

## Selection and Morphological Characterization of Crossed Anthurium (*Anthurium andreanum*) cv. Midori × Angel

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### ABSTRACT

*The floriculture industries depend on market and consumer preferences which dynamically change. Innovation to create new varieties is one of the solutions. The breeding program enhances genetic variation and new varieties. One of the methods was conventional cross breeding. The research objective was to characterize and select the potential clones in the F1 population of crossing anthurium cv. Midori × Angel. Anthurium Midori as female parent and Anthurium cv. Angel as male parent. The individual selection method was used to select the F1 population of Anthurium cv. Midori × Angel. The observation parameters were spathe length (cm), spadix length and width (cm), total number of leaves, total number of shoots, total number of flowers, inflorescent length (cm), and plant height (cm). There were 26 individual offspring from the crossing Anthurium cv. Midori × Angel. Most of the offspring inherited from both the combination of Midori and Angel. They were greenish white. Green was from Midori and white was from Angel. MA-16 and MA-27 were selected as potential clones to be registered as new varieties. The character of these clones was green spathe inherited from Midori as female parent.*

## 1. INTRODUCTION

The floriculture industry in the developed countries has become an important source of national income, with countries like the Netherlands, Thailand, and Japan leading the way. Among the ornamental plants exported, one notable species is anthurium (*Anthurium andreanum*). The largest exporter and producer of anthurium is Anthura in the Netherlands, with flower exports valued at US\$ 4.2 billion, followed by Colombia at US\$ 1.4 billion. The Netherlands dominates the European market, followed by Mauritius in Hawaii for the American market (Islam *et al.*, 2013). In Indonesia, anthurium is widely produced with a total of 1.96 million plants in 2022 (BPS, 2023).

Anthurium belongs to the largest family of *Araceae*, comprising of 1500 species. This plant is known for its attractive and long-lasting flowers. Some anthuriums have less striking flowers but feature beautiful leaves with various textures, such as velvet-like or coarse, heart-shaped, ovate, and ribbed. This flower type was first introduced in the Philippines around 1970 and has since dominated several local nurseries. The flowers come in various colors, sizes, shapes, and textures. The flower consists of a spathe, which is a modified leaf, and a spadix, a protruding structure from the base of the spathe and petiole (Rosario & Aurigue, 2009; Evelyn *et al.*, 2020).

Anthurium is semi-epiphytic, grows slowly, and is a perennial plant that can live year-round, requiring specific temperature and light intensity. Anthurium thrives in well-aerated media with sufficient organic matter (Biñas Jr *et al.*, 2023). In recent years, the commercial production of ornamental plants in several countries has attracted producers

and investors aiming for higher profits, intensive demand, and production, as well as quick return on investment with market growth exceeding 15% (Barreto *et al.*, 2023).

Globally, *Anthurium andreanum* ranks number two for cut flowers, after orchids. The highest market demand for Anthurium is for potted plants and cut flowers (Jouen *et al.*, 2019; Soleimanipour & Chegini, 2020). In Indonesia, the harvested area of Anthurium increased from 133,815 m<sup>2</sup> in 2020 to 146,984 m<sup>2</sup> in 2021, with the highest flower production in 2019 at 5,390,417 stems (BPS, 2021). The plant's advantages lie in its beautiful colors that align with market trends and consumer preferences, long blooming periods, and the ability to bloom simultaneously (Ramirez *et al.*, 2019). Anthurium, a tropical plant in the *Araceae* group, easily adapts to both indoor and outdoor environments, suitable for decoration, cut flowers, and gardens (Barreto *et al.*, 2023).

High demand for anthurium can be met by developing new varieties with superior characteristics, healthy and uniform plants, and reducing production costs, especially for pest and disease control. This also involves enhancing multiplication capabilities through in vitro propagation (Martínez-Estrada *et al.*, 2019). Generally, the economic value of anthurium plants lies in the diversity of leaf shapes, sizes, and the colors of spathes and spadices (Daengsuwan *et al.*, 2021). Consumer preferences and trends for anthurium flower colors, shapes, and types change over time. The dominant colors found in Indonesia are red and white. With the advancement of technology and the introduction of new superior varieties through breeding, there has been a shift in flower color preferences, shapes, and sizes. In recent years, colors like salmon, soft shades, and green have become popular choices among consumers in Europe and Japan. Understanding these changing preferences and trends, this research focuses on developing superior green and white Anthurium flower varieties (Martínez-Estrada *et al.*, 2019).

