Reproductive phenology of Bruguiera sexangula (Lour.) Poir. in Berbak and Sembilang National Park, South Sumatra

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Original Article

Reproductive phenology of *Bruguiera sexangula* (Lour.) Poir. in Berbak and Sembilang National Park, South Sumatra

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Abstract

Phenology is the study of the period phases which occured naturally in plants. Information about phenology is essential for the sustainable management of mangrove area. During these phases was significantly influenced by the circumstances surrounding environment as ever shines, temperature, and humidity. Observations of the phenology is devoted on mangrove *Bruguierasexangula*, especially since the phenology information about *B. sexangula* is still restricted in Berbak and Sembilang National Park, South Sumatra. Research was carried out in February-September 2016. The methods used in this research is a tagging method or labelling on flower buds and observed till the stage of being a mature propagule. Initiation of flowering *B. sexangula* was occurring in February, the next step was the flowering that occurs from April to June, while the bear season occured from late June-July. The stage of maturation of propagule until October. Harvest time of propagule *B. sexangula* was conducted in October. Flower initiation of *B. sexangula* stage to propagule maturity stage takes about 7 months

Keywords: *Bruguiera sexangula*, conservation, flower, mangrove, phenology

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Introduction

The condition of the mangrove in Berbak and Sembilang National Park (BSNP) area, South Sumatra suffered the pressures and degradation from year to year since 1995 (2010; Suwignyo et al., 2012; Munandar et al., 2014; Sarno et al., 2015). The current state of the forest experienced a reduction of area of 3,552 ha during the period 2001-2009. One of the damage the mangroves in the region caused by conversion of mangrove forests being farmed. Instead the conversion of forest resulted in depletion of mangrove ecosystem function so that the necessary existence of replanting efforts. Anthropogenic factors is the cause major on the damage of mangroves ecosystem (Duke et al., 2007; FAO, 2007; de Silva and Amarasinghe, 2010; Satyanarayana et al., 2011; Aluri, 2013).

The replanting of mangrove seedlings required i.e. mature propagule as the nursery. Seed maturation process that occurred since fertilization is shown by the existence of changes in morphology, biochemistry or physiology. One of the factors that have a level of quality seed is a process of growth and maturity of the seed. Thus to know when the propagule is mature by its phenology.

The study of developmental stages of the developmental process of flowering up to seed or mature propagule called phenology. phases was significantly influenced by the circumstances surrounding environment as ever shines, temperature, and humidity. Therefore the research aspect to noted in the study of environmental factors is phenology as an important factor of mangrove phenology observations. Due to environmental factors and the developmental process of interest, relationship of mutual reciprocity between climate and biological phenomenon (Sarno et al., 2015; Sarno & Ridho, 2016).

Bruguiera in Indo-West Pacific mangrove genus is a dominant (Sun & Eyy, 2011), global distribution is affected by environmental factors such as temperature (Tomlinson, 1986) and salinity (Robertson & Alongi, 1992). Bruguiera can grow up to 30 m, usually associated with *Sonneratia caseolaris* (Duke et al., 2010). Bruguiera Is a kind of mangrove which has Important Value Index (IVI) low on the region (BSNP, South Sumatra). The role of a kind of showed a high IVI then these types of very big role against other types of mangrove in the ecosystem. Bruguiera has a low IVI compared to other types of mangrove. This proves the role of Bruguiera are smaller in ecosystem (Theresia & Pratiwi, 2016). Therefore, for the sustainability status of Bruguiera type then it becomes interesting to learn the phenology development.

The phenology information about *B. sexangula* is still restricted in BSNP, South Sumatra. As long as this data is used as a reference to see the characteristics and phenology of the mangrove is "Handbook of Mangrove in Indonesia Bali and Lombok" (Kitamura et al., 1997). The use of the book is only used for reference in view of the characteristics of mangrove type and could not be used as a reference to illustrate the propagule time of *B. sexangula* is rippen in the region.

