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The Morphological Character and Flowering Phenology of White Jasmine (*Jasminum sambac* (L.) Aiton)

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Abstract: White jasmine *(Jasminum sambac* (L.) Aiton*)* is one of the ornamental plants whose flowers are widely used. However, information regarding flower development, especially the flowering phenology of this plant, is still limited. This study aims to obtain information on the flowering phenology of melati putih and the morphological characterization of the flowers. Flowering phenology data was analyzed qualitatively, while flower morphology character data was analyzed quantitatively. The results show that the flowering phenology of melati putih takes place in an average of 26 days with environmental factors being light intensity 337.00-2639.00 lux, air temperature 27-34^{o}C, humidity 61-82%, and rainfall 0.0–9.6 mm. Air temperature and humidity influence the process of bud emergence and the length of time for large buds to develop towards anthesis. The morphological characters of the flower is *inflorescentia cymosa, pleiochasial type* with trumpet-shaped, white color, and classified as a complete flower. Small flowers have an average flower length of 26 mm and an average diameter of 31 mm. There are 8-10 petals (*calyx*) with an average length of 8 mm and diameter is 6 mm. The crown (*corolla*) is composed of 7-10. Each flower has two *stamens* and a *pistil*.

Keywords: Characterization; Flowering phenology; Morphology; White jasmine

Introduction

Flowers are an important part, especially for angiosperms as a generative organ that plays a role in the reproduction process. Most ornamental plants have flowers. There are various types of ornamental plants in Indonesia that can reproduce well in tropical climates. One of them is a plant from the genus *Jasminum* which is often found from lowland to highland areas depending on the type, especially in tropical areas (Setyawati, 2015). Many types of jasmine grow wild in the forest and some have been successfully cultivated, such as white jasmine (*Jasminum sambac* (L.) Aiton) as a fairly popular and potential ornamental plant. Flowers are generally used as raw materials for the perfume industry, cosmetics, tea mixtures, religious rituals, bridal headdresses, and wedding decorations, making this flower widely sought after and in demand (Hayati & Sugiarti, 2009). The high demand is not supported by adequate production, resulting in limited information and knowledge about white jasmine cultivation.

White jasmine is a shrub, upright, creepers when young, has pure white flowers and emits a fragrant aroma, shaped like a trumpet with many crowns arranged in bunches (Mursito & Prihmantoro, 2005). In addition, according to Widyastuti (2018) jasmine flowers can grow and bloom all year round (*perennial*) if they are in loose soil conditions and get enough sunlight. Therefore, a phenology study needs to be conducted to determine the flowering period and its relationship to weather conditions that are suitable for the development of white jasmine.

Flowering phenology is related to a series of flower development phases that occur naturally and are

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important to know because they are related to the flowering period as the initial stage of the plant reproduction process. It begins with the emergence of generative shoots or flower primordia, forming buds, blooming (*anthesis*), then wilting, drying, falling off, and ending with fruit development (Deswiniyantie et al., 2012). This process is related to the reproductive success of a plant, one of which can be determined through flowering time. Information related to flower development phenology can be a supporting factor for the success of plant hybridization programs, especially in creating superior varieties (Farida & Ardiarini, 2019). In addition, in flowering phenology, environmental factors in the form of climate also stimulate plants in determining the right time to produce leaves, flower, or produce fruit (Pau et al., 2011). Each stage that is passed through in the flowering process of each plant has a different pattern of behavior and character, as well as a different period (Trimanto et al., 2020).

Morphological characterization of flowers can be used as an aspect that needs to be considered in plant breeding programs to obtain superior varieties. Information about each plant characteristic can be obtained through characterization activities. Characterization is carried out by identifying important properties and characteristics found in a plant variety (Kusumawati et al., 2013). Parameters that are generally used in measurements include the length and diameter of flower parts, namely flower length, flower stalk length and diameter, crown diameter, and flower petal length and diameter (Duangjai et al., 2011). Morphological characterization of white jasmine includes the shape and nature of the flower observed from the external structure of the flower and then measuring the flower and its parts.

