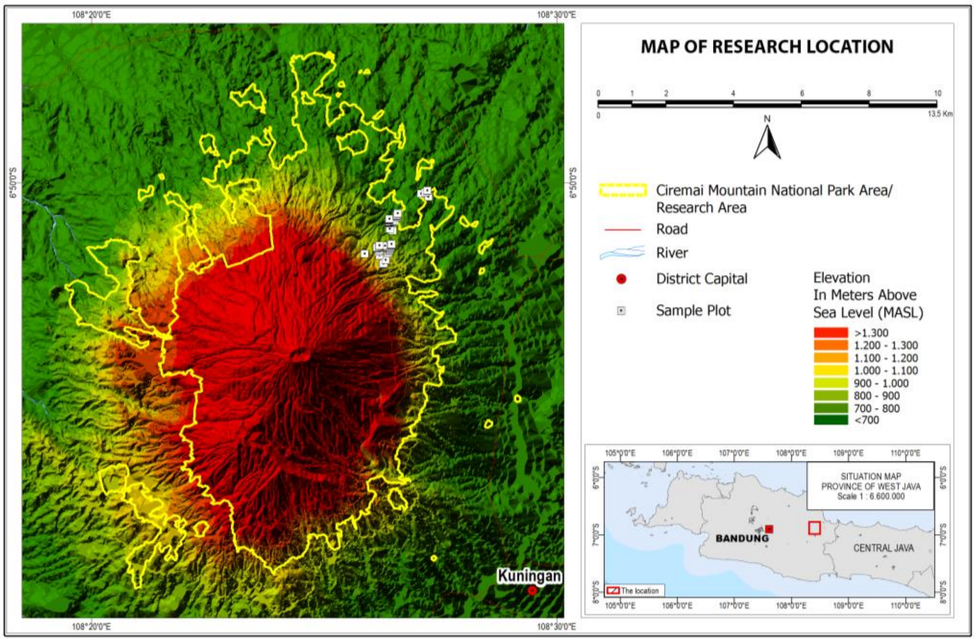

Figure 1. Reseach location at Bintangot Block, Gunung Cermai National Park. West Java

Table 1. Description of *C. sintoc* flower and fruit development phases (Dafni, 1983).

Phase	Symbol	Description
Flower initiation	F_0	Floral initiation begins when the bud emerges on the flower primordium until the beginning of the small bud phase characterized by the presence of clusters of composite flowers
The small bud	F_1	The small bud phase refers to the development phase occurring from the end of floral initiation until the flower crown emerges from the fruit primordium.
The big bud	F_2	The big bud phase begins when the crown emerges from the fruit primordium until the crown is open.
Flower opening	F_3	This phase occurs since the flower crown is open until the initial stage of fruit formation, indicated by the fall of the flower crown indicating the fertilization and the beginning of the fruit development phase.
Fruit development	F_4	The fruit development phase occurs from the end of the flower opening phase until the fruit is physiologically riped.

RESULT AND DISCUSSION

In total, 120 flowers were observed across the 30 sample trees. On average, the F_0 stage lasted for 14 days (range: 12–15), F_1 for 12 days (7–15), F_2 for 7 days (5–9), F_3 for 7 days (6–11), and F_4 for 82 days (77–90) (Table 2). On average, the entire flowering and fruiting cycle was completed in 121 days (112–132), i.e., approximately 4 months (Figure 2).

Light is one of the most important environmental cues for plants, influencing almost every life stage (Singh et al, 2014. Light acts as a sophisticated input signal influencing physiology and growth, as well as serving as the source of energy for CO_2 fixation during photosynthesis. We assessed floral orientation because flower development is strongly influenced by light intensity (Watanabe et al, 2015) and there is some evidence that temperature and photoperiod may work in tandem to affect flower opening (Razad et al., 2018). In our study, flower orientation did not significantly explain variation in the duration of the F_0–F_2 phases. However, there were significant differences among orientations in the F_3 and F_4 phases, with east-facing flowers having the shortest overall cycle and individual phase lengths. This is likely due to light intensity and duration, given that flowers that face east receive more intense light and have longer photoperiods.

