

Phenology of flowering and seed development of jernang rattan (*Daemonorops* spp.)

NELLY FRIDAYANTI¹, ENY WIDAJATI², SATRIYAS ILYAS², SRI WILARSO BUDI³,
ENDAH RETNO PALUPI^{2,✉}

¹Program of Seed Science and Technology, Graduates School, Institut Pertanian Bogor. Jl. Meranti, Kampus IPB Darmaga, Bogor 16680, West Java, Indonesia

²Department of Agronomy and Horticulture, Faculty of Agriculture, Institut Pertanian Bogor. Jl. Meranti, Kampus IPB Darmaga, Bogor 16680, West Java, Indonesia. Tel./fax.: +62-251-8629352, ✉email: endah_retno@apps.ipb.ac.id

³Department of Silviculture, Faculty of Environment and Forestry, Institut Pertanian Bogor. Jl. Ulin, Kampus IPB Darmaga, Bogor 16680, West Java, Indonesia

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Abstract. *Fridayanti N, Widajati E, Ilyas S, Budi SW, Palupi ER. 2023. Phenology of flowering and seed development of jernang rattan (Daemonorops spp.). Biodiversitas 24: 349-358.* Jernang rattan has a high economic value due to its resin content in the exocarp, as the raw material of dyes, medicines, and cosmetics. The resin is highest in the immature fruit skin (exocarp); therefore, fruits are harvested before the seed is germinable. As a consequence, regeneration is very scarce, and the species is categorized as a rare plant. This research was aimed at investigating the flowering phenology and seed development of jernang rattan until they reach physiological maturity, when the viability and vigor are at their highest. The flowering phenology was observed based on *Biologische Bundesanstalt Bundessortenamt and Chemische Industrie* (BBCH), at the inflorescence stage, flowering stage, fruit development stage, and fruit ripening stage. The inflorescence development from flower bud until ready to bloom took 136.4 ± 10.9 days for male plants and 141.6 ± 16.4 days for female plants. The inflorescence of staminate flowers bloomed longer (29.4 ± 2.7 days) than pistillate flowers (15.4 ± 4.0 days). Fruit abortion mostly occurs during the first six months of fruit development, coincides with the nuclear stage of endosperm, and the final seed set is 56%. It takes around 27 months of one reproduction cycle from the appearance of the inflorescence to seed maturity. The fruit reaches physiological maturity approximately at 22 MAA when the seed is of high viability and vigor, and harvesting at 22 MAA is best for seed production. It is recommended to set up a seed production area separated from the resin production area.

Keywords: Inflorescence, pistillate, physiological maturation, seed set, staminate

INTRODUCTION

Jernang rattan (*Daemonorops* spp., Arecaceae) has a high economic value due to resin content in the fruit skin or exocarp. Jernang resin is used as the raw material of dyes, cosmetics (Gupta et al. 2007), medicine against dysentery, diarrhea, astringent in the tooth-powders, and anti-aging skin creams (Morawiec and Tulik 2016; Rustiami et al. 2004). In international trade, this resin is called dragon's blood.

Jernang resin is extracted from the fruit skin or exocarp. High-quality resin is obtained from young fruit, and resin quality decreases as the fruit matures (Sahwalita and Herdiana 2019). Therefore, the fruits to produce high-quality resin contain immature seeds that are not worth planting materials (Sulasmi et al. 2012). Not only for the resin extraction but the inner part of the young fruit (except exocarp) is also commonly consumed as traditional medicine for stomach aches by the local community in Pante Bahagia Village, Sawang Sub-district, North Aceh District, Indonesia. The high demand for this resin is accompanied by high prices, ranging from Rp 2,000,000-5,000,000 per kilogram (approx. USD 130-330) in 2020 (Nurwiyoto 2021), causing the exploitation of jernang rattan in their habitat forest. In the Pante Bahagia Village,

Sawang Sub-district, North Aceh District, Indonesia, jernang rattan for resin production is usually harvested from the forest, in many cases, cutting down the plants. This practice disrupts natural regeneration and decreases the population, which urges a villager to domesticate jernang rattan for seed production. However, the germination rate is inconsistent due to genetically varied plants. Jernang rattan cultivation can be used as a measure to preserve the species, as well as used for resin production. Plantation for resin production should be separated from that for long-term seed production. Hence, quality seeds are required. To date, limited information on the flowering phenology and seed development of jernang rattan is available, and the identification of quality seeds for planting materials has not been set up yet.

Flowers play a vital role in plant reproduction. The fruit of jernang rattan determines resin production because the resin is sourced from the fruit. Knowledge about the flowering phenology and seed set is beneficial to (i) assist breeding activities, (ii) improve resin quality and yield, and (iii) produce quality seeds. Furthermore, the phenology study can be utilized to estimate a species' reproduction capacity and conservation management (Morellato et al. 2016; Copete et al. 2018). Jernang rattan is reported to have a polycarpic type of flowering with vegetative and

generative growth continuing until the plant dies (Dransfield and Manokaran 1996; Hourt 2008). Rattan jernang is included in the dioecious plant because staminate and pistillate flowers are born on different plants. Rattan flowers are in the form of panicles and arranged in bunches, each stem can produce 3-4 panicles every season (Renuka et al. 1998). Flowering times vary widely between species depending on location and season, as reported by Renuka et al. (1998) in *Calamus thwaitesii* and *Calamus andamanicus*, which flower in July-August.