The objective of this research is to obtain new clones of anthurium from the cross between cv. Midori and Angel. The new clones will be registered as new varieties for distribution. Breeding green anthurium aims to create new color trends as alternative choices for consumers and the domestic market, as an effort to substitute imports and reduce the export of anthurium products from abroad.

## 2. RESEARCH METHOD

The research was conducted in the plastic house of the Center for Standardization and Instrumentation of Ornamental Plants, Segunung, Cianjur, West Java. The parent plants used for crossing were anthurium from the germplasm collection, specifically the green variety (cv. Midori) and the white variety (cv. Angel). The crossing of these anthuriums was carried out from 2019 to 2023, starting from parent selection, crossing, fruit and seed formation, seed planting, and up to the flowering phase and selection of new anthurium clones resulting from the cross.

### 2.1. Tools and Materials

The tools used in this research included tweezers, petri dishes for pollen storage, crossing labels with crossing codes and dates, scissors for cutting fruits and flowers from the crossing, fruit storage boxes, pots for seed sowing and plant repotting until flowering, a logbook for recording crossings and observations, rulers for measurement, and the RHS horticultural color chart for flower color characterization. Plant maintenance tools included sprayers for watering, fertilization, and pest control.

The materials used were the F1 population resulting from the cross of Anthurium cv. Midori x Angel, consisting of 26 selected individuals used for the selection and characterization of potential new anthurium clones. The growing medium was a mixture of bamboo humus, manure, and burnt husk in a ratio of 1:1:1. This research is descriptive, focusing on the observation of morphological and qualitative and quantitative characteristics (flower color).

### 2.2. Research Stages

#### 2.2.1. Crossing of Anthurium cv. Midori × Angel

The breeding of anthurium flower varieties involves several stages, including the selection of parent plants, crossing, fruit harvesting, seed planting and germination, transplanting the plants into medium-sized pots/polybags (10 cm diameter) to larger ones (15 cm diameter), and selection and evaluation based on the targeted plant characteristics. The

parent selection for crossing included Anthurium Midori (Figure 1a) and Angel (Figure 1b) to achieve variations in flower color and shape, inheriting the characteristics of both parents.



Figure 1. Parent plants for the crossbreeding of anthurium flowers: (a) the Midori variety of anthurium flower as the female parent, and (b) the Angel variety as the male parent.

Crossing was conducted in the morning from 7:00 to 9:00. The process was performed on plants ready for pollination, indicated by the sticky spadix. Female anthurium pollen matures earlier than male pollen, so the timing of crossing is crucial for its success. The difference in maturation times can be managed by increasing the number of parent plants. Fruit formation and harvesting depend on the parent plants used. Generally, fruits form 4 months or more after crossing. The seeds are then sown in small pots (15 cm diameter) until they germinate and reach a height of  $\pm 2-3$  cm. The seedlings are transferred to larger pots for  $\pm 4$  months until they grow to a size of 10-15 cm. They are then moved to even larger pots for  $\pm 8$  months until they reach 20-25 cm. Finally, at 12 months old, with a plant size of 30-40 cm, they are transplanted to the field to achieve optimal flower production for cut flowers.

### 2.2.2. Selection and Characterization of Anthurium F1 Population

Selection and evaluation were performed individually by choosing plants that met the selection criteria. Individual selection was carried out on the F1 population resulting from the cross to obtain selected clones, which were then clonally propagated for variety registration through preference testing. Morphological selection was performed on flowering individuals in the F1 population. Observations included morphological characteristics such as spathe length (cm), spadix length (cm), spadix width (cm), number of leaves, number of shoots, number of flowers, flower stalk length (cm), and plant height (cm). Observations were made when the flowers were fully bloomed, starting from the first flowering (1 year after planting). Subsequent observations were conducted monthly when other flowers on the same plant were fully bloomed. The color of the spathe and spadix was classified according to the RHS (Royal Horticulture Society) color chart. Characterization was based on the anthurium characterization guidebook from the Ministry of Agriculture. Data analysis was performed using IBM SPSS Statistics 19.