Research on flowering phenology and characterization of white jasmine flowers is still limited. Therefore, a study was conducted to analyze the morphological changes that occur and the time required during the flowering phase, and to relate them to weather conditions at the research location. The results of this study are expected to provide the latest information in the field of flowering phenology and flower character, providing basic data for cultivation programs and plant breeding.

Method

The research was conducted at Nirwana Housing, RT.09, Mendalo Indah Village, Jambi Luar Kota District, Muaro Jambi Regency, Jambi from January to February 2023. The population included all white jasmine plants found at the research location. The sample consisted of 5 flower pots, from each flower pot 3 flowers were observed, so that the total reported was 15 flowers. Data collection techniques used observation and documentation methods. The tools used during the study were calipers, rulers, label paper, stationery, cellphone cameras, applications downloaded and accessed via smartphones (*Galaxy Sensors* to see the intensity of sunlight and *AccuWeather* to observe temperature, humidity, and rainfall). A further explanation of the research procedure is presented as follows:

Sample Preparation

White jasmine plants totaling 5 flower pots with good and fertile morphological conditions are characterized by sturdy stems, fresh green leaves, and have many flowers, uniform in size with stem diameters ranging from 25-40 mm, have shown the emergence of flower buds as a sign that they are ready to flower. Furthermore, the plants are placed in the yard to get sunlight and are watered sufficiently.

Flower Observation

Observations are carried out every day at 11:00-13:00 WIB and documentation from when the flowers start to show the emergence of flower buds measuring 1.5-5 mm until they fall off. Observations carried out include:

a) Flowering Phenology

Observation of white jasmine flowering phenology by recording each important phase of the flowering stage using a time unit in the form of days, starting when the flower buds appear in the form of protrusions at the base of the shoots, then forming flower buds which are marked by the visible parts such as flower stalks (*pedicellus*), petals (*calyx*), and crowns (*corolla*), the flower blooming phase (*anthesis*) when the corolla opens wide, the flower blooms to its maximum (*perfect bloom*), the flower color is bright, then wilts seen from the color of the flower which begins to fade, the corolla folds, the stamens, and pistils dry up until they come off and finally fall off. In addition, observations of environmental factors by looking at the intensity of sunlight, air temperature, humidity, and rainfall using the *Galaxy Sensors* and *Accu Weather* applications.

b) Characterization of Flower Morphology

Characterization of flower morphology is carried out by identifying the nature and characteristics, and measuring the parts of the flower using a ruler and caliper including flower length (PB), flower diameter (DB), stalk length (PT), stalk diameter (DT), crown diameter (DM), number of crowns (JM), petal length

(PKL), petal diameter (DKL), number of petals (JKL), number of pistils (JP), and number of stamens (JBS).

Result and Discussion

White jasmine that successfully goes through each flower development stage has an average flowering period of 26 days. The development process of white jasmine flowers begins with the emergence of reproductive buds in the form of rounded light green protrusions at the end of the stem (*flos terminalis*) until the crown falls off. A series of important phases are divided into five stages including initiation, young flower buds, large buds (*pre-anthesis*), blooming (*anthesis*), and wilting, drying and then ending in falling off (*post-anthesis*). Each phase has its own morphological characteristics that can be observed directly. The stages of development of white jasmine flowers in sequence can be seen in Figure 1.