Studies on the flowering phenology as well as fruit and seed development of jernang rattan are limited, and investigation on treatments to increase the seed yield and quality of jernang rattan has not been determined. Schmidt et al. (2019) reported that jernang rattan requires one year from flowering to seed maturation. The seed quality, i.e. viability and vigor, is highest when the seed reaches physiological maturity. However, information on the time the seed reaches physiological maturity, as well as the criteria of quality seed of jernang rattan is not available. According to Coimbra and Jorge (2011) one of the indications of mature fruit of Areceacea is that the fruits would abort. Nevertheless, the seed's physiological maturity may have been reached sometime before the fruits abort. Information on the flowering phenology, including fruit and seed development until reaching physiological maturity, is crucial to acquire quality seeds. Information on physiological maturation and criteria of quality seed would contribute to cultivation expansion for resin production as well as jernang rattan conservation in the future. The study aimed to investigate the flowering phenology, reproductive success, and seed maturation of jernang rattan.

MATERIALS AND METHODS

The observations on flowering and seed development were carried out from January 2019 to March 2021 at Sawang Sub-district, North Aceh District, Indonesia (5°3'10'N and 96°56'6E), with a latitude of 338 m asl. The plant samples were seedlings taken from the forest nearby and domesticated six-year earlier that have flowered 1-3 times.

Flowering and fruiting phenology

The observation on flowering phenology used five male plants and five female plants, which have flowered and were randomly selected from the jernang rattan-producing plant available inside (Figure 1). Three bunches of each plant were used as the replicates, with a total observation unit of 15 bunches of each male and female plant. Jernang rattan flowering phenology was directly observed, including flower and fruit morphological development from inflorescence to 24 months after anthesis (MAA). Morphological observation included the inflorescence and blooming phases, the sheath remains attached in the bunches after flower blooming, the length of the rachis, the number of subrachis (rachilla), the number of rachilla per rachis and the number of flowers per rachis of male and

female plants, the structure of staminate and pistillate flowers (number of petals, stamens, and pistils), and flower morphology (flower color, length, and width). Flower color was examined using Royal Horticultural Society (RHS) color chart.

Inflorescence and flower development

Jernang rattan flower development was observed based on *Biologische Bundesantalt Bundessortenamt and Chemische Industrie* (BBCH) (Meier 2001; Hormaza et al. 2012). The observed phases were inflorescence (phase 5), flowering (phase 6), fruit development (phase 7), and fruit ripening (phase 8). Measurement of the length of flower bunches (rachis) used three flower bunches of each plant, measured from the base to the end of the flower bunch when all flowers bloom (cm). The number of rachilla was calculated based on the number of rachilla contained in each rachis and averaged. The number of flowers per rachis was obtained from the total flowers contained in each rachis and averaged. Measurements on the average flower length and width used a vernier caliper, and 30 flowers were observed for each plant.

Stage 5 (Inflorescence): The inflorescence stage begins with flower buds until the flower sheath is fully formed on male and female plants.

Stage 6 (Flowering): The flowering stage was observed when the flower started to bloom (the prophyll leaves started to lift until all the flowers bloomed).

Stage 7 (Development of fruit): The fruit development stage was observed from one to 18 months after anthesis (MAA).

Stage 8 (Ripening of fruit): The fruit ripening stage was observed when the fruit size reached maximum until the fruit was ready to harvest.



Figure 1. Representatives of male (*left*) and female (*right*) *Daemonorops* plants that were domesticated six-year earlier that have flowered 1-3 times used in this experiment

Fruit and seed development

Observations on fruit and seed development were conducted from 1 MAA until 18 MAA with a two-month interval. The observed parameters were fruit set, seed set, fruit diameter, endosperm development, and seed length and width. Each ovary (pistillate flower) contains only one ovule, and therefore, the fruit set is also indicated as the seed set. The fruit set was calculated by the percentage of pistillate flowers that developed into fruits from 2-18 MAA. The fruit development was observed from 2-18 MAA based on the increase in diameter of 5 fruits each from 5 female plants. Observation on the endosperm was carried out at 1, 4, 8, and 2 MAA, with 2-3 young fruits from each inflorescence cut longitudinally to observe the development of endosperm from the nuclear state until they have cellularized (solid). Fruit length and width were measured directly while they were still intact on the inflorescence (non-destructive). The mature fruits are indicated by brownish mesocarp. The seed set was calculated by the percentage of flowers that developed into fruits with fully developed seeds inside in all rachis at 18 MAA.

Seed viability and vigor tests were used to determine the time when the seed reached physiological maturity. The study was arranged in a Completely Randomized Design (CRD) with a factor, fruit maturity, i.e.; 18, 20, 22, and 24 MAA with three replications, with 15 seeds used for each replication. The seed operculum was disposed of before germination by prying and then soaking in 1% chlorox solution for 30 minutes (Matana et al. 2013). Seeds were germinated on a sand medium in a plastic box (35 cm x 25 cm x 10 cm) at the screen house of Leuwikopo Research Station, IPB University. Observations were carried out on (i) germination percentage based on the number of normal seedlings at first count (72 days after planting/DAP) and final count (104 DAP), (ii) vigor index based on the number of normal seedlings on the first count (72 DAP) and (iii) speed of germination based on the percentage of normal seedling/day. The normal seedling criteria of jernang rattan are a minimum plumule length of 15 mm and fully developed roots with primary and adventitious roots (Figure 2).

Data analysis

Quantitative data was analyzed using F test ($\alpha=0.05$) and Duncan Multiple Range Test (DMRT) ($\alpha=0.05$) was used to test the significant difference among treatments whenever necessary. Other data were analyzed descriptively and presented using the standard deviation (SD).

