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Morphological and phenological characteristics of petunia (*Petunia hybrida* Vilm.) flowering

Asri Ferianti Sareh[1*], Pinta Murni[1], Ervan Johan Wicaksana[1]
[1]Department of Biology Education, Faculty of Teacher Training and Education, Universitas Jambi,
Jl. Jambi - Muara Bulian No.KM. 15, Mendalo Darat, Kec. Jambi Luar Kota, Kabupaten Muaro Jambi, Jambi, 36361, Indonesia
*corresponding author: asriferiantis@gmail.com

ABSTRACT

Petunia hybrid Vilm. is an ornamental plant that has the potential to be developed because its flowering period does not know the season and comes with various motifs and flower colors that can add cultivation and commercial value. Information on the morphological characteristics of flowers and flowering phenology is the basis for their development. The aim of this study was to characterize the morphological structure of flowers and observe a series of phases in flower development stages associated with environmental factors. This research was conducted in the sustainable twin housing complex in the city of Jambi on March 25–May 27, 2022, and the data obtained was analyzed descriptively, qualitatively, and quantitatively. The results of flowering phenology observations showed that petunia flower development occurred over an average period of 37 days. Based on the characterization of the morphological structure of the flower, the average length is 72 mm and the diameter is 42 mm. It is categorized as a complete flower because it has a main organ consisting of five petals with an average diameter of 42 mm, five petals with an average length of 14 mm, and an average diameter of 16 mm. Furthermore, the genitals of the flower, namely the stamens, are five in number, and there is one pistil in each flower.

Keywords: anthesis, flower morphological characters, flowering phenology, petunia

INTRODUCTION

The diversity of flowering plants is estimated to reach approximately 90%, equivalent to a number of 235,000–400,000 plant species widely distributed worldwide. Flowering plants dominate terrestrial ecosystems and are considered the most successful organisms throughout life (Magallon, 2009). In relation to this, flowering plants have potential economic value as ornamental plants (Huda et al., 2020). One of them is Petunia (*Petunia hybrida* Vilm.), which is a hybrid of *P. axillaris* and *P. integrifolia* or related species such as *P. inflata*. It belongs to the order *Solanales,* family *Solanaceae*, and originates from South America (Morita & Hoshino, 2018). It is classified as an annual ornamental plant that has been present since the early days of horticulture and is important for developing new varieties (Talang et al., 2019). Up to the present, petunias are available in a wide variety of flower colors and patterns.

Petunia is an ornamental plant with global commercial value in the floriculture industry (Azizah et al., 2014). The market demand for this plant is significant and ranks first in the auction of ornamental plants, reaching up to 130 million dollars per year (Bombarely et al., 2016). This is supported by seed demand in several countries, such as the Netherlands, which imports an average of 31.25 kg per month; Poland, which averages 7.3 kg per month; and Germany, which averages 4.16 kg per month (Panji & Marina, 2020).

Petunias are the preferred choice of 12.5% of the sellers who offer them, according to a survey of ornamental plant vendors in the city of Jambi, specifically in the districts of Alam Barajo, Kota Baru, Telanai Pura, Mayang Mangurai, and South Jambi, which total 40 locations. However, there are still sellers who are unfamiliar with and

unaware of the potential of petunias, accounting for 87.5%. Therefore, this plant has the potential to be developed due to its attractive flowers and high commercial value. Efforts can be made to explore the potential of petunias through the characterization of their morphological structures and the study of their flowering phenology.

Characterization is an activity aimed at identifying the distinctive traits or characteristics of a variety (Kusumawati et al., 2013). Characterization of flower morphology aims to understand the reproductive system, enabling the determination of appropriate conservation measures (Baskorowati & Pudjiono, 2015). Flowering phenology is a series of natural phases that occur during the flower's development and serve as the initial process for plants to reproduce (Yulia, 2007). This event is related to reproductive biology, as it reflects changes in the timing of reproduction in response to climate change (Rindyastuti & Maufiroh, 2019). Flowering phenology is also useful for understanding morphological changes that occur during the flower's development, the time it takes for a plant to flower, and the duration of its flowering period (Triastinurmiatiningsih et al., 2021).

The assessment of the morphological characteristics and flowering phenology of petunias is still very limited. Although research has been conducted on the tolerance of two types of petunias to shade (Prasundari et al., 2018) and the genetics of petunia flower development (Rijpkema et al., 2006), however, the information regarding petunia flowering described is still lacking in detail, especially the morphological characteristics of its flowers. This study aims to characterize the morphological structure of petunia flowers and study their flowering phenology, which is associated with environmental factors such as sunlight intensity, air temperature, air humidity, and rainfall. The data obtained from the characterization will be beneficial in plant breeding as it provides information that can be used in selecting superior traits (Farida & Ardiarini, 2019). Similarly, flowering phenology is also useful in predicting a plant's ability to produce seeds, thus determining the appropriate strategy for the development of a particular plant species (Sarno et al., 2020).