## 3. RESULTS AND DISCUSSION

### 3.1. Crossing of Anthurium cv. Midori $\times$ Angel

The crossing of Anthurium cv. Midori  $\times$  Angel was carried out to obtain new clones with soft green, white, or a combination of both colors. Fruits from the crossing were obtained 6 months after pollination. The success of the crossing was determined by the fertility of both male and female pollen. Generally, female pollen matures earlier. The difference in pollen maturation times was managed by storing pollen and increasing the number of Midori and Angel parent plants.

The success of fruiting was also influenced by the growing conditions during crossing and the crossing process itself. The crossing was conducted continuously and repeated every 3 to 5 days in the morning. From the crossing of Anthurium Midori  $\times$  Angel, 96 seeds were obtained, planted, and maintained until flowering. The first stage of individual selection in the F1 population resulted in 26 individuals. These selected plants were then characterized to obtain new clones that meet consumer and market preferences.

### 3.2. Selection of Anthurium MA Clones Resulting from the Cross of Anthurium cv. Midori x Angel

The development of cut flower anthurium varieties Midori x Angel was carried out through conventional crossing to form an F1 population. The results of the cross showed genetic diversity within the F1 population. Morphological diversity included variations in spathe and spadix colors and sizes. This diversity forms the basis for selecting plants that meet consumer preferences and have superior plant performance. Selection criteria were based on flower performance, including spathe and spadix color and flower shape. In the first selection stage, 26 individual plants were selected from 96 seeds sown and maintained until flowering. The second selection was performed on the 26 plants from the first selection stage, resulting in the selection of 6 plants (Figure 2). These six selected anthurium plants were further selected, yielding 2 plants, MA-27 and MA-16, that met the selection criteria. Clone MA-27 had the advantage of a salmon-colored spadix, while MA-16 had a bright yellow spadix (Figure 2).

The description and classification of the selected clone plants based on their growth habits included plant growth patterns, apical growth direction, stem growth, and root presence related to the growth pattern. The growth pattern of clones MA-27 and MA-16 was sub-erect (semi-upright) (Figure 3A), with plant size falling into the medium category, having a height of 51-125 cm and a width of 31-75 cm. These measurements were based on the overall proportionality of the plants, comparing height and width (Suskindari *et al.*, 2015).

Based on leaf type, clones MA-27 and MA-16 had single leaves (Figure 2a,b). The leaf blade shape was ovate, that is rounded oval with a wider base towards the petiole (Figure 2b), and cordate (heart-shaped) (Figure 2c). In some flowering anthuriums, there is a pattern of color distribution change on the upper leaf surface with age, but this was not observed in these clones. The color change in the leaves of clones MA-27 and MA-16 occurred due to senescence.

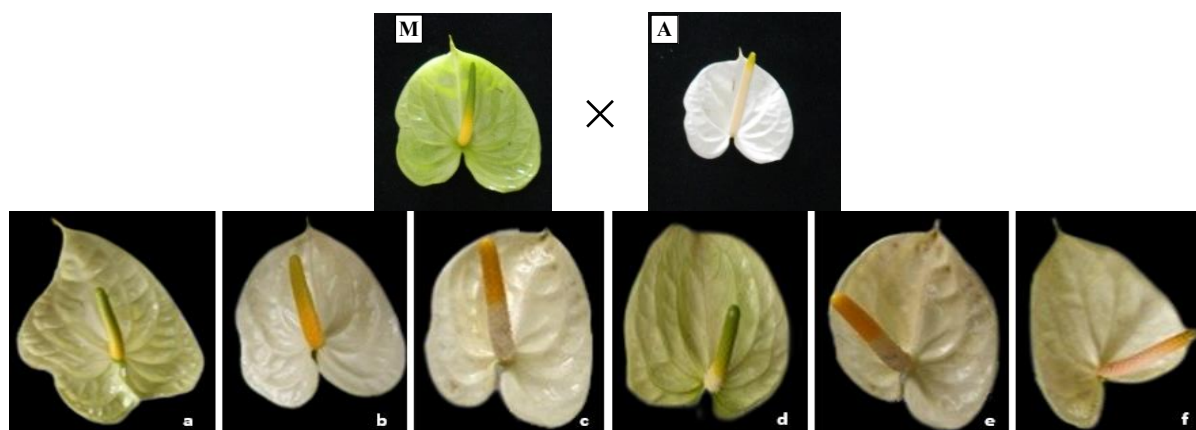


Figure 2. Selected clones resulting from the crossbreeding of Midori (M) × Angel (A) with various shades of green: (a) Clone MA-26; (b) MA-16; (c) MA-28; (d) MA-14; (e) MA-4; and (f) MA-27.