There were significant differences in the duration of all five phenological phases, and total cycle length, among the three elevation ranges assessed in this study. The shortest-duration F_0 (12.7 ± 0.948 days), F_1 (9.4 ± 3.800), and F_2 (6.8 ± 1.0327) phases were seen at the lowest elevation range (500–700 m). The shortest F_3 and F_4 phases were observed in the mid-elevation range (700–900 m), as were the shortest total cycle lengths (119.8 ± 5.788) (Table 2). These differences are presumably related to variation in temperature and humidity across the elevation range. Differences in elevation relate to differences in plant flowering times (Widhiono et al., 2017) As elevation increases, temperature decreases and light intensity and ultraviolet radiation increase, which shortens the period available for plant growth (Kieltyk, 2021). Wind speed and evaporation also tend to increase with elevation. These factors are often associated with morphological changes, where plants growing at higher elevations tend to have smaller leaves and flowers relative to those at lower elevations. These changes tend to be more pronounced in large than small species. These factors all combine to create clear differences in plant phenology between high and low elevation areas (Maad et al., 2013). In general, plant reproductive physiology tends to be driven by temperature and humidity, which affect flowering time, pollen maturation and germination in vitro, as well as fruit formation (Singh et al., 2014). Bucher and Römermann (2020) noted that phenological patterns, including first and last flowering days and flower duration, are strongly influenced by daily air temperature and humidity, which are in turn related to elevation (Gordo & Sanz,2010).

We found that the period from flower initiation has an average length of 40 days, with an additional 82 days required for fruit maturation, in *C. sintoc*. We also found that the earliest mature fruit developed within approximately 116 days at an elevation of 700–900 m, and were from east-facing flowers. Understanding phenological cycles is critical for determining appropriate conservation strategies for endangered species (Rosemartin et al., 2014, Numata et al., 2022). Conservation area managers should understand factors that stimulate, regulate, and drive phenological cycles, and how these factors may change within or between plant populations and communities targeted for conservation (Polgar and Primack, 2011, Wolf et al., 2017). Understanding how these factors vary across time and geographic scale is also critical for managing conservation areas (Richardson et al., 2013)

Table 2. Duration of flowering and fruiting phase across three elevation ranges and four floral orientations relative to the cardinal directions (n =120).

Phase	Number of samples (n)	Average (day)	Min (day)	Max (day)
Flower initiation (*F_0*)	120	14	12	15
Small buds (*F_1*)	120	12	7	15
Big buds (*F_2*)	120	7	5	9
Flower opening (*F_3*)	120	7	6	11
Fruit development (*F_4*)	120	82	77	90
Flowering and fruiting phase	120	121	112	132