METHOD

This research was conducted in Kembar Lestari Housing, RT. 56, Kenali Besar Village, Alam Barajo District, Jambi City. The observation period started on March 25th and ended on May 27th, 2022. The population consisted of all the petunia plants in the backyard of Mrs. Adharyani's house, and five petunia pots were selected as samples. The sample selection category was plants that were ready to flower, as indicated by the emergence of small buds in the leaf axils, with an average age of five months. The tools used were a ruler, caliper, and software consisting of a camera, a weather application (Accuweather), and Galaxy sensors available on a mobile phone. The materials used were label papers and five pots of petunia plants with homogeneous conditions in terms of soil composition and volume in each pot. Data collection was performed through measurements and observation. In each pot, three flower buds were selected as representatives, meeting the criteria of having the same budding time and being approximately 0.1 mm in size during the observation. The complete procedures for morphological characterization and flowering phenology observation are explained as follows:

Characterization of flower morphology

The morphological characterization of the flower was conducted using two parameters: namely observation of the morphological structure, then measurements which included the whole flower, stalk, petals, and crown. The first parameter involved observing the number and arrangement of flowers, the scattered or clustered arrangement of flowers, as well as branch growth and arrangement on the main stem. Based on the morphological structure, it was divided into sterile parts (the flower stalk, base, and decorative parts of the flower) and

fertile parts (male and female reproductive organs). In the sterile parts, the shape of the flower base, stalk shape, and surface texture of the flower stalk were observed. Next, the decorative parts (sepals and petals) were observed, including the shape and arrangement of sepals and petals, as well as whether they were fused or separate.

The fertile parts consisted of the male reproductive organs (stamens) and the female reproductive organs (pistils). The observation of stamens included the position of the stamen, the number of stamens, the color and shape of the stamen heads, the position of the stamen head in relation to the stamen stalk, and the pollen produced by the anther. Meanwhile, the observations of pistils included the number of carpels that make up the pistil, the shape and texture of the pistil head, and observations of the developing fruit. The position of the developing fruit in relation to the flower base was categorized as superposed, half-submerged, or submerged. Furthermore, the observation of the outer structure of the fruit and its categorization as a false fruit or true fruit, as well as the seeds produced in one fruit, were recorded.

The second parameter involved measurements, starting with the overall length and diameter of the flower, the length and diameter of the stalk, and then the length and diameter of the flower sepals, referring to Navarro & Guitián (2002). The number of sepals and petals and the measurement of petal diameter were also recorded, following Kusumastuti et al. (2017). Furthermore, the number of stamens and pistils in one flower was counted.

Flowering phenology

The phenology of flowering involved observing each stage of flower development and marking them using label paper on the stem or branch. The observation began with the emergence of buds, which then developed into flower buds. The flower buds then g rew larger, and the petals bloomed until the petals withered, dried up, and fell off. Concurrently, environmental factors such as sunlight intensity, air temperature, humidity, and rainfall were also observed using weather applications and Galaxy sensors on a smartphone. Environmental observations were conducted simultaneously with flower development, starting at 8:00 a.m. until the five pots of petunia plants had finished being observed. This activity was repeated daily until complete data on flower development was obtained. The observation results were documented through photographs, and periodic notes were taken regarding the observed changes.

RESULTS AND DISCUSSION

Characterization of flower morphology

Petunia flowers are located in the leaf axils (axillary flowers), numbering more than one on the branches, thus being classified as a multi-flower plant (*Planta multifloris*) (Tjitrosoepomo, 2016). Its parts are arranged in a circle and classified as a compound inflorescence with a distinct boundary, characterized by the tip of the stem being covered by a single flower. The branches on the main stem are not opposite each other and differ in size, categorizing them as monochasial. There is one larger branch compared to the others, and their arrangement resembles a staircase or alternate branching, known as a scorpioid cyme (*cincinus*) (Castel, 2010).

The measurement results show that the average length of petunia flowers is 69–74 mm and the average diameter is 37–42 mm. The measurements include the corolla (petals), calyx (sepals), stamen, pistil, as well as the fruit and seeds, as presented in Figure 1.

Based on Figure 1, it can be observed that the petunia flower is a complete flower (*flower completus*) because it consists of several sterile and fertile reproductive parts attached to the receptacle (*receptaculum*) at the base of the flower.