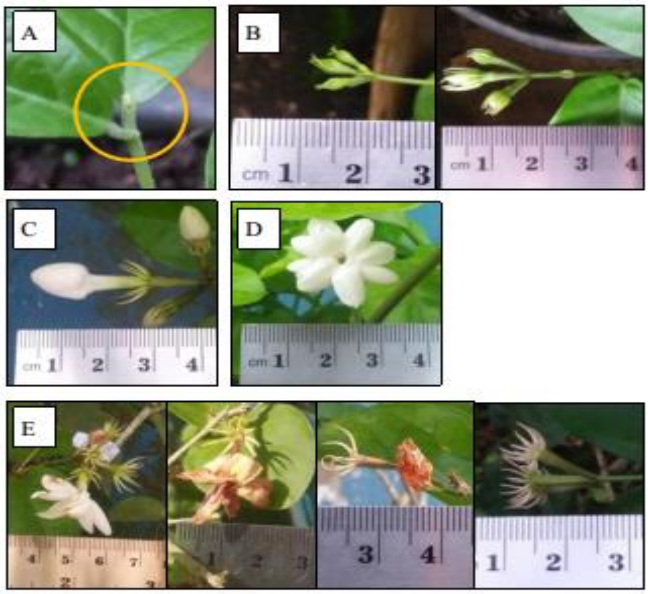

Figure 1. Development phases of white jasmine flowers, A) Flower buds, B) Young flower buds-whitish green buds, C) Enlarged buds, D) Flower crowns bloom, and E) Crowns curl and wilt-Crown dries-Crown falls off leaving flower petals

Table 1. The Average of White Jasmine Flower Development Phase

Flower Development Phases	Time (day)					Mean
	P1	P2	P3	P4	P5	
Bud - Young Flower Bud	5	3.7	3.7	4	5	4.28
Young Flower Bud – Preanthesis	10.3	9	9.3	9.3	10	9.58
Preanthesis – Anthesis	3.3	3	4.3	3.3	3	3.38
Anthesis -Withered	1.7	2.3	1.7	2.3	2.7	2.14
Withered – Dry – Fall	7	5.7	5	8.3	7	6.6
Total Time	21.3	23.7	24	27.2	27.7	25.98

Notes: P = Flower pot

Each phase that is passed through in the flowering process requires a different period of time for each flower pot. The longest phase of this observation is on young flower buds towards large buds (*preanthesis*), while the end of the blooming phase (*anthesis*) to wilting is the shortest stage which lasts for an average of 1-3 days. The following data on the average development time of white jasmine flowers in detail are presented in Table 1.

Flowering Phenology

The flowering phenology of white jasmine takes 21 to 27 days with an average of 25.98 days to complete the flowering stage, starting from the emergence of reproductive buds in the form of rounded light green protrusions at the end of the stem (*flos terminalis*), forming small yellowish green buds, enlarging and the buds turning white (*pre-anthesis*), then bursting wide open flower crowns (*anthesis*), after which the crown rolls up, withers, dries, and ends up falling off leaving flower petals as seen in Figure 1. A, series of important phases are grouped into 5 stages referring to the research of Trimanto et al. (2020) including initiation, small buds, large buds (*pre-anthesis*), blooming (*anthesis*), and wilting, drying to falling off (*post-anthesis*). During each phase of flower development, changes occur in the parts of the flower including its shape and size. Observations were carried out every day since the emergence of flower shoots or also called flower buds (*gemma florifera*) until the crown fell off, so that it can be seen that there are morphological changes in each flowering phase that are observed visually and can be used as characteristics of each phase. As according to Harmiatun et al. (2016) the study of the phenology phase of Wijaya Kusuma (*Ephiphylum oxypetalum*) flowering obtained information related to morphological changes in plant parts starting from the emergence of flower stalks measuring 0.2 cm continuing to lengthen until the third day the flower buds are visible, the corolla opens, then the size of the buds decreases (*wilts*), and falls off.

In general, from 15 flowers, the flowering phases do not always occur simultaneously and require different lengths of time. The flowering phase that begins from the initiation stage of flower buds to become small buds takes an average of 4.28 days, while from the small bud phase to the large bud (*pre-anthesis*) is the longest phase lasting for a period of 9.58 days, then from the pre-anthesis phase to the blooming flower phase (*anthesis*) around 3.38 days, flowers can last 2.14 days as the shortest stage, after that entering the wilting phase (*post-anthesis*) for an average of 6.6 days can be seen in Table 1.