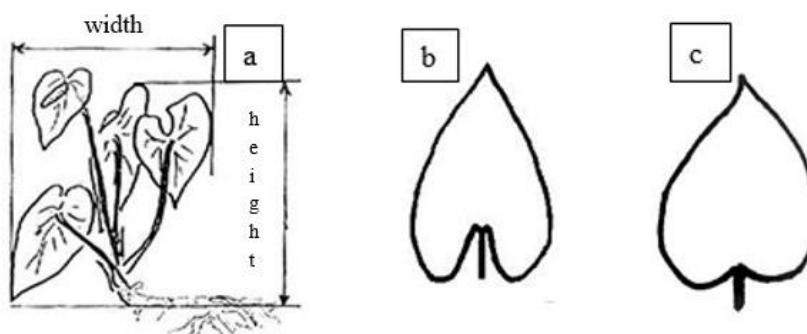


Figure 3. First stage selection of anthurium plants: (a) Leaf size; (b) Lobe position; and (c) Leaf types.

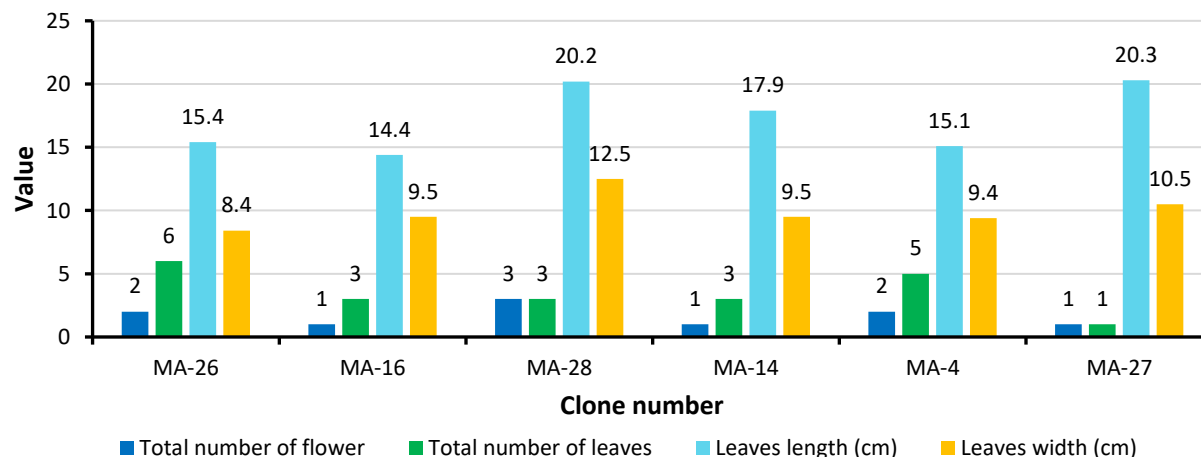


Figure 4. Morphological performance of flowers resulting from the MA (Midori × Angel) cross based on quantitative characteristics: number of flowers (buds), number of leaves (blades), leaf length (cm), and leaf width (cm).

### 3.3. Quantitative Characteristics of Anthurium Midori x Angel Clones

The quantitative characteristics of the anthurium clones from the crosses included plant height (cm), stalk length (cm), spadix length (cm), and spathe length and width (cm) (Figure 4).

#### 3.3.1. Plant Height

The selected Anthurium MA clones had an average height ranging from 21.4 cm to 37.4 cm. This cross result had a higher range compared to previous studies, which had an average plant height of 22.35 cm to 26.84 cm. Anthurium flowers from previous studies were planted in manure media combined with coconut husk (Biñas Jr *et al.*, 2023) (Figure 4). These selected clones showed improved characteristics for plant height compared to the heights obtained by Biñas Jr *et al.* (2023). This result can be recommended for garden and landscape plants.