This research was conducted to know the stages of flowering phenology of *B. sexangula* and it characteristics, to know the rippen propagule of *B. sexangula* and it characteristics from the ripen propagule phase to the mature, to know the characteristics of

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generative organs of *B. sexangula* flower. Based on the objective above, the results of this study are expected to provide information about phenology data of *B. sexangula* in BSNP area.

Methods

The phenology observations has been performed in February 2016 until September 2016 in Barong Kecil, BSNP, South Sumatra (Fig. 1). The tools used on these observations are stationery, notebooks, cutter, GPS, caliper, the meter of fabric, ribbon, and soil tester.

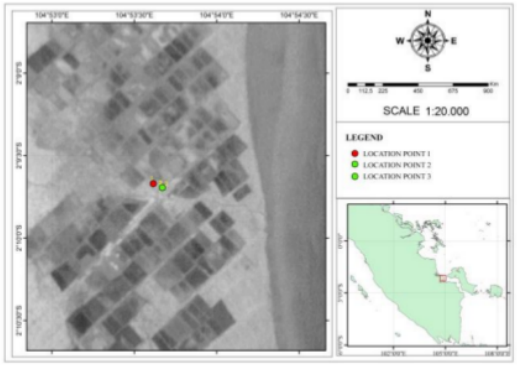

Figure 1. Tree location map of the research. Three points of tree location coordinate: (1) S 02 °09,670' E 104 °53,615'; (2) S 02 °09,694' E 104 °53,670'; and (3) S 02 °09,694' E 104 °53,671'

The Observation of Study Area

The measurement of pH and soil moisture around the roots of trees used soiltester. Additional supporting data as indicators of the environment influence of phenology *B. sexangula* is as secondary data include maximum daily temperature-minimum, daily rainfall, humidity, and wind speed average. The data obtained from the Meteorological Agency of Climatology and Geophysics (*Badan Meteorologi, Klimatologi dan Geofisika = BMKG*), Palembang, South Sumatra.

The degree of acidity (pH) on the environment around stem growth of *B.sexangula* is i.e., 6.2. This showed the growing environment of *B. sexangula* is acidic almost neutral. Other environmental parameters usedas the secondary data as well as environmental parameters appear as correlation with phenology data of *B. sexangula*. The environmental parameters from 2006-2015 (Buletin BMKG, 2016) andaverage rainfall of each month can be seen with a period of at least 10 years.

Beside of the rainfall data, there is also the number of rainy days, average temperature, average maximum temperature, average minimum temperature, air humidity, and the dominant wind direction (Tab. 1, 2, and 3).

Rainfall rises at its peak at the early October to April. The average rainfall from October to April exceeded> 150 mm. The flowering process at initiation stage occured from February at a temperature of 26.6 °C and rised steadily when the plant differentiated from bud to the blooming flowers. The blooming flower occurred in April at a temperature of 27.5 °C means that the blooming flower blooms occurred at high temperatures. The wind is one of the biotic factors in the pollination of mangrove. In this research, wind is a supporting factor for blooming flower.

Reproductive Phenology of *Bruguiera sexangula*

The methods used in the reproductive development of *B. sexangula* is a tagging method. The tree of *B. sexangula* is observed the flower parts marked with different ribbon colors to make it easier focusing on observations. Each stage of development documented from floral initiation stage to propagule mature phase. The method observation of phenology activities included in the size change and color change at each stage

The observation is performed periodically every month. The observed parameters included the initiation of flower, small bud, big bud, flowers bloom, young propagule, and mature propagule. Initiation (bud appears on a stalk of flowers until the early stages of small buds), small bud (marked with little visibility yet petal structure) while the sepal already appears clearly. Blooming flowers (the opened of crown and petals at the maximum followed by pistil and stamen upright to the formation of propagule marked with the falling of crown of flowers as a mark of fertilization), young propagule (new hypocotyl out of the skin of the fruit, the position is already at the base of the flower and the fruit is still green or yellow) and mature propagule (it is marked by a change in color and size).