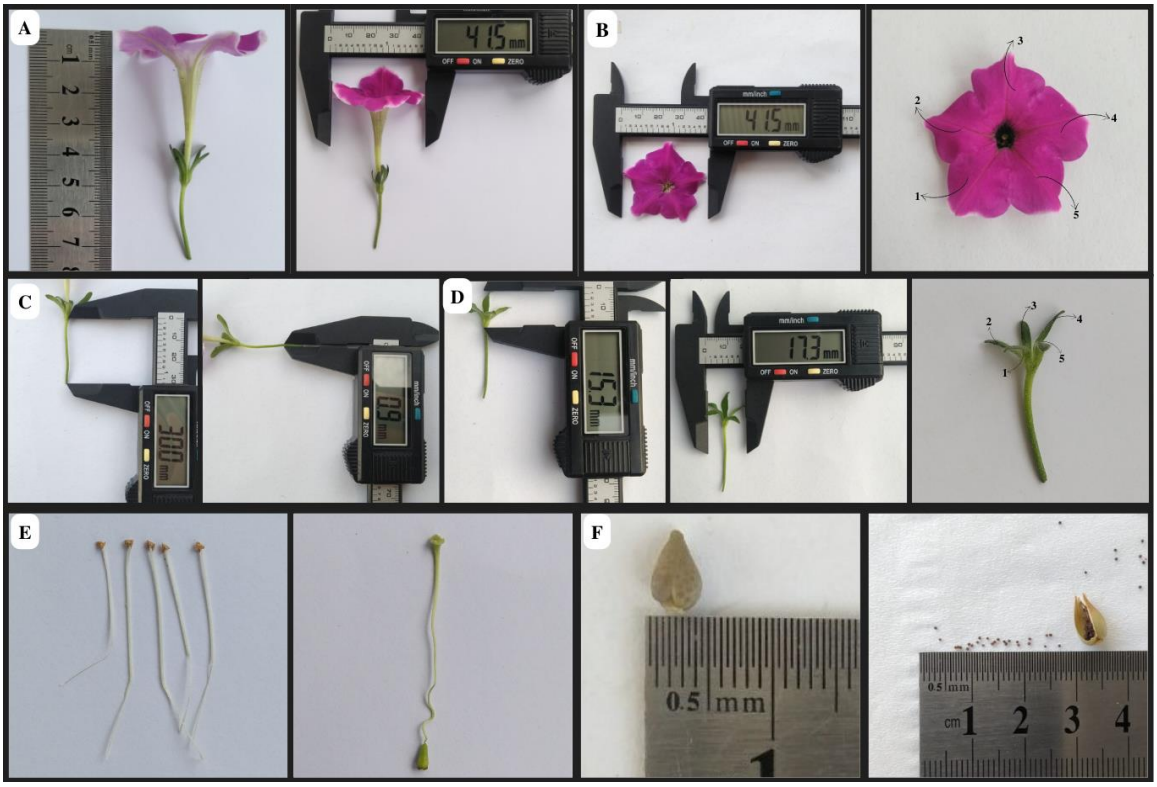

Figure 1. Measurement of flower parts: (a) flower length and diameter, (b) crown diameter, (c) stalk length and diameter, (d) the length and diameter of the calyx, (e) the number of stamens and pistils in one flower, and (f) fruits and seeds.

The detailed explanation is as follows:

a. Sterile section of a petunia flower

The sterile parts of the flower are categorized into three categories: the flower stalk, the base of the flower, and the floral adornments. The first part, the flower stalk, is cylindrical and light green in color, with a smooth, hairy outer texture. It has an average length of 19–27 mm and an average diameter of 1 mm. The second part, the base of the flower, supports the expanded and flat pistil, and it is hypogynous. The third part is the floral adornments, consisting of the sepals and petals. The sepals are composed of five sepals (calyx), fused together and star-shaped. They are free (*polysepalous*) in nature, with an average length of (11–16) mm and an average diameter of (12–21) mm. On the other hand, the corolla is composed of five petals that are fused (*gamopetalous*), forming a trumpet shape with a flat upper part. The average diameter of the corolla is 37–47 mm.

b. Fertile or reproductive parts of the petunia flower

The fertile or reproductive parts consist of the male reproductive organ, called stamens; and the female reproductive organ, called pistil. There are five stamens, but only two are long compared to the other three, making them categorized as two long stamens (*didynamous*). Each stamen is attached to the corolla at its tip and is known as adhesion stamens (Silalahi 2015), and the attachment of the stamens is categorized as *epipetalous* (epipetal). The anther, which is the pollen-bearing part, is pale yellow and elongated in shape. The anthers are attached upright (*innatus* or *basifixus*) to the stamen, showing clear boundaries. Pollen is produced from two pollen sacs (*thecae*), and each pollen sac consists of two pollen chambers (Herliani & Theodora, 2020).

The pistil of the petunia flower is composed of two carpels, making it a compound pistil (*compositus*). The stigma, the receptive part of the pistil, is round in shape

and has a sticky texture on its upper surface. The average length of the pistil is 23–35.4 mm, and the diameter of its developing fruit is 0.7–1.6 mm. The developing fruit is categorized as a superior ovary (*superus*) because it is positioned higher than the flower base and its sides are not fused with the base of the flower, as shown in Figure 2.