RESULTS AND DISCUSSION

Flowering and fruiting phenology

Inflorescences appear consecutively from January until September, when the average temperature ranged 26.5-

27.4°C. The inflorescences emerged as early as August to September with a rainfall of 2.33 mm per month, while the peak emergence of inflorescence was from March to May, coinciding with higher rainfall of 6.67-20.75 mm per month, during which both staminate and pistillate inflorescences appeared. Inflorescences appear in the axils of the leaf midrib, protected by a flower sheath. Inflorescence development from appearance until reaching the maximum size took a total of 166-179 days for staminate inflorescences and 157-177 days for pistillate inflorescence (Figure 3). The inflorescence development consisted of several stages (Table 1). The entire inflorescence was covered by a large protective leaf or flower sheath before blooming. The main axis on which the flower grows is called the rachis, while the lateral branches from the inflorescence axis are called the rachilla (Mercadante Simoes et al. 2006). Flowers bloom from the top rachilla towards the end of the flower sheath. This process is called acropetal.

Table 1. Stages of development of staminate and pistillate inflorescences of jernang rattan (stage 5)

Stage	Inflorescence development
501	Inflorescence appeared in the axils of the leaf midrib (Figure 3.A)
502	Inflorescence elongated (16 cm) (Figure 3.B)
503	Inflorescence elongated further (28 cm) and began to show prophyll leaves (Figure 3.C). The flower was still protected by a flower sheath (spatha)
505	The rachilla was formed, and the numbers varied, ranges from 11-14 rachilla in staminate inflorescences, and from 9-11 rachilla in pistillate inflorescences (Figure 3.D)
509	The inflorescences or flower sheath was fully formed, 66-121 cm long in staminate inflorescences, and 66-98 cm in pistillate inflorescences (Figure 3.E)

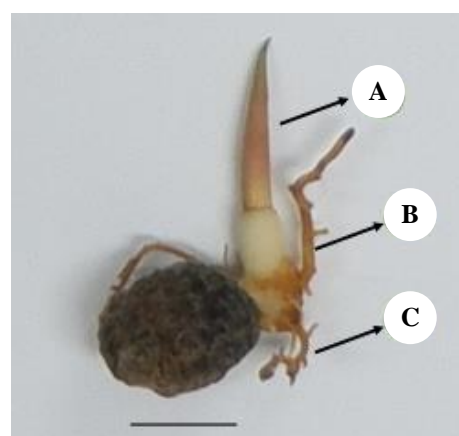


Figure 2. Normal seedling of jernang rattan: A. Plumule, B. Adventitious roots, and C. Primary root. Scale = 1 cm

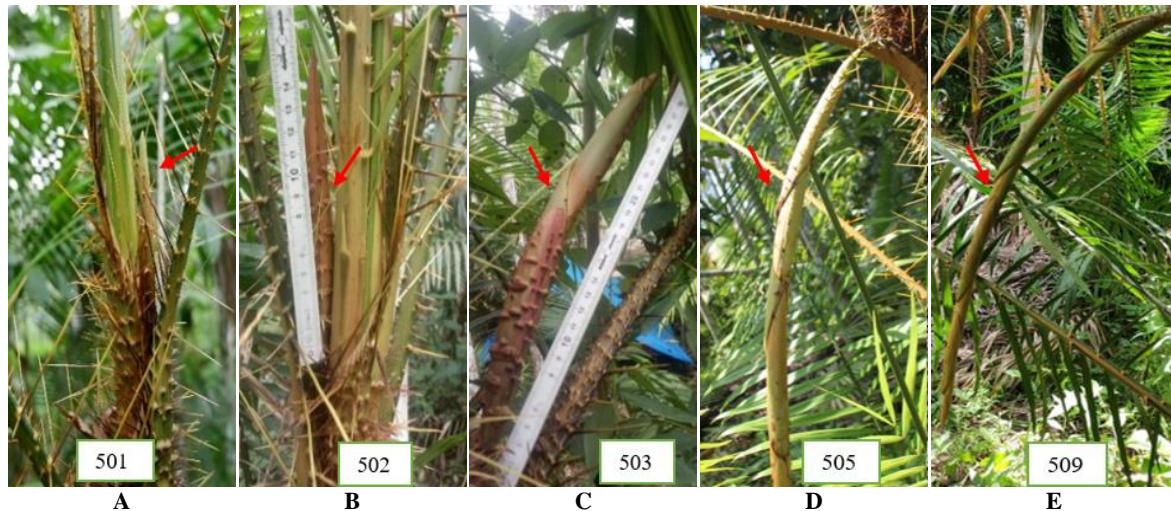


Figure 3. Inflorescence development stages from emergence to fully formed flower sheath (red arrow) of jernang rattan

Staminate and pistillate flowers bloom as early as May, when the temperature is 27.20°C with rainfall of 20.75 mm and last until October, when the temperature is 27°C and the rains less at 6.91 mm. The peak of blooming occurs in July-August, when the transition of the rainfall of 12,55 mm to 1.50 mm, followed by fruit development (Figure 4). An inflorescence of pistillate flowers blooms for 15.4±4.0 days (Table 2), during which around 542.7±80.2 of flowers are blooming consecutively. Staminate flowers inflorescence blooms for a longer period of 29.4±2.7 days (Table 3), during which around 5168.8±1349.8 flowers are consecutively blooming. The number of flowers in the staminate inflorescence is almost ten-fold those of pistillate inflorescence, showing that lack of pollen is not very likely the limiting factor of seed production, but lack of pollinators could be. But, along with the observation of the blooming period, some insects were found in the blooming male and female flowers, mainly in the ordo *Coleoptera* family Curculionidae, Nitidulidae, dan Staphylinidae.