Data Analysis

The data presented in the data tabulation and pictures. A descriptive analysis was conducted toward the development stage of the reproductive organs *B. sexangula*.

Results

Reproductive Phenology of Bruguiera sexangula

The field observations toward phenology reproduction of B. sexangula retrieved that the initiation of flowers began in February 2016. The mature propagule occurred in September. The phenology stage of B. sexangula as presented in figure 2 represented the results that obtained from the observed wild tree. The figures are presented to describe the beginning and ending phases for each month.

Tabel 1. Climate parameter in study area

Climate elements		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)		369	217	409	327	131	132	107	66	58	172	239	240
Rainfall period (days)		27	19	23	20	16	14	15	9	9	15	20	25
Air Temperature (°C)	Average	26.0	26.8	27.4	27.6	27.9	28.1	28.0	27.5	28.0	28.7	27.8	27.2
	Max.	23.4	23.6	24.0	24.3	24.8	25.0	24.7	24.1	23.6	24.3	24.2	24.1
	Min.	30.6	31.8	33.3	33.5	33.4	33.0	33.0	33.1	33.9	34.8	34.0	32.1
Air humidity (%)		87	84	82	84	84	78	79	79	73	73	79	84
Wind speed (knot)		6	5	4	4	4	4	5	5	5	5	3	3
Wind direction		NW	N	E	SE	SE	SE	SE	SE	SE	E	NE	W

Source: BMKG class II Kenten, Palembang, South Sumatra (2016)

Table 2. The number of rainy day in study area (Palembang for ten years) (days/month)

Year	Months												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
2006	26	17	23	22	19	16	12	2	2	2	23	28	192
2007	28	18	22	22	18	13	13	8	8	18	18	24	210
2008	23	20	23	22	9	11	12	16	17	22	22	26	224
2009	27	25	24	20	16	10	10	7	6	22	24	23	214
2010	25	24	20	19	18	15	12	17	18	20	13	23	224
2011	27	26	26	22	21	21	23	21	22	18	17	15	259
2012	19	25	19	25	18	10	1	7	3	16	24	27	194
2013	29	21	23	26	20	14	10	13	17	17	24	25	239
2014	19	25	19	25	18	10	1	7	3	16	24	27	194
2015	27	19	23	20	16	14	15	9	9	15	20	25	211
Average	25.00	21.99	22.24	22.34	17.28	13.41	10.86	10.68	10.54	16.66	20.87	24.27	216.13
Min.	19	17	19	19	9	10	1	2	2	2	13	15	192
Max.	29	26	26	26	21	21	23	21	22	23	24	28	259

Source: BMKG class II Kenten, Palembang, South Sumatra (2016)

Table 3. Rainfall in study area (Palembang for ten years (days/month)

Year	Months												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Ag	Sep	Oct	Nov	Dec	
2006	360	253	420	289	92	191	120	10	1	0	135	221	2088
2007	503	179	208	379	187	130	98	3	58	114	123	382	2364
2008	204	143	372	323	48	24	150	175	61	318	634	232	2685
2009	275	134	564	339	112	140	36	97	33	212	184	284	2410
2010	251	325	542	420	243	171	91	194	371	312	252	210	3382
2011	240	240	280	270	190	110	100	90	110	200	260	330	2420
2012	201	348	246	405	205	199	86	51	1	226	650	465	3083
2013	309	333	613	368	119	150	86	154	282	191	281	294	3380
2014	184	15	116	351	90	110	112	63	16	2	249	243	1651
2015	369	217	409	327	131	132	107	66	58	172	239	240	2467
Average	290	219	377	347	142	136	99	90	99	175	301	320	2593
Min.	184	15	116	270	48	24	36	3	1	0	123	210	1651
Max.	503	348	613	420	243	199	150	194	371	318	650	494	3382