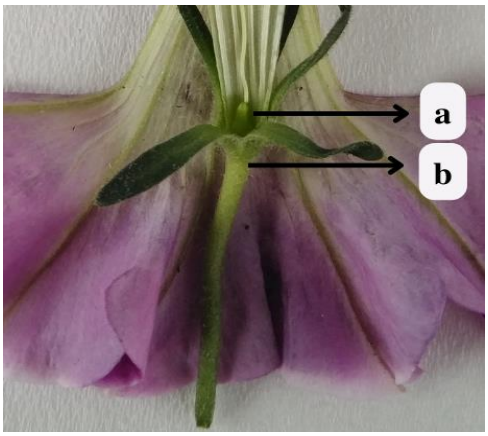

Figure 2. Position of developing fruit relative to the flower base: (a) developing fruit, (b) flower base.

In further development, the developing fruit will mature into a fruit, and the developing seed will mature into a seed. This phenomenon occurs if the pollination proceeds smoothly, resulting in the formation of a fruit that contains seeds. The fruit of the petunia flower is classified as a true dry single fruit, as it is formed from a single flower with one developing fruit containing more than one seed. The fruit's skin structure is hard and dry, resembling dry brownish skin (Figure 1.f). The average length of
the fruit is 3.4–9.5 mm, and the average diameter of the fruit is 3.4–3.8 mm.

Flowering phenology

Based on the observation results, it can be seen that the flowering phenology of petunia occurs within an average period of 37 days. The fastest stage is the phase of the bud enlarging, which takes an average of 2 days, while the longest stage is the drying and wilting of the corolla, which takes an average of 12 days. Further explanation regarding the time range of each phase of flower development is presented in Table 1.

Table 1. Development of petunia flowers from five pots.

Flower development stage	Pot 1	Pot 2	Pot 3	Pot 4	Pot 5	Means
Flower bud	8	6	14	6	10	9
Young bud	4	3	4	4	7	4
Whitish green bud	2	2	3	2	2	2
Bud enlarging	1	1	2	2	2	2
Corolla blooming	5	5	5	5	5	5
Corolla wilting	3	2	4	2	3	3
Corolla drying and falling off	22	3	24	5	6	12
Total	**45**	**22**	**56**	**26**	**35**	**37**

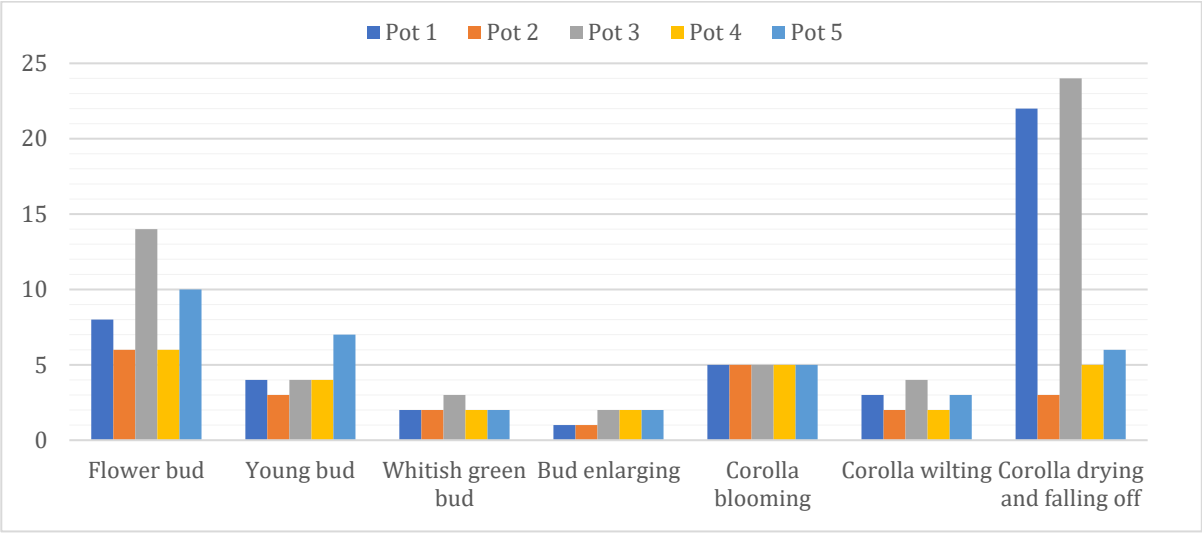

Figure 3. Graph of average petunia flower development from five pots.

According to Table 1, the development of petunia flowers occurs at different durations. However, the stage of corolla blooming tends to be consistent, with an average of five days. The progression of petunia flower development can also be visualized through a graph, as presented in Figure 3.