Table 2. Stages of pistillate flower blooming of jernang rattan (stage 6)

Stage	Pistillate flower blooming
600	Flower bunch reached the maximum size. The prophyl leaf uplifted indicating the beginning of flower blooming (Figure 5.A)
601	The protective leaf of the flower began to open. Some flowers started blooming, beginning from those at the proximal end (Figure 5.B)
602	The protective leaf was completely opened, and more flowers were blooming. The blooming of a pistillate inflorescence lasted about 15.4±4.0 days (Figure 5.C)
607	Peak blooming period, most flowers were blooming, the perianths splayed widely showing pistil with three-forked stigma. The pistillate flowers emitted a sweet odor possibly to attract pollinators (Figure 5.D)
609	The petals and stigma dried up, but the pistil remained fresh and intact. The ovary began to enlarge, indicating the beginning of fruit development (Figure 5.E)

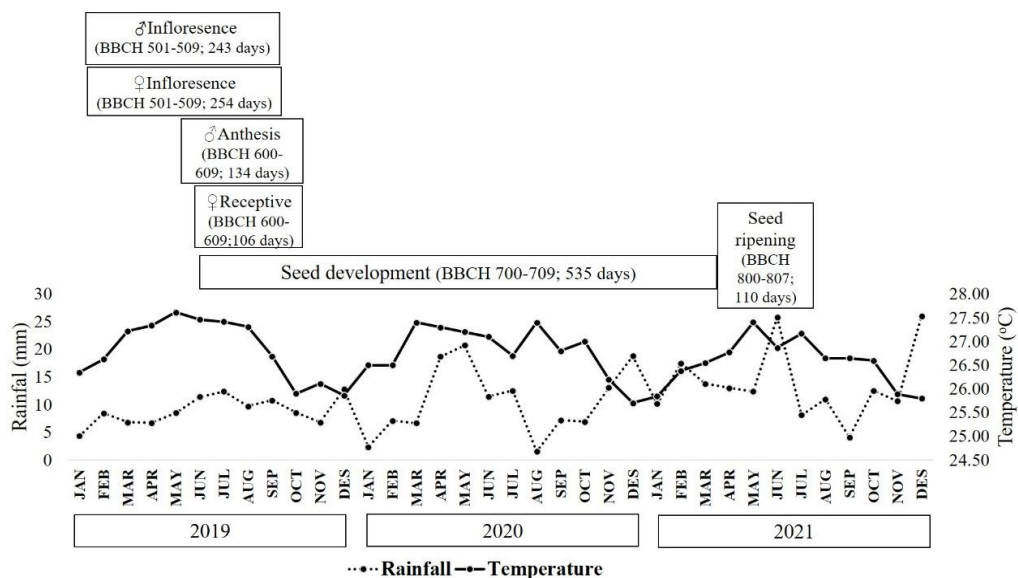


Figure 4. Flowering phenology and seed development based on BBCH criteria taken from 3 consecutive inflorescences from 5 male and female plants in *Daemonorops* spp. population in Pante Bahagia, Sawang Sub-district, North Aceh District, Indonesia from 2019 to 2021

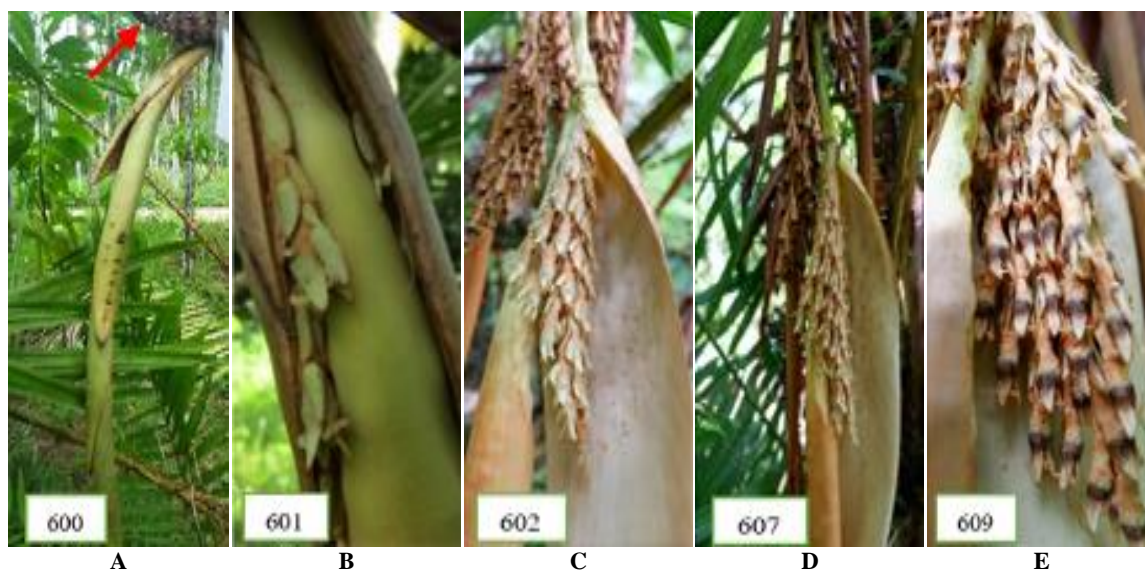


Figure 5. Stages of pistillate flower blooming of jernang rattan

Table 3. Stages of staminate flower blooming of jernang rattan

Stage	Staminate flower blooming
600	The flower inflorescence reached maximum size, the prophyll leaves opened up indicating the beginning of flower blooming (Figure 6.A)
601	The protective leaves of the flower began to open starting from the top rachilla and few flowers at the proximal end of the inflorescence started blooming (Figure 6.B)
602	The protective leaf was completely opened, more flowers were blooming. The blooming of a staminate inflorescence lasted about 29.4 ± 2.7 days (Figure 6.C)
607	Peak blooming period most flowers were blooming, the perianth as well as the stamens splayed widely (Figure 6.D)
609	After anthesis, all the staminate flowers dried and aborted (Figure 6.E)

Each bract in pistillate inflorescence (Figure 7A.1) subtended a dyad of a fertile pistillate flower and a sterile staminate flower (Figure 7A.2) (Dransfield and Uhl 1998).