Source: BMKG class II Kenten, Palembang, South Sumatra (2016)

Figure 2. Reproductive phenology of *B. Sexangula* began with flower initiation in February 2016 until mature propagule in September 2016. **Phenology of *Bruguiera sexangula* in February 2016:** The initial structure of small buds formed in the prospective of the leaf **(A).** The leaf candidate would rather begin to open to let out the little buds **(B).** The leaf candidates would have started to open and small buds would start to look a little. **Phenology of *Bruguiera sexangula* in March 2016**: Small buds or flower buds getting out marked with invisibility the petal structure while the calyx has emerged clearly **(C).** Two small buds begin to appear in the axil of a leaf **(D).** Leaves and small buds are already opened perfectly and discoloration of the calyx to be red in the middle while the tip of leaves and small buds are still yellowish. The color change occurring at this stage is very clear, the red color on the calyx is already beginning to look clearly. There is still no color change significantly but the size changed to be bulging in the middle and going on long multiplication. **Phenology of *Bruguiera sexangula* in April 2016**: Size and color are no significantly changed in color **(E).** The enlargement begins in the middle as a sign that the tip of the petals will open (calyx lobes). The added size and magnified diameter occur on flowers. Calyx structure is clearly visible, marked with stripes and the color looks perfectly which marked the changes from small to large buds. The changes from small to large buds is characterized by discharging of designate petal from designate fruit. Flower blooming is characterized by the opening of sepal and petal with maximum followed by upright of the stigma and stamens **(F). Phenology of *Bruguiera sexangula* in May 2016**: the end of blooming time is marked by the formation of propagule with the falling of petal as a mark of being fertilization **(G).** The petal on the first propagule candidate have occurred and petal left by the formation of small holes **(H).** At the second candidate of propagule, the falling of flowers was already half happening. The flower position documented at the outside when the time of the falling petal, pistil and stamen, and the calyx has seen as perfectly red from the outside. The flower position documented the inside of a white calyx after the falling of petal. The fruit candidate submerged entirely aboard in the middle, and the appear of a hypocotyl candidate will come out on the skin of the fruit. **Phenology of *Bruguiera sexangula* in June 2016:** the hypocotyl candidates were coming out from the skin of the fruit because the germination occurred when the seeds still attached to the old tree because the root system of *B. sexangula* is viviparous **(I).** The structure was beginning to look a little bulge of green which marked hypocotil was slowly out **(J).** The changes look is still the same with small protuberance which indicated hypocotyl will be out. **Phenology of *Bruguiera sexangula* in July 2016:** the size was greater than that before **(K).** About 5 cm of long hypocotyl has come out **(L).** At the end of propagule is brown indicated radicula and the green indicated it hypocotyl. The increase of propagule length is longer than that before. The width propagule about ± 6 mm with the green color and radicula changed to be green color. The length propagule reached about 25 mm and ± 10 mm for hypocotyl. The color change was conducted. **Phenology of *Bruguiera sexangula* in August 2016**: the change of color indicated the propagule will mature perfectly with the yellowish color and longer size. The tip of the petals (calyx lobes) started getting away from hypocotyl and the propagule size is already reached 50 mm **(M).** The tip of the petals start getting away from hypocotyl and radicula colored to be purplish. The length of propagule reached 7 cm with radicula increasingly turned into a purple indicated the color change that that propagule was ripen **(N). Phenology of *Bruguierasexangula* in September 2016**: the color change of radicula indicated that propagule will ripen, thus the preparation was conducted to hang the net on the first propagule because propagule will fall when it had started to mature **(O).** The second propagule on the same day have also been signaling the maturity of propagule which marked on the ends of radicula changed the color to be purpulish and the petal was increasingly interested. When the propagule was already off from it stalk indicated that propagule is perfectly ripen and already harvested. The fallen propagule has length

about 7 cm and occured discoloration to be purplish on the hypocotyl and radicula. The old propagule will reveal the petal **(P).** The mature propagule in Bali and Lombok (Indonesia) (Kitamura et al., 1997) and Singapore have length respectively 6-12 cm and 6-8 cm (Sheue et al., 2005).