The development of petunia flowers is divided into five phases, which are explained as follows:

a. Initiation phase

The initiation phase is the initial stage of flower development, where various morphological changes can be observed macroscopically. In the initiation phase of petunia flowers, buds can be seen in the leaf axils, which subsequently develop into branches and flower primordia, as visually presented in Figure 4.

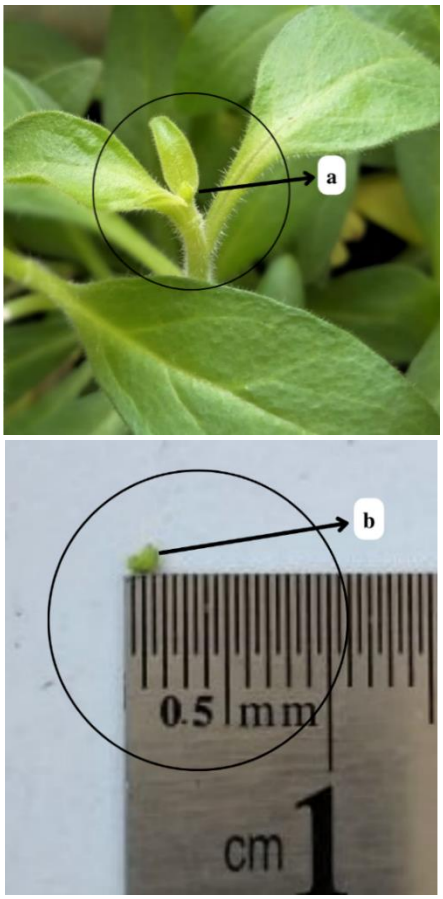

Figure 4. Early initiation phase (a and b) flower buds in the form of small protrusions in the leaf axils.

Based on the graph in Figure 3, it can be observed that the initiation phase involves the development of flower buds until the formation of young flower buds, which takes an average of 6–14 days. The buds start as small protrusions and undergo development to form sepals and stalks. At the end of the initiation phase, petal growth begins, but they have not yet fully closed or formed a bud. According to Damaiyani & Metusala (2011), at this stage, the floral reproductive organs start to form. This condition is similar to the longitudinal section observation of petunia flower buds, where the floral reproductive organs have formed but are still very simple, as shown in more detail in Figure 5.

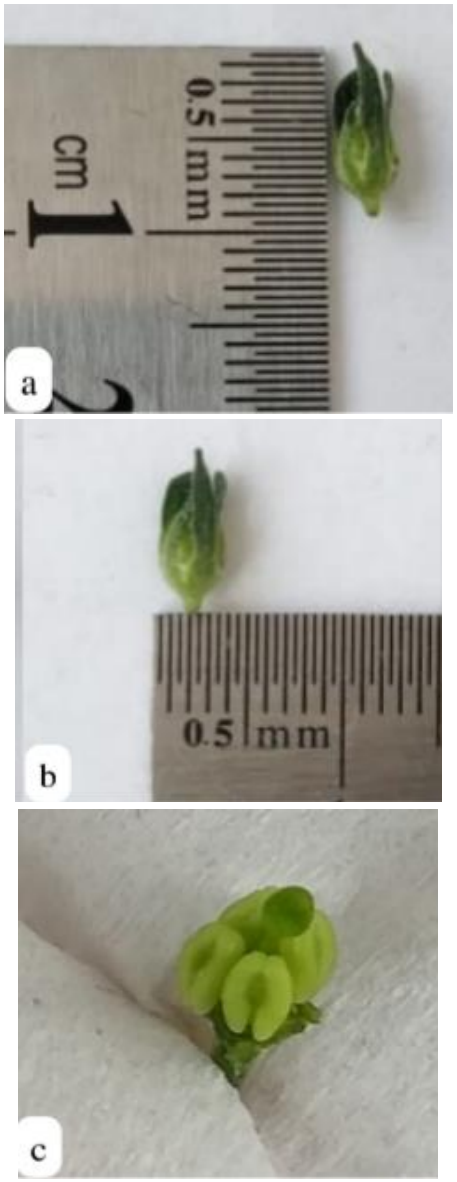

Figure 5. Late initiation phase: (a) length of flower buds, (b) diameter of flower buds, (c) longitudinal section of flower bud.

The environmental factors observed during the bud stage until the formation of young flower buds are sunlight intensity (308.00–8904.00) lux, air temperature (26–38) °C, air humidity (50–95%), and rainfall (0.0–2.2) mm.

b. Small bud stage

1. *Young bud stage*

The development of the bud begins with the young bud stage, characterized by a light green corolla that is fully closed or tightly folded. Based on the graph in Figure 3, this phase typically lasts for an average of 3–7 days. There is an elongation of the bud tube, which ends with the bud turning a whitish green color. This condition is supported by Rustam & Pramono (2018), stating that the young bud stage concludes with a whitish corolla. The progression of the young bud stage is presented visually in Figure 6.