The stamens of the sterile staminate flowers were not fully developed (Figure 7A.3). The pistillate flower was larger than the staminate flower, and had a pistil with a three-forked stigma (Figure 7a.4). Staminate inflorescences (Figure 7B.1) bore a large number of fertile staminate flowers (Figure 7B.2) with six stamens, and was larger than the staminate flowers in the pistillate inflorescence (Figure 7B.3). Both staminate and pistillate flowers have three yellow petals (RHS 8C) (Figure 7).

The development of staminate inflorescence (136.4 ± 10.9 days) was five days shorter than pistillate inflorescence (141.6 ± 16.4 days), but the number of flowers in a staminate inflorescence (5168.8 ± 1349.8 flower) was much larger than the pistillate inflorescence (542.7 ± 80.2 flower). Staminate inflorescence had an average length of flower sheath, number of rachilla, and number of flowers on each rachis greater than pistillate inflorescence (Table 4). The blooming phase of a staminate inflorescence (29.4 ± 2.7 day) was longer than the pistillate inflorescence (15.4 ± 4.0 day) which ensured the availability of pollen during the flowering season.

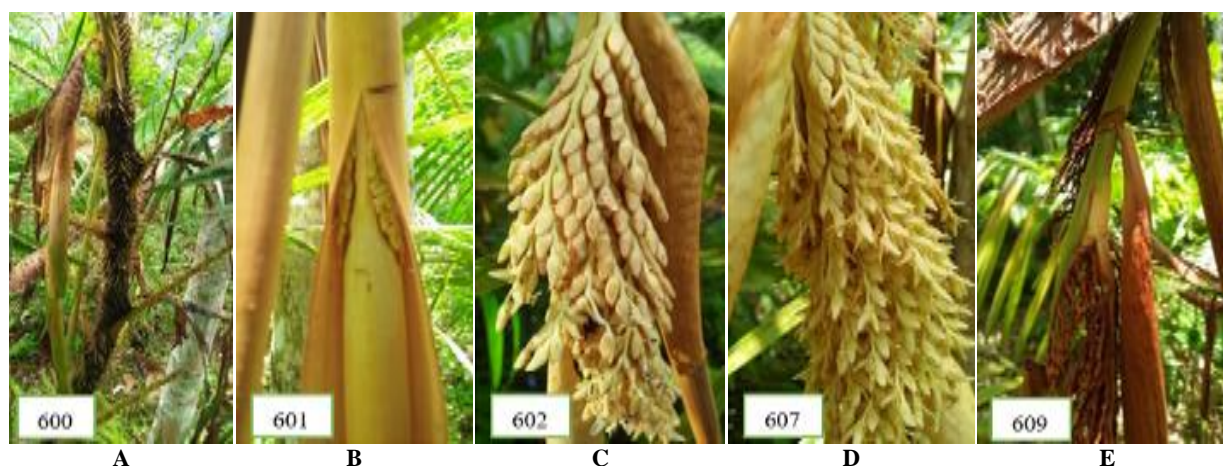


Figure 6. Stages of staminate flower blooming of jernang rattan

Table 4. The characteristics of staminate and pistillate inflorescences of jernang rattan

Sampel	Inflorescence phase (day)	Blooming phase of an inflorescence (day)	Inflorescence length (cm)	Number of rachises	Number of flowers per inflorescence	Flower length (mm)	Flower width (mm)
SI 1	138.0	29.3	120.7	12.0	5111.3	5.3	2.0
SI 2	133.7	33.0	66.3	11.7	3125.7	6.0	2.0
SI 3	121.0	25.7	82.3	12.7	5246.7	5,5	2.0
SI 4	138.0	30.7	121.3	14.0	6907.7	5,6	2.0
SI 5	151.3	28.3	120.7	12.7	5452.7	6,5	2.0
Average	136.4 ±10.9	29.4 ±2.7	102.3 ±26.1	12.6 ±0.9	5168.8 ±1349.8	5.8 ± 0.5	2.0 ± 0.0
PI 1	125.3	11.7	98.7	9.0	554.3	10.1	4.4
PI 2	165.7	13.0	94.7	10.3	662.7	9,9	4.3
PI 3	146.0	21.7	91.7	12.0	553.3	9,9	4.1
PI 4	127.3	16.7	66.7	10.0	493.3	9,6	4.2
PI 5	143.7	14.0	80.0	9.0	449.7	9.6	4.1
Average	141.6 ±16.4	15.4 ± 4.0	86.3 ±13.0	10.1 ±1.2	542.7 ±80.2	9.8 ± 0.2	4.2 ± 0.1

Note: SI: staminate inflorescence; PI: pistillate inflorescence

The development of staminate inflorescence coincided with pistillate inflorescence (Stage 5) which lasted for about four months, followed by flower blooming of both sexes that lasted about a month (Stage 6). Following pollination, the pistils developed into fruits. Fruit development from anthesis until they reached the almost maximum size (Stage 7) took about 18 months, followed by accumulation of reserves until the fruits physiologically matured, that took about six months. Therefore, from generative bud appearance until the fruit's maturation took about 29 months (Figure 8). For resin production of the

highest quality, the fruit needed to be harvested at stage 707, about 7-8 months after anthesis (Table 6). At that stage, the seed had not yet matured physiologically and was of low viability, therefore, the seed could not be used as planting material.