Discussions

Reproductive Phenology of *Bruguiera sexangula*

Pollinators agent of *B. sexangula*is pollinated by a biotic component factors. It can be seen from the Crown of *B. sexangula* flowers that could attract the birds attention to visit it. According to Tomlinson (1986) and Noor et al. (2012), the large flowers on *B. sexangula* are pollinated by birds and the tiny flowers are pollinated by small insects. Birds visit the flowers to take the nectar or pollen. Pollinator agents are consciously or unconsciously put the pollen (male sex cells) from the male flower (same plant types) to the stigmas of female flowers. The pollen entered the pollen pathway and fertilize the ovum. Sepal opened completely with the discharge of hypocotyl and the length of hypocotyl added about ± 26 mm. According to Nadia & Merchado (2014), the initial stages of fruit development is vulnerable to predation by predator.

The stages reproductive development of *B. sexangula* were included the flowering initiation, the small buds, the big buds, the blooming flowers, the young propagule, and the mature propagule.

Flowering Initiation Stage

Characteristics of the initiation stages is generally described the initiation phase, and appeared the stalk and bud in the prospective of the leaf. The time of the initiation of the flower is about ± 9 days. The initiation phase observed from late February to early March where rainfall increased, from 219.8 mm up to 386 mm. According to Baskorowati & Pudjiono (2015), high rainfall prior to the development of flower buds is generally indicated as an important factor in the formation of flower buds and flower development. Rainfall rises at its peak from October to April. This is consistent with the phenological data observed that flower bud formation occurs in the rainy season from March to April.

Small Buds Stage

At the end of the rainy season (March) the plant has formed many flower buds in one tree. In April rainfall will be much reduced and the plants begin to slow growth. The flower buds that have formed have reached a length of 3 cm. On the small buds phase will come out two small buds colored greeny at the leaf axil and will change color to pinkish to bigbud phase.

Large Buds Stage

The large bud phase to the bloom takes ± 32 days and occurs from March to April. In that time period the precipitation began to decline from 368.4 mm in March to 362.8 mm. According to Setiawan (2015), several studies have shown a positive correlation between increased flowering and the possibility of low humidity in summer, usually due to low rainfall. Low humidity is often associated with the formation of reproductive shoots and is usually followed by the temperature and intensity of light. The average temperature in March to April reaches 27 °C - 27.5 °C, an increase in temperature where it is associated with falling rainfall and low humidity at the time of the large buds stage to the blooming flower. At the stage of the blooming flowers decreased rainfall and affect the occurrence of flowering. Period of the process of flowers bloom until the final phase of the abortion of initiation occurred in April to May.At the big bud phase was marked by appearance of the petal from the fruit candidate and the flower will bloom with the opening of petal completely followed by pistil and stamen upright. According to Sheue et al. (2005) and Noor et al. (2012), the characteristic of *B. sexangula* is located in the axil of a leaf with the formation of the solitary (one flower per bunch). The leaf crown amounted to 10-12, with length 15 mm, smooth-haired at the edges, the petal about 10-12 colored yellow greenish or reddish or brownish, and long tubes 10-15 mm.

Flowering Bloom Stage

Flower blooms occur in April with a temperature of about 27.5 °C means that at the stage of blossom flower occurs when the temperature is high. After the phase of the blooming flowers will occur abortion petal this indicates there has been pollination. Pollination in general in mangrove is also assisted by the wind. Wind speed in May was 2.6 knots higher than April at 2.3 knots. It is consistent with this study that the pollination of *B. sexangula* occurring in May, marked by the fall of generative organs, indicates the success of the pollination process. According to Tomlinson (1986) and Noor et al. (2012), *B. sexangula* pollinated by birds and small flowers pollinated by insects. Birds visit flowers to pick up nectar or pollen. At the time of leaving the flower, the agent consciously or unconsciously puts pollen (male sex cells) from male flowers (same plant species), to the pistil head of the female flower. The pollen then moves into the pollen tube and fertilizes the ovum. After blooming phase, the next phase will abort the petal indicated the occuring of pollination and will be heading into next phase at young propagule.