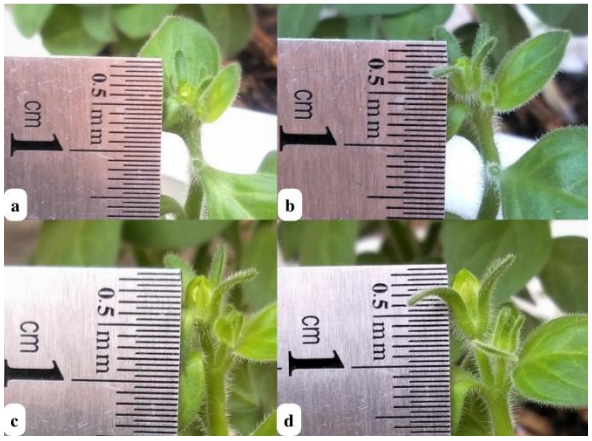

Figure 6. Development of the young bud (a-d) progression from the beginning to the end of the young bud stage.

2. *Bud with whitish green color*

This phase is a continuation of the development from the bud stage and is characterized by the whitish green color at the tip of the bud tube. Based on the graph in Figure 3, it can be observed that this phase lasts an average of 2–3 days, with an increase in the size of the bud tube, as shown in Figure 7.

Figure 7. Development of whitish green bud (a-b) from the beginning to the end of the phase of the whitish green bud.

The addition of the bud tube indicates that development is taking place inside, and it can be observed through a longitudinal section. This condition is similar to the development of the bud of *Centella asiatica*, where the flower primordia inside the bud show growth and development (Damaiyani & Metusala, 2011). Here is a longitudinal section of the petunia bud, presented visually in Figure 8.

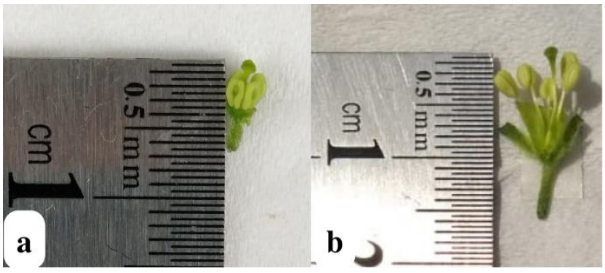

Figure 8. Longitudinal section of the flower bud: (a) young flower bud, (b) greenish-white flower bud.

The environmental factors observed during the phase from young flower bud to whitish flower bud are sunlight intensity (174.00–10,649.00) lux, air temperature (25–33) °C, air humidity (60–95) %, and rainfall (0.0–4.0) mm.

c. Bud enlargement phase (pra-anthesis)

Based on the graph in Figure 3, the bud enlargement phase lasts for an average of 1-2 days. The development is characterized by an uneven outer structure of the bud's tip, and it starts to exhibit colors indicating the hue of its petals. In line with this, Hamim et al. (2019:4) stated that in the development of mature buds of *Calophyllum inophyllum* L. flowers, there are

protrusions on the upper surface of the bud tube. These protrusions will open during the blooming phase, allowing the stamens and pistil to emerge from the bud's tip. The bud enlargement phase is visually represented in Figure 9.

Figure 9. Bud enlargement phase: (1) small protrusions at the beginning of the bud enlargement phase, (2) small protrusions at the end of the bud enlargement phase.

By making longitudinal incisions, the reproductive organs of the flower can be clearly observed, indicating their development towards maturity. Here is a longitudinal incision of the enlarged bud, presented visually in Figure 10.

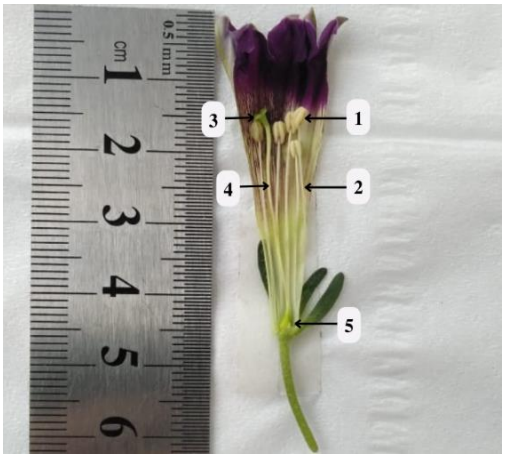

Figure 10. Longitudinal incision of the enlarged bud: (1) anther, (2) filament, (3) stigma, (4) style, (5) ovary.