Fruit ripening was the final stage of seed production. The ripened fruit was characterized by a bright reddish and slightly shiny exocarp (Table 7, Figure 10) at about 29-30 months after anthesis. At this stage, the fruit is prone to predatory due to the sweet taste of the mesocarp. The fruit will abort naturally when they were not harvested.

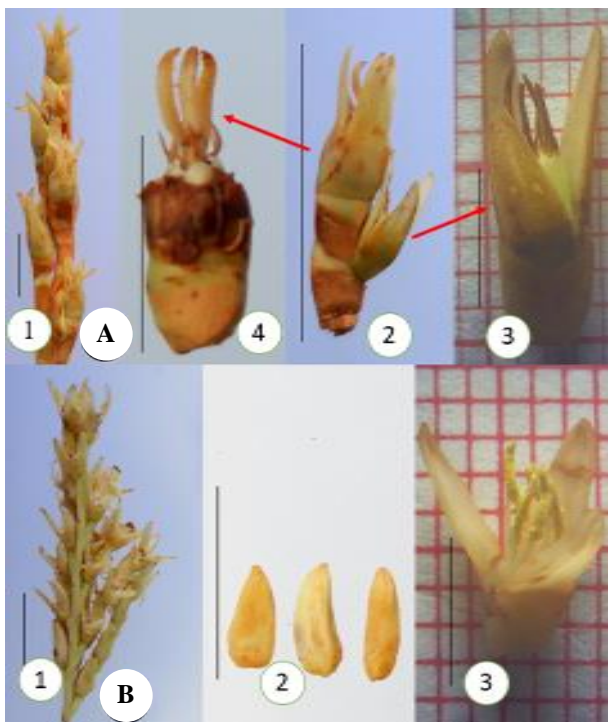


Figure 7. Morphology of pistillate and staminate flowers: (A.1) female inflorescence, (A.2) dyad of a fertile pistillate flower accompanied by a sterile staminate flower, (A.3) a sterile staminate flower, (A.4) pistil with three forked stigma, (B.1) staminate inflorescence, (B.2) fertile staminate flowers, and (B.3) fully developed stamens. 1 cm scale

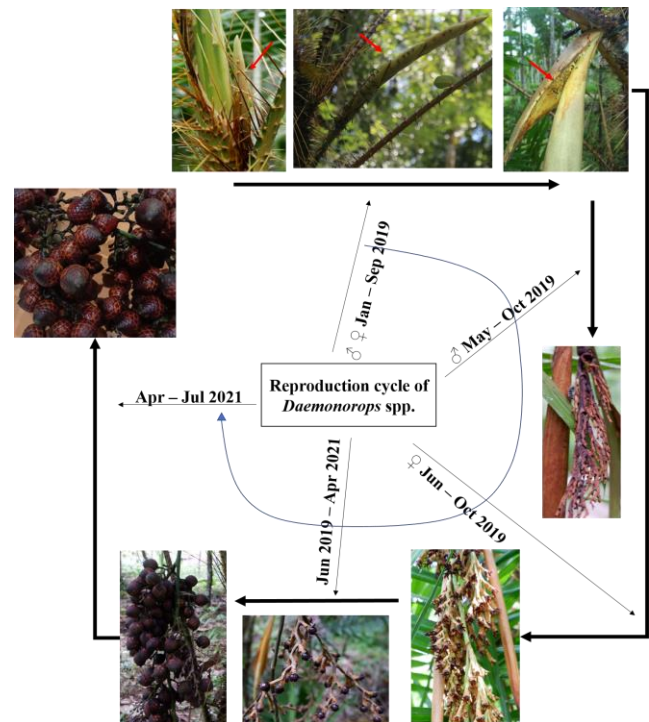


Figure 8. Reproduction cycle of *Daemonorops* spp. population in Pante Bahagia Village, Sawang Sub-district, North Aceh District, Indonesia during 2019-2021

Table 6. Stages of fruit development of jernang rattan

Stage	Fruit development
700	Beginning of fruit development following the pollination of pistillate flower, all perianth were aborted, the stigma was kept intact and the ovary began to enlarge (Figure 9-700)
705	The fruit (ovaries) diameter had enlarged to about 10.90 mm, black in color and glossy, the endosperm was still fluid indicating a nuclear type of endosperm (Figure 9-705)
707	The fruit development continues, became reddish black with diameter of 14.17 mm (Figure 9-707)
708	Fruit size has reached 80% of maximum size (17.44 mm), the endosperm became cellularized/solid and the endocarp becomes harder (Figure 9-708)
709	Fruit development reach its final stage in which the fruit had reached its maximum size. The exocarp was black in color and less shiny because the resin content had been declined, with harder endocarp (Figure 9-709)