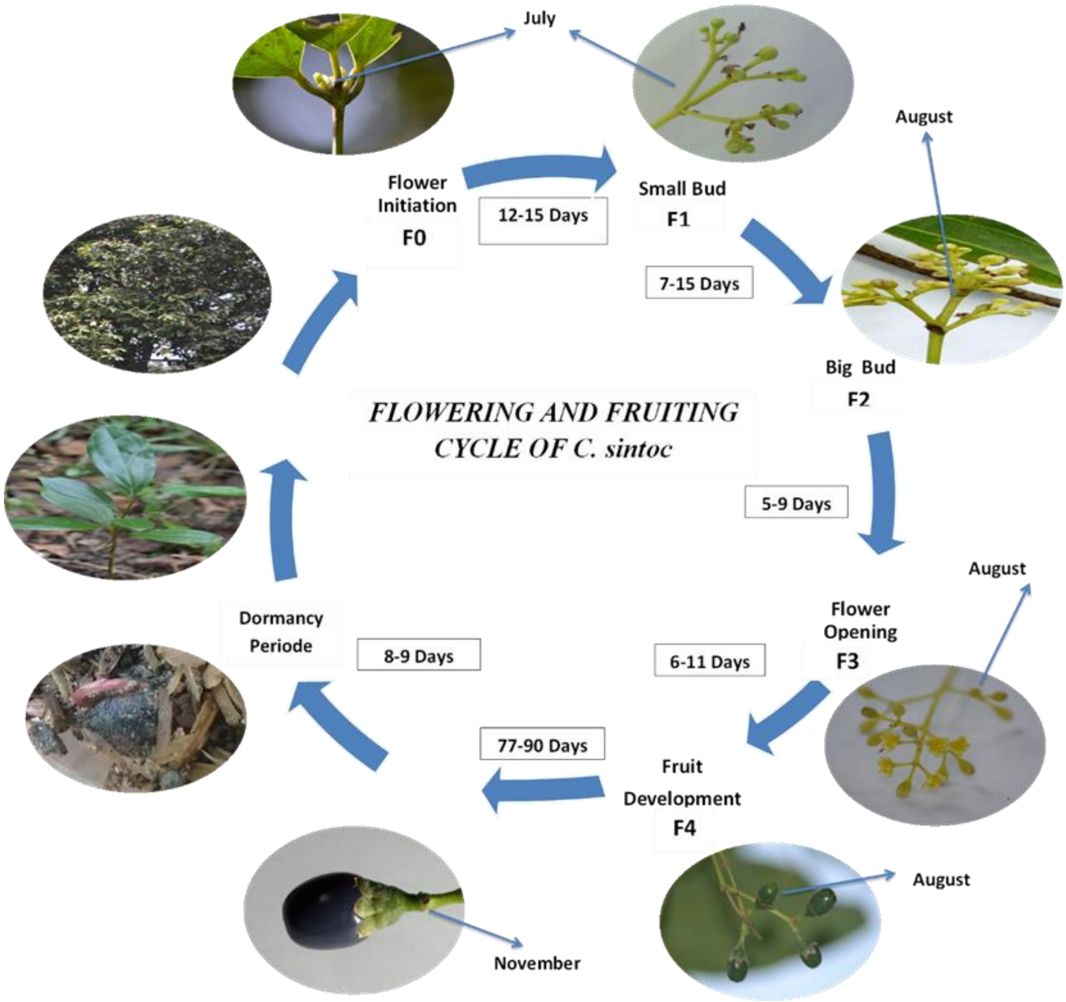

Figure 2. The flowering-fruiting cycle of *C. sintoc*

Table 3. Duration of flowering and fruiting phase between elevation and direction (means±stdev) (n=120)

Elevation	Parameters	North	South	East	West
500-700	Flower initiation (F_0)	14,2±0,421	14,2±0,421	14,2±0,421	14,2±0,421
700-900	Flower initiation (F_0)	12,7±0,948	12,7±0,948	12,7±0,948	**12,7±0,948** **
900-1100	Flower initiation (F_0)	14,0±0,000	14,0±0,000	14,0±0,000	14,0±0,000
500-700	Small bud (F_1)	12±3,464	12±3,464	9,4±3,864	9,4±3,800
700-900	Small bud (F_1)	9,4±3,864	9,4±3,864	**9,3 ±3,713***	9,4±3,800
900-1100	Small bud (F_1)	13,3±2,213	13,3±2,213	9,4±3,864	9,4±3,800
500-700	Big bud (F_2)	6,8±1,0327	6,8±1,0327	6,8±1,0327	**6,8±1,0327** **
700-900	Big bud (F_2)	7,2±0,632	7,2±0,632	7,2±0,632	7,2±0,632
900-1100	Big bud (F_2)	7,2±0,6324	7,2±0,6324	7,2±0,6324	7,2±0,6324
500-700	Flower Opening (F_3)	7,4±2,065	7,5±2,127	7,4± 2,065	7,4± 2,065
700-900	Flower Opening (F_3)	7,9±1,449	7,7±1,481	7,9± 1,449	7,9± 1,449
900-1100	Flower Opening (F_3)	6,1±0,316	6,1± 0,316	**6,0±0,00***	**6,2± 0,632** **
500-700	Fruit development (F_4)	82,1±4,148	82±3,887	81,4±3,921	82,8±3,614
700-900	Fruit development (F_4)	82,7±2,945	82,7±3,128	79.3±3,335	82,6±3,0623

Elevation	Parameters	North	South	East	West
900-1100	Fruit development (F_4)	82,5±2,549	82,5±2,415	**81,2±3,190***	82,3±2,496
500-700	Flowering and Fruiting phase	122,5±5,542	122,4±4,971	121±5,308	132,2±4,871
700-900	Flowering and Fruiting phase	119,9±0,519	119,9±4,771	**116,3±6,056***	**119,8±5,788****
900-1100	Flowering and Fruiting phase	123,1±4,773	123,1±2,643	121,8±3,326	123±2,309
500-700	Total cycle	122,5±5,542	122,4±4,971	121,8±5,308	123.2±4,871
700-900	Total cycle	119,9±5,820	119,9±4,771	**116,3±6,056***	**119,8±5,788****
900-1100	Total cycle	123,1±2,923	123,1±2,643	121,8±3,326	123±2,309

Legend : * shortest time between direction, ** shortest time between elevation

CONCLUSION

The average time from flower initiation to flowering in *C. sintoc* is 40 days, with an additional 82 days required for the production of fully mature fruit. The total flowering and fruiting cycle, from initiation to the production of ripe fruit, begins in late July and ends in early November. East-facing flowers reach maturity faster than those facing other directions, with the shortest total floral cycles for east-facing flowers seen at an elevation of 700–900 m. These results could inform conservation and seed collection efforts for *C. sintoc* in Gunung Cermai National Park area.

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