Based on Figure 10, it can be observed that the reproductive organs of the flower, such as the stamen and pistil, are growing longer. The anther appears pale yellow and will release pollen when the corolla blooms. In contrast, the development of the enlarged bud in *Kopsia pauciflora* shows that the pollen is already perfectly formed (triangular). It has a powdery texture and brownish-yellow color, indicating that the pollen is ready to pollinate the stigma when the flower's corolla blooms (Trimanto et al., 2020:86). Environmental factors observed during the enlargement of the bud until corolla blooming include sunlight intensity (174.00–7418.00 lux), air temperature (25–33°C), air humidity (60–95%), and rainfall (0.0–4.0 mm).

d. Phase of full bloom of the corolla (anthesis)

In this phase, only a portion of the corolla opens up, as the shape of the petunia flower resembles a trumpet. This statement is supported by Rustam & Pramono (2018:16), who state that the blooming of the Tembesu flower (*Fagraea fragrans*) only involves a partial opening of its tube, while the remaining parts remain fused to form the tube. During the phase of full bloom of the corolla, each petal carries stamens and pistils located in the middle. This is because the number of petals is the same as the number of stamens.

Based on observations, it is noted that the corolla, when fully bloomed, no longer undergoes further growth. This phenomenon is similar to what happens with the Gambir flower (*Uncaria gambir*) during its blooming (*anthesis*), where there is no growth in length or diameter (Jamsari et al., 2007). The process of petunia flower blooming is presented visually in Figure 11.

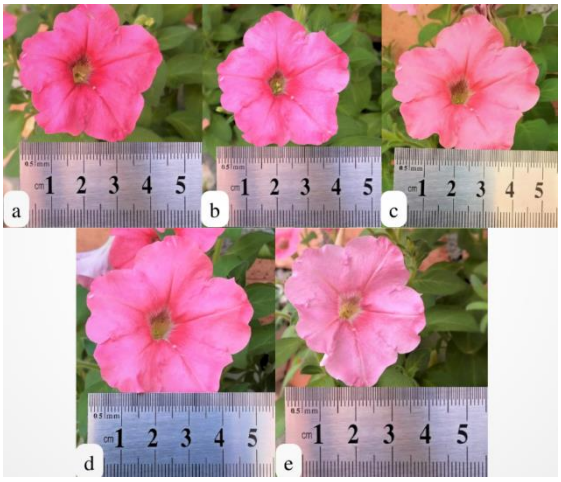

Figure 11. Process of petunia flower corolla blooming: (a) first day of blooming, (b) second day of blooming, (c) third day of blooming, (d) fourth day of blooming, (e) fifth day of blooming.

At the beginning of corolla blooming, the stamens are still in a solid yellowish state, but a few hours later, the stamens start to rupture, as indicated by the release of pollen from the anther sacs. The *anthesis* period occurs around the third or fourth day, as at this time the pollen accumulates in clusters, covering the stigma head. Meanwhile, the condition of the style head is sticky, indicating that it is in a receptive state. This phenomenon is supported by Agustin & Garvita (2021), who state that in the flowering of *Cereus jamacaru* D.C. (*Cactaceae*), the receptive period is characterized by the presence of pollen on the stigma head and a thin layer of mucus on the surface of the style head.

Flowers that have passed the anthesis phase can only last for an average of 1–2 days. The changes that occur can be seen in Figure 10, parts d and e, where the color of the corolla starts to fade and the texture of the style head still feels sticky due to the remaining mucus, while the condition of the stigma head dries up and turns brown. The process of corolla blooming is influenced by environmental factors, particularly the intensity of sunlight. During the observation period around 8:00 a.m., the corolla buds were enlarging and the corolla lobes started to open. Subsequently, the corolla lobes continued to open as time passed until 11:00 a.m., reaching a diameter of approximately 17.8 mm with an intensity of sunlight ranging from 174.00 to 10,649.00 lux. The development continued until 3:00 p.m., with sunlight intensity ranging from 82,500 to 10,353 lux and the corolla diameter reaching about 31.5 mm.

A similar phenomenon occurs during the blooming process of Surian flowers (*Toona sinensis* Roem), where at 6:00 a.m., the flowers are still in the early blooming stage, and then from around 11:00 a.m. to 2:00 p.m., the corolla lobes gradually open until the corolla is fully bloomed (Hidayat, 2010). Other environmental factors observed during the corolla blooming process include air temperature (25–37°C), air humidity (60–95%), and rainfall (0.0–6.2 mm). However, these three factors do not show a clear tendency toward the blooming process of petunia flowers.

e. Phase of withered, dried, and fallen corolla (post-anthesis)

The *post-anthesis* phase marks the end of the flowering process through three stages: corolla wilting, drying, and eventually falling off. During the observation, on average, only a few flowers that have gone through the *post-anthesis* phase end up producing fruit, with around 2-3 flower buds successfully developing into fruits in a single pot. This condition suggests that the processes of pollination and fertilization did not occur effectively. According to Gomes & Pinheiro (2009), not all flowers can produce fruit during the reproductive process due to limiting factors that occur at each stage. In the case of petunia flowers, one limiting factor is the position of the stigma, which is located higher than the anther, hindering the process of pollination.