Table 7. Stages of fruit ripening of jernang rattan

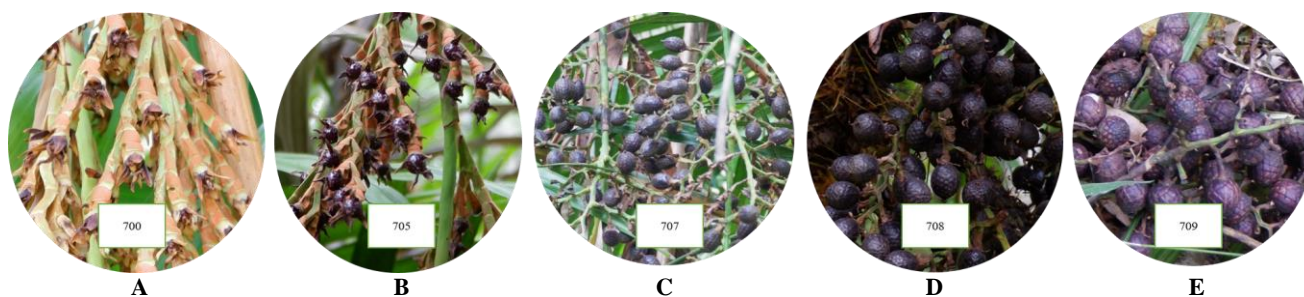
Stage	Fruit ripening
800	The fruit reaches its maximum size, black in color and dusky due to lessened resin content, and the fruit scales are visible. Endocarp and endosperm become harder (Figure 10-800)
805	The fruit was reddish, the endocarp and endosperm become very hard, and the mesocarp was soft and sweet
807	Fruits had ripened, with reddis hexocarp, the fruit scales were clearly visible, the mesocarp was soft and sweet. The seed had a hard endosperm

Seed set and seed production

The initial seed set was high, reaching 100% at 2 MAA, indicating that pollination was not a limiting factor for seed production, however, the final seed set was around 50% (Table 8). Abortion of immature fruits was as high as 36% during the first six months of fruit development. The cause of fruit abortion could not be clarified from this research, but possibly due to nutrient competition among the developing fruits. In most cases, the aborted fruits did not show any defect or infection of diseases but were usually smaller than the average. The fruit diameter continued to increase from the initial fruit set until 16 MAA, when the increment was no longer significant.

Observation of endosperm showed that the endosperm was of nuclear type as also in date palm (DeMason et al. 1989) and oil palm (Kok et al. 2015), another member of Arecaceae. The nuclear endosperm was observed from 1 MAA until 8 MAA when it started to become cellularized. The endosperm was completely cellularized by 12 MAA (Figure 11). Fruit abortion was highest during the first six months of development (Table 8) and coincided with the nuclear stage of endosperm development.

The quality of the seed was maximum at 22 MAA when the germination percentage, vigor index and germination speed were highest (Table 9). Delaying fruit harvesting until 24 MAA did not increase the seed quality. The data implied that the seed's physiological maturity was reached at 22 MAA, when the dry weight also has at the maximum, much later than fruit harvesting for resin production (7-8 MAA).

**Figure 9.** Stages of fruit development of jernang rattan**Figure 10.** Stages of fruit ripening of jernang rattan

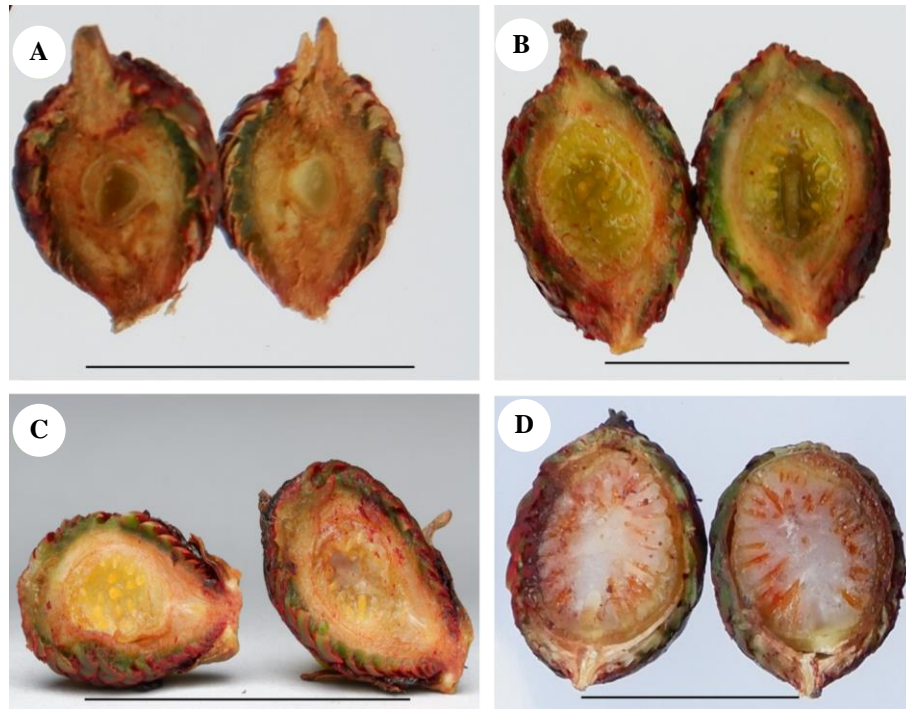


Figure 11. Endosperm development: A. 1 MAA, B. 4 MAA, C. 8 MAA, D. 12 MAA (scale = 1 cm)

Table 8. Fruit set and diameter during fruit development of jernang rattan

Variables	Stage of fruit maturation (MAA)								
	2	4	6	8	10	12	14	16	18
Fruit set (%)	100	76.9	64.0	59.8	57.9	57.1	56.7	56.4	56.2
Fruit diameter (mm)	7.3	9.7	12.2	14.3	16.5	18.5	20.4	21.4	21.8

Table 9. The seed viability and vigor of jernang rattan at different stages of maturation

Harvest age	Variables			
	GP (%)	VI (%)	GS (%NS/day)	DW (g)
18 MAA	75.56 bc	62.22 b	1.21 b	32.65 a
20 MAA	60.00 c	48.89 b	1.03 b	33.57 b
22 MAA	97.77 a	95.56 a	1.67 a	33.29 b
24 MAA	95.53 ab	86.67 a	1.64 a	33.27 b