The initial stage of flowering is preceded by the flower induction process as a change from the vegetative phase to the reproductive phase in the cell, but it is

difficult to observe visually. The first phase macroscopically occurs after the white jasmine is free from water shortages, conditions when temperature, humidity, and rainfall allow, then it will form flowers through the initiation process so that flower buds appear in the form of small, round, yellowish-green protrusions, growing at the end of the stem (*flos terminalis*). The initiation phase towards the formation of young flower buds occurs on average 3-5 days. The buds that are formed are initially around 1.5-5 mm in size, still covered by calyx leaves and the flower structure cannot be distinguished. Then from these buds, elongation begins to form a flower stalk that branches with a forked type. This condition is also found in *Diospyros perfida* Bakh. the emergence of flower bud protrusions (*buds*) at the beginning of the initiation phase, then elongates with a crown that is still rolled up (Rindyastuti & Maufiroh, 2019). Next, it forms compound flower stalks and other flower parts through bud differentiation (Baskorowati & Pudjiono, 2015). Each end of the flower stalk is covered by a green-yellowish circle that will develop into a small bud. The buds at the end of the main stalk experience earlier growth and development so that they are larger in size compared to the left and right sides. The stalk and buds become longer and larger followed by the development of the inner structure of the flower. Some visible flower parts and reproductive organs are still in a simple form during initiation.

The appearance of the external structure of the flower bud at the initiation stage only shows a light green calyx covering the corolla, while other parts of the flower are still indistinguishable. However, after observing the longitudinal section of the white jasmine bud at the end of the initiation phase, the arrangement of flowers in some umbrellas has begun to appear consisting of a light green calyx, a yellowish-green corolla, and newly growing stamens with an imperfect shape. Some flowers such as *Kopsia pauciflora* Hook.f. according to Trimanto et al. (2020) at the end of the initiation phase through longitudinal sections, the flower structure begins to appear including petals, crowns, stamens, anthers, and filaments which are light green but not yet developed. This shows that the development of each flower is different, *K. pauciflora* has a more complete flower structure at the end of the initiation phase compared to white jasmine. Meanwhile, the research results of Triadiati et al.(2021) stated that from the longitudinal cross-section of the shoot, during the initiation phase the flower structure in *Sarcotheca macrophylla* was not yet visible.

After successfully forming shoots, the young flower bud phase is continued, a condition where the buds that were originally green then continue to experience a growth and development process in the flower organs which causes morphological changes and an increase in the size of the buds until they finally start to turn white. Visually at the beginning of this phase, the buds appear to be small, light green in color, the crown is not yet visible because it is still covered by the calyx which are tightly arranged with pointed tips forming a cone. Meanwhile, the part of the stalk with compound flower arrangement continues to elongate. The branching of the flower stalks that were initially attached close to the peduncle begins to elongate so that the division of its structure is clearly visible. This morphological characteristic distinguishes between the end of the initiation phase and the beginning of the young flower bud. This phase lasts an average of 9 to 11 days. Towards the end of the young bud phase, the crown part slowly becomes yellowish white and continues to elongate until it exits the calyx. The bud already has flower parts with a complete structure and can be clearly distinguished. The reproductive part of the flower consists of one green pistil that is taller than the two stamens that are starting to turn yellowish still covered by the corolla, indicating that at that time it was in the development process. The pistil has shown the stigma and stalk, while the stamen stalk is still growing together with the base of the petal. The tip of the pistil shows an ovary with an unclear shape. Until the end of the phase is marked by the crown of the bud has shown a completely white color. According to research by Rustam et al. (2018), when at the end of the development phase of young flower buds, the crown is found to be white.