Young Propagule Stage

The formation of young propagules occurs in June - August, when the temperature of 27.6 °C drops to 27.4 °C. The temperature is considered normal and no significant changes that spur the success of fertilization. Fertilization occurred in June with rainfall of about 135 mm and the precipitation fell to 83.7 mm in July to coincide with the time of the formation of young propagules. According to Alwidagdo et al. (2014), rainfall such as the amount, duration, and distribution of rain affect the development of mangrove plants, the rainfall that affects the conditions of air, water temperature, water and soil salinity.

Mature Propagule Stage

There are sizes and colors change at hypocotyl on young propagule to mature propagule stage. Propagule matures occur from August to September i.e. at that month the temperature is 27.4 °C rise up to 27.8 °C. The increase in temperature affects the sooner or later the fruit ripening. The effect on the process of ripening propagule (Kartasapoetra, 2006) is the higher the temperature the more quickly mature. The rising temperature causes the humidity of the air to drop as the propagule process matures. Humidity decreases from 81.5% to 77.4%. The rise of air humidity follows the rise and fall of rainfall intensity per month. According to Arifin et al., (2013) moisture is much related to temperature, rainfall, and wind. The relationship between the climatic elements, such as air temperature with rainfall, provides a basis for climate and plant distribution. The large moisture of a region is a factor that can stimulate rainfall. The highest air humidity in Indonesia is reached during the rainy season and the lowest in the dry season.

Hypocotyl elongated cylindrical, green-colored when young and reddish brown when old with a length of 6-12 cm and diameter of 1.5-1.8 cm. According to Cooper et al. (2016), Bruguiera is characterized by the presence of calyx with 8-16 lobes lanseolat and the number of stamen about 16-32. The petals have a calyx tube and calyx lobes. According to the Prosea (2007), *B. sexangula* is have 10-12 lobes (the tip) with the length of the tube about 1-1.5 cm. The flower structure of *B. sexangula* is composed of 10 petals/calyx, 10 corolla/crown, 20 stamen and one pistil. This is in accordance with the statement of the Duke (2006) that the number of petal 10-12 and a number of stamen is about 20-24.

The flower of *B. Sexagula* bloomed in April with rainfall about 362.8 mm and the rainfall was falling down until 86 mm in September coincided with the time of propagule mature. The cycle of air humidity can inform that air humidity is followed and influenced by rainfall intensity for each month. The greater air humdity conducted in November-April. According to Farooqui & Siddiqui (2014), the fresh water is necessary for rapid growth rate of mangrove.

Ecologycally, the mangrove has a great benefits for a variety of land and sea organisms (Tomlinson, 1986; Goudkamp & June, 2006). The basic information related to the biological processes such as the mangrove phenology became crucial for the restoration of a degraded mangrove area (Sharma et al., 2011; Maxwell, 2015; Dey & Kar, 2016). The seasonal growth pattern is closely related to rainfall, temperature and relative humidity of a region (Ghost, 2011; Landry, 2013; Souza et al., 2014; Farooqui & Siddiqui, 2014; Krauss et al., 2014; Short et al., 2016).

Life Cycle of *B. Sexangula*

The phenology of *B. sexangula* which observed from February to September, depicted the cycle of breeding reproduction particularly in BSNP, South Sumatra. If they are sorted, all stages can be seen in figure 3.