Note: Numbers followed by the same letter within the same column are not significant differences based on DMRT $\alpha=0.05$. GP: germination percentage; VI: vigor index, GS: germination speed, NS: normal seedling; DW: seed dry weight

Discussion

Jernang rattan flowered throughout the year. Flowers appear sequentially, starting from the bottom and continuing upward following the growth of plant height. Before the seed reaches physiological maturity, another flower is formed. The inflorescence of jernang rattan is categorized as determinate and develops from January to September. Several other types of Arecaceae also flower throughout *Manicaria saccifera*, *Johannesteijsmannia lanceolata* and *J. perakensis* (Copete et al. 2018; Chan dan Chua 2019). The peak flowering occurs during March-May, at the beginning of the dry season, when more insect pollinators are available, similar with what was reported by Chan and Chua (2019) in *Johannesteijsmannia* spp.

showed the peak of flowering in April. The fruit was developed early before pollination and pistillate blooming, similar to other Arecaceae plant species showed that fruit development is independent with pollination (Thomas and Josephraj Kumar 2013; Krisanapook et al. 2019). Therefore, the initial fruit set is as high as 100%. The pollination occurs when the pistillate flowers are blooming (June to October 2019) whereas the staminate flowers blooms earlier, providing pollen before the first pistillate bloom (June) until the end of pistillate last bloom (October). Since the blooming period of pistillate and staminate flowers overlap, indicating the source of pollen is not an issue. The fact that staminate flowers are much higher in number (ten-fold) and longer in blooming period than pistillate flowers.

This ensures that sufficient pollen is available to pollinate the pistillate flowers (Mohd-Rusdi et al. 2022; Otero-Arnaiz and Oyama 2001). Higher number of staminate flowers than pistillate flowers is also found in other members of Arecaceae, i.e., *Licuala spinosa*, *L. distans* and *L. peltate*, *Cocos nucifera* L., and *Bactris guineensis* (Barfod et al. 2003; Perera et al. 2010; Oviedo et al. 2020). The flowers are arranged in a dyad, in which all fertile pistillate flower is accompanied by a sterile staminate flower (without pollen). Kidyoo and McKey (2012) reported that sterile staminate flowers on *Calamus castaneus* act to attract insect pollinators that are more attracted to staminate than pistillate flowers. The staminate flowers produce some chemicals named olfactory, which is also found in dyad flowers but not as strong as in the fertile staminate. We predict such a phenomenon also occurs in the *Daemonorops* spp. population observed in this study and this may also be a mechanism to ensure sufficient pollination.

Fruit development (fruit ring increase) starts to occur from 2 MAA to 16 MAA. Fruit development occurs due to cell division and development. The double fertilization event angiosperm type initiates the development of two different structures: the embryo and the endosperm. The endosperm plays a critical role in supporting embryo growth. The main function of the endosperm is as a source of nutrition and/or as a regulator of embryonic growth during seed development and germination (Yan et al. 2014).

Fruit abortion mostly occurs during the first six months of fruit development coincides with the nuclear stage of the endosperm. The early and rapid development of endosperm requires high food reserves, therefore competition among fruits within an inflorescence is high. Carvalho et al. 2015 reported Thinning of smaller fruits could be one of the alternatives to reduce abortion, but more detailed research is needed to clarify this problem. Stephenson (1981) proposed some hypotheses to explain low surplus flower and juvenile fruit production: (i) uncertainties pollinations, (ii) predatory and resource availability, (iii) the male in the hermaphroditic flowers, and (iv) maintain the fruit/seed quality by selective abscission. Oviedo et al. (2020) reported that the protective leaf might inhibit or limit insect pollinators. In this study, the staminate inflorescence bloomed longer than the pistillate ones, the blooming time of both staminate and pistillate inflorescences overlapped, indicating that sufficient pollen was available for pollination. The possible cause of fruit abortion during the first six months of development can not be clarified in this study. However, we observed that the inflorescence sheath remained attached to pistillate inflorescence until the blooming period was completed, which may cause pistillate flowers were less exposed to the pollen dispersal resulting in insufficient pollination, that is a low number of pollen reaching the stigma.

Fruit ripening starts with the fruit having the maximum size, black color, and looking dusky until the fruit is ready for harvest (Figure 10). The maximum fruit size is associated with the accumulation of food reserves formed.

The fruit reaches physiological maturity at approximately 22 MAA when the seed is of high viability and vigor.

Fruit abortion is as high as 44%, resulting in 56% seed set. Bearing in mind that the population of the species is getting rare in nature and the reproduction cycle takes a long period (>2 yrs) it is worth taking the effort to set up a seed production area that is separated from the resin production area. So that resin production can be maintained or enhanced without endangering the species.

One reproductive cycle of rattan jernang takes around 27 months. The beginning of the rainy season and relatively low temperatures mark the start of the reproductive phase, starting with the appearance of inflorescence. Both pistillate and staminate inflorescences appear in January-September. The peak flowering season occurs in May. Staminate flower inflorescences are more numerous, last longer, and overlapping with pistillate flowers ensures pollen supply for pollination. Jernang rattan type of flowering is dioecious, the morphology of female flowers is sheathed and the dyad is observed as the lack of fertilization possibility responsible for low reproductive success. The fruit development and ripening phases are the most prolonged reproductive cycle. Seed physiological maturity attained at 22 MAA. Although one reproductive cycle takes a very long time, the rattan jernang fruiting all year round and the flowering with vegetative and generative growth continuing until the plant dies makes it possible to produce rattan seedlings throughout the year.

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