Flower development continues with the process when the flower reaches the large bud phase. In this phase, the generative organs develop towards maturity along with the increase in the length of the crown section which then supports the bud to grow larger and more bloated until it is ready to bloom. During this stage, the bud tube that was previously invisible in the young bud phase, is now starting to grow larger and longer. The corolla section increasingly shows a pure white color. The petals open and all the strands have turned greenish white. Meanwhile, through a longitudinal section, the development of the inside of the large bud can be seen from the yellowing stamen head but is still in the process of maturation followed by the increasingly elongated stamen stalk. In addition, the pistil in the middle is green with a shorter size and has a *stigma, style*, and *ovary*. In line with these characteristics, the inflorescence of the dove orchid (*Dendrobium crumenatum* Sw.) before blooming shows that the buds are white with clearly visible parts, separate petals and sepals, and on its reproductive organs there are two paired *pollinia* with a dark yellow color and the *stigma* displays the behavior of releasing a little mucus (Nita et al., 2015). The *pre-anthesis* stage does not last long, only in a short period of

time, an average of 3 to 4 days. After that, the flower buds will slowly open entering the *anthesis* phase starting from the tip of the bud.

The white jasmine flower phase begins to open (*anthesis*) on average from the 17th to the 18th day after the flower buds begin to appear. This stage is marked by a fully opened crown arranged like a circle and attached halfway to the bottom which is called the *corolla* tube so that it is shaped like a trumpet. *Petals* consist of 7 to 10 strands divided into two layers of tightly arranged circles, the first layer has 3 crown strands, and 2 to 5 strands in the second layer. In blooming flowers there are 2 stamens that are seen protruding slightly from the mouth of the crown tube. While the pistil sinks inside the crown tube, so it cannot be seen from the outside. Observations on the first day of blooming, the crown strands have formed a circle with a flat top surface, then on the following day the diameter of the crown increases. During *anthesis*, the flower diameter will reach a maximum average of 33-34 mm before finally rolling up as a sign of entering the wilting phase. Reported observations (Lakshmi & Ganga, 2017) noted that several lesser-known *Jasminum* species such as *J. calophyllum, J. flexile, J. multiflorum* (Pink), *J. nitidum* and *J. rigidum* have flower diameters ranging from 2.1 to 4.2 cm. White jasmine flowers have pistils and stamens, but during *anthesis* there is no pollination process. It was found that some broken stamens do not produce pollen, and if there is any, it is difficult to stick to the pistil. This is the condition observed so that it appears that the *ovary* does not develop to produce *ovules* because there is no pollination or fertilization process. When they bloom, the flowers can only last for 1 to 3 days if the weather conditions, wind and rainfall intensity support the flowers not to fall off.

The change from anthesis to *post-anthesis* phase is marked by morphological characteristics in the form of crown strands that are no longer pure white and begin to curl so that their diameter size decreases. Then, on some flowers, purple spots appear on the crown strands. This condition is the beginning of the wilting process as part of the *post-anthesis* phase. After these signs appear, it is followed by the next characteristic, namely purple spots that turn brownish, some parts of the crown are found to be torn and shriveled. Until all parts of the flower turn brownish or are also called having entered the dry stage and do not last long and then fall off the stem. This stage is the end of a series of flower development phases. *Post-anthesis* occurs for varying periods of time ranging from 5 to 9 days. After the flower falls off, it does not leave an ovule because there is no fertilization process, only the flower stalk and petals still survive, therefore the dominant reproduction process is carried out vegetatively with human assistance. In petunia flowers, the post-anthesis stage is the longest phase during flower development, lasting an average of 12 days, while the fastest phase is during shoot enlargement with an average time of 2 days (Sareh et al., 2023).

During the observation, environmental factors around the research location consisting of light intensity, air temperature, humidity, and rainfall also played a role in the flower development process. Based on observations made with the help of the Galaxy Sensors and Accu Weather applications, it shows that the weather tends to change but is still in optimal conditions for the development of white jasmine flowers, as shown in Table 2.