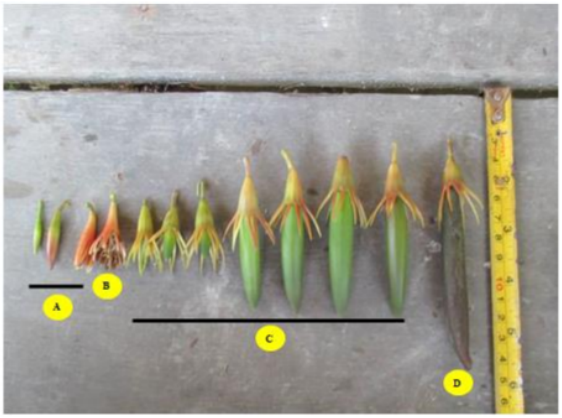

Figure 3. Stages of reproductive development *B. sexangula*, (Left to right: flower bud until mature propagule): (a) flower buds, (b) flower, (c) growth of young propagule, (d) mature propagule

Hypocotyl of *B. sexangula* colored green when young and reddish-brown when mature, 6-12 cm long (Kitamura et al., 1997), in Singapore 6-8 cm long (Sheue et al., 2005). The number of petals 10-12 and the number of stamen range of 20-24 followed 2 times the amount from petal (Duke, 2006). The phenology of mangrove plays an important role in the rehabilitation program of the degraded mangrove area (Sarno et al., 2017).

Bruguiera is the largest genus of Rhizophoraceae family with distinctive characteristics (Sheue et al., 2012; Surya & Hari, 2016). The observations of *B. sexangula* phenology is started from the flowering initiation phase to propagule mature phase. The flower initiation stage occured in February 23, 2016 and mature propagule occured in September 19, 2016 (Fig. 4). The time span of the development stages from initiation phase to mature propagule phase is 210 days or 7 months and 2 days. The time and the characteristics of the ripen mangrove fruit help the regeneration of mangrove (Upadhyay & Mishra, 2010; Arunprasath & Gomathinayagam, 2015). Microclimate effect on regeneration and development of

mangrove plant (Wang'ondu et al., 2013; Lugo & Medina, 2014; Silva et al., 2015).

The presence of information about *B. sexangula* phenology will help the reader the time to get it propagule. This is useful for mangrove replanting area that degraded with the provision of adequate seed or propagule.

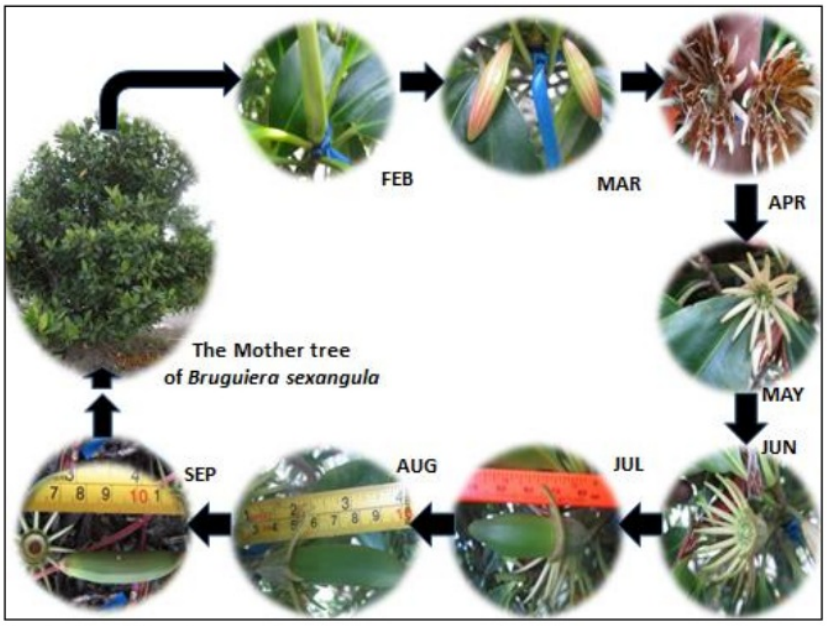

Figure 4. Reproductive phenology of *Bruguiera sexangula*

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