#### 3.3.2. Number of Flowers

The number of flowers, aside from genetic factors, affects the flower size; the more flowers, the smaller the size of each flower. Plants with single flowers will have larger flowers compared to those with many flowers. The anthurium MA clones resulting from the Midori x Angel cross had the highest number of flowers, with 3 flowers per stalk during the first flowering stage (Figure 4). During the first flowering phase in anthurium plants, the flower structure and performance are generally not optimal. Optimal flower performance is usually obtained in the third flowering phase. Clone MA-28 had the most flowers compared to other clones (Figure 4) (Kurniati *et al.*, 2023).

#### 3.3.3. Number of Leaves

The number of leaves in Anthurium plants is not a primary criterion for consumers. However, the number of leaves is important for meeting the plant performance assessment standards, especially for landscape and garden functions. The composition of the number of leaves and plant height will determine the plant's performance. Selected clones MA-26 and MA-4 had the highest number of leaves compared to other clones (Figure 4).

#### 3.3.4. Leaf Length (cm)

The leaf length of the selected anthurium clones did not show any significant differences. The average leaf length ranged from 14.4 cm to 20.3 cm (Figure 4). This result is lower compared to previous research, which had a range of 26.21 cm to 28.61 cm (Biñas Jr *et al.*, 2023). The difference is due to the MA anthurium clones being grown from cross-seed, while Binas *et al.* (2023) used offshoots. In crossbred anthurium plants, the plant performance generally stabilizes and reaches optimum levels in the third year from initial crossing to flowering (Kurniati *et al.*, 2023).

### 3.3.5. Leaf Width (cm)

The leaf width of the selected anthurium clones did not show any significant differences. The average leaf width ranged from 8.4 cm to 12.5 cm (Figure 4). This width falls within the average range for flowering Anthurium leaves.

## 3.4. Morphological Characteristics of Anthurium Midori × Angel Cross Clones

### 3.4.1. Flower Stalk Length

According to the anthurium characterization guide (Suskandari, 2015), flower stalk length is grouped into four categories: very short, short, medium, long, and very long. The results of the Anthurium Midori x Angel clones can be categorized into two groups: (1) very short (stalk length less than 20 cm) including clones MA-14 (19.4 cm) and MA-16 (19.4 cm), and (2) short (stalk length 20-40 cm) including MA-4, MA-26, MA-27, and MA-28 (Figure 5).

Stalk length is an important criterion in characterization, linked to the suitability of the stalk length for decoration or flower arrangements. The measurement is taken from the base of the plant to the tip of the spathe. Spadix length is also a key selection criterion in evaluating anthurium flowers. Generally, spadix length should be proportionate to the size of the spathe. The balance between spadix length and spathe size is a key aesthetic criterion for flower assessment. The selected MA anthurium clones had an average spadix length ranging from 2.8 cm to 5.8 cm.

### 3.4.2. Spathe Length

Spathe length is crucial in the characterization of anthurium flowers. It determines the size and proportion of the flower relative to the spathe width. The selected MA anthurium clones had a spathe length range of about 5.8 cm to 10.2 cm (Figure 5).