Table 2. Observation of Environmental Factors (Weather)

Flower Development Phases	(Environmental factor (Weather)			
	Sunlight Intensity (Lux)	Temperature (◦C)	Humidity (%)	Rainfall/Precipitation (mm)
Bud → Young Flower Bud	337.00 – 2639.00	27 – 32	61- 82	0.0 – 9.6
Young Flower Bud → Preanthesis	337.00 – 2639.00	27 – 34	61- 82	0.0 – 9.6
Preanthesis → Anthesis	367.00 – 2294.00	29 - 34	61- 78	0.0 – 6.9
Anthesis → Withered	367.00 – 2294.00	30 – 34	61- 82	0.0 – 6.9
Withered → Dry → Fall	367.00 – 2294.00	30 – 34	61- 82	0.0 – 6.9

The results of Table 2 show that the weather tends to change but is still in optimal conditions for the development of white jasmine flowers. The observed light intensity is in the range of 337.00-2639.00 Lux, the air temperature ranges from 27-34^{o}C, the humidity is quite high reaching 61-82%, and the rainfall is 0.0-9.6 mm. This is further strengthened by the research of Triastinurmiatiningsih et al. (2021) that the flowering phenology of *S. boerlagei* has a different flowering process duration at each stage which is influenced by environmental factors such as weather. As is the case in the development process of *S. Hirtum*, the environmental factors that play the most important role in influencing the production of the number of flowers and fruits produced include temperature, rainfall, and light intensity (Astuti et al., 2021).

Morphological Characterization of Flowers

White jasmine is a plant that has small, pure white flowers, including trumpet-shaped flowers. These

flowers appear at the end of the stem (flos terminalis) by forming compound flower branches with boundaries (*inflorescentia cymosa*) because through one flower stalk (*pedunculus*) it can support more than two branches of the same height, each of which is covered by one flower. Therefore, this flower is also categorized as a plant that has many flowers (*planta multiflora*) with 2 to 9 flowers from one *pedunculus*. Similar to the flowers of the Sabrina cultivar long bean, from one compound flower cluster structure, 2 to 4 flowers are found that are shaped like butterflies (Rizkyma et al., 2023). Morphological characterization is carried out on all parts of the flower during the perfect bloom phase (*anthesis*), namely when the crown is wide open and has a maximum size.

In addition, characterization activities were carried out on the parts of the morphological structure of the flower which were used as information on the characteristics or characters of white jasmine. The results of the morphological characterization of the flower showed that each flower had parts with varying sizes as shown in Figure 2.