Several pieces of evidence indicate that the relative position of the stigma and anther affects pollination. For example, in the flowering of *Cassine koodersi* Kostermans (*Celastraceae*), the position of the anther is slightly higher than the stigma, allowing the released pollen to directly fall onto the stigma and facilitate pollination (Ardhianto et al., 2009). Similar conditions occur in the flowering of *Syzigium pycnanthum*, where the stigma is positioned in the center of the circle formed by the anthers, which is considered an ideal position for easy pollen deposition and pollination (Mudiana & Ariyanti, 2010).

Based on observations, it was found that flower buds that successfully develop into fruits are characterized by the enlargement of their ovaries. However, if no fruit is formed, there is no development observed in the ovaries. The development of petunia flowers in

the *post-anthesis* phase is presented visually in Figure 12.

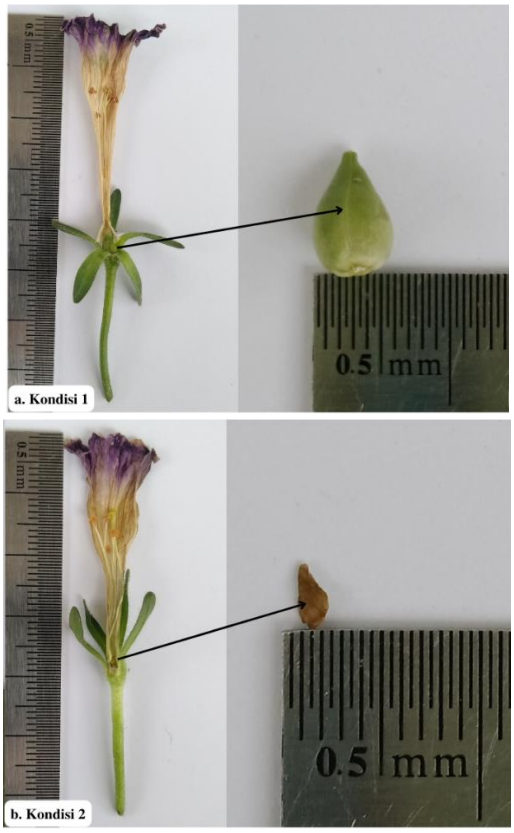

Figure 12. Development of flowers in the post-anthesis phase: (a) developing into fruit, (b) not developing into fruit.

This is in line with Nita et al.'s (2015) observations that, in the Pigeon Orchid flower (*Dendrobium crumenatum* Sw.), development results in fruit formation and is characterized by the withering of the floral adornment and the enlargement of the ovary. If no fruit forms, the corolla also remains withered, then dries up and falls off. The corolla will naturally fall off after going through a series of flower development phases as it becomes smaller and drier, making it easily blown away by the wind.

The phenomenon of corolla shedding in petunia flowers is different from the flowering of Nyamplung (*Calophyllum inophyllum* L.), where shedding can occur in several stages, including the bud phase, *pre-anthesis* phase, and *anthesis* phase. However, corolla shedding most commonly occurs during the *anthesis phase* (Hamim et al., 2019). The main factors causing corolla and fruit shedding are the influence of auxin, gibberellin, and ethylene hormones (Kurniawati & Hamim, 2009). The environmental factors observed during the *post-anthesis* phase include sunlight intensity (342.00–10649.00) lux, air temperature (25–35) °C, air humidity (55–95) %, and rainfall (0.0–6.2) mm.

CONCLUSION

Based on the observations, it is found that Petunia is a plant that produces multiple flowers on its stems and branches (*Planta multiflora*), covering each end of the main stem, thus being classified as a compound flower with distinct boundaries. Measurements conducted on five pots of petunia plants show an average length of flowers ranging from 69–74 mm and an average diameter ranging from 37–42 mm. Furthermore, the average length of the flower stalk is 19–28 mm, with an average diameter of 1 mm. It is categorized as a complete flower because it has main parts, including the corolla with an average diameter of 37–42 mm, the sepals with an average length of 11–16 mm, and an average diameter of the sepals ranging from 12–21 mm. In addition, the flower's reproductive organs consist of five stamens and one pistil in each flower.

The flowering period of petunias lasts an average of 37 days, and its stages show distinct changes that can be distinguished. Based on observations of environmental factors, sunlight intensity appears to play a role in the opening of the corolla. However, other environmental factors such as temperature, humidity, and rainfall do not show a clear tendency towards the development of petunia flowers. This statement can be observed in the continuous development of the flowers until the final stage. Therefore, based on the observed environmental factors, it can be categorized as optimal for the development of petunia flowers.

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