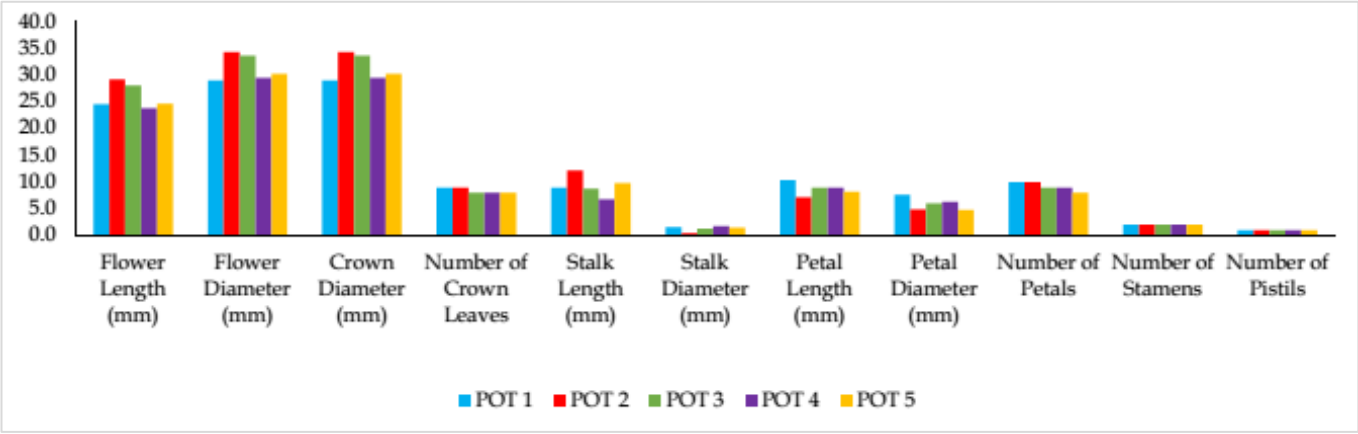

Figure 2. Graph morphological character of *Jasminum sambac* (L.) aiton

The results of the morphological characterization of flowers show that each flower has parts with varying sizes. White jasmine has a complete flower structure with an average length of (23.8-29.2) mm from the tip of the flower stalk to the crown and a retata flower diameter of (29-34.4) mm. The parts that make up the flower structure can be divided into sterile and fertile or reproductive parts as follows:

a) Sterile Parts

The sterile parts consist of flower stalks (*pedicellus*), flower bases (*receptaculum*), and flower decorations (*perianthum*). The white jasmine flower stalks have a round green shape with fine hairs on the outside, have an average length of (6.8-12.2) mm with a diameter ranging from (0.5-1.7) mm. The flower base as a place to attach the flower components, supports the presence of the pistil. The position of the white jasmine flower decoration in relation to the sitting of the ovary is included in the *hypogynous* type, namely the presence of *sepals, petals*, and *stamens* below or lower than the position of the *ovary*. Meanwhile, the flower decoration components include the calyx and corolla. The flower petals number 8 to 10 whitish green petals in a cylindrical shape with an average length of (7.2-10.4) mm and a petal diameter of (4.8-7.6) mm. The corolla is free, separate from one another (*polysepalus* flowers). The shape of the petals from its symmetry is included in the regular or actinomorphic group (*actinomorphus, regularis*). The crown is shaped like a trumpet with the base attached to form a crown leaf tube (*gamopetalus*). Consisting of 7 to 10 stacked petals consisting of two layers forming a circle arranged tightly, the first layer has 3 to 4 crown leaves, and the second layer with 2 to 5 leaves.

b) Fertile Parts

The fertile parts play a role in the reproductive process of plants consisting of male genitalia in the form of stamens and female genitalia in the form of pistils, both of which can be found in one white jasmine flower. This condition can also be found in *R. trisperma* flowers which have pistils, stamens, corollas, and petals (Ajijah et al., 2019). The stamens in white jasmine consist of two parts, namely the yellow anther and the greenish filament. Generally, white jasmine has two stamens which are attached to the corolla tube. Stamens tend to be the same size. The position of the anthers is free from one another. There is pollen in the anthers which when ripe, the anthers will burst releasing pollen. Meanwhile, the white jasmine pistil is cylindrical in shape and green in color with a slightly slimy texture, has parts consisting of the stigma, stylus, and ovary. The ovary part of the pistil does not develop to produce seeds so it ends up

drying and falling off. The pistil is shorter than the stamens in white jasmine.

Conclusion

The results of the study obtained information that the phenology of white jasmine flowering contains a series of stages containing flowering phases that take place in an average of 26 days. The phase begins with the emergence of flower bud protrusions, forming small whitish green buds, becoming large white buds, the corolla opens (*anthesis*), then wilts, dries, and falls off (*post-anthesis*). Environmental conditions such as sunlight intensity, air temperature, humidity, and rainfall mutually support the development of flowers. The morphological characteristics of white jasmine flowers have compound inflorescences with limits (*inflorescentia cymosa*) of the *pleiochasial* type, appearing at the end of the stem (*flos terminalis*). The flowers are trumpet-shaped, white, small, have an average flower length of 26 mm and a crown diameter of 31 mm. They are classified as complete flowers with 8 to 10 calyxes that are free (*polysepalus*), the corolla is attached at the base to form a tube (*gamopetalus*), has two stamens and a pistil.

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Author Contributions
Conceptualization, methodology, F.K. and P.M; writing—original draft preparation, collect data, F.K.; formal analysis, P.M. and E.J.W; writing—review and editing, P.M., E.J.W., and F.K. All authors have read and agreed to the published version of the manuscript

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