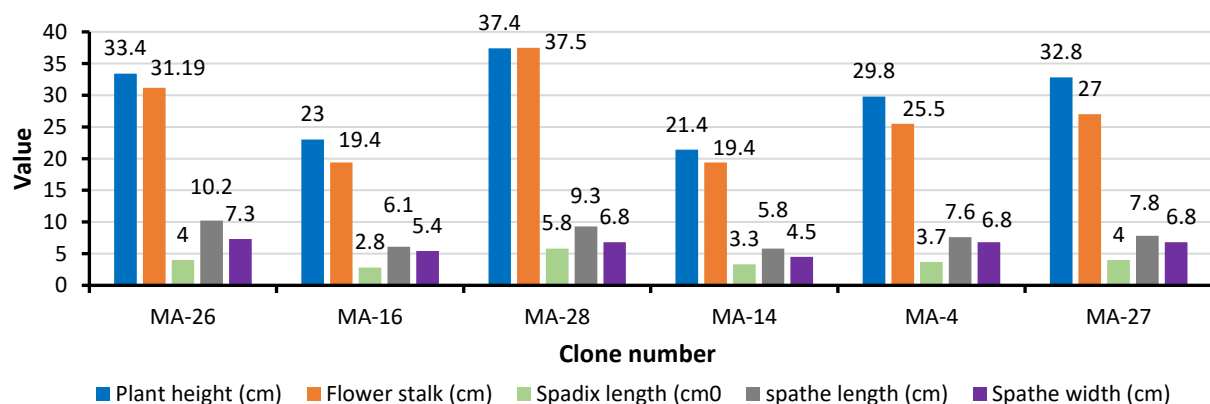


Figure 5. Morphological performance of flowers resulting from the MA (Midori x Angel) cross based on quantitative characteristics: plant height (cm), stalk length (cm), spadix length (cm), spathe length (cm), and spathe width (cm).

### 3.4.3. Spathe Width

Similar to spathe length, spathe width affects the size of the flower, influencing consumer preferences and market demand. The selected MA anthurium clones had a spathe width range of about 4.5 cm to 7.3 cm (Figure 5).

## 3.5. Qualitative Morphological Characteristics of Flowers

A distinctive feature of anthurium flowers is the presence of spathe and spadix. The size of the spathe and spadix significantly impacts flower quality, which is also determined by a long post-harvest duration, including physical conditions such as color, spathe diameter, stalk length, and stalk diameter in some anthurium varieties and species. A market survey conducted on 73 retailers in Hawaii indicated that Anthurium vase life and spathe color were key factors in purchase decisions, with 88% of florists desiring a vase life of 10-15 days (Favero *et al.*, 2020).



Spathe size classification based on the anthurium characterization guide includes five categories: very small, small, medium, large, and very large. The selected MA hybrid clones fall into the very small (MA-14) and small (MA-4, MA-16, MA-26, MA-27, and MA-28) categories. The small category is defined by spathe length of 5-10 cm and width  $\leq 5$ -10 cm, while the very small category is defined by spathe length  $\leq 5$  cm and width  $\leq 5$  cm (Figure 5). If not influenced by genetic factors, these sizes will continue to improve by the third flowering phase. By this stage, the flower size and shape are more stable (Kurniati *et al.*, 2023).

### 3.6. Qualitative Characteristics of Anthurium MA Clones

Another key qualitative characteristic for selecting anthurium hybrids is flower color. The Anthurium Midori x Angel hybrids have spathes with soft, gentle colors and matching spadixes. The color of the spadix and spathe determines the quality and selection of anthurium plants, including vase life duration (Simões *et al.*, 2018). Spathe and spadix colors are often dynamic, changing with market demand and consumer preferences.

Flower color is determined by pigments (Clegg & Durbin, 2000). The primary pigments in plants include anthocyanins, betalains, carotenoids, and chlorophyll. Anthocyanins, carotenoids, and chlorophyll play significant roles in the color of Anthurium spathes. The concentration, ratio, and intensity of these pigments determine spathe color (Lin *et al.*, 2022). Betalains are not found in anthuriums (Timoneda *et al.*, 2019). Anthocyanins form the largest group of pigments with colors ranging from pink, red, purple to blue. Anthocyanins are synthesized through the flavonoid pathway (Pucker & Selmar, 2022). Cinnamate-4-hydroxylase (C4H) plays a key role in flavanol accumulation at the early stages (Mizutani *et al.*, 1993; Ren *et al.*, 2019).

#### 3.6.1. Color of Spathe

The color of the spathe is a crucial aspect in evaluating the important characteristics of anthurium. The color of the spathe and the spadix are closely related as they form a combination that enhances the beauty of anthurium flowers. The hybrids of anthurium resulting from crossing A. Midori  $\times$  A. Angel possess spathes in the color range of yellowish-green, greenish-yellow to yellow based on the RHS color chart (Table 1).

Table 1. Colors of spathe and spadix of selected MA (Midori  $\times$  Angel) hybrids

Character	Clone number					
	MA-26	MA-16	MA-28	MA-14	MA-4	MA-27
<b>Spadix color</b>	Yellow green 144b, Yellow 12A	Green yellow 1A (Upper) Yellow orange 17A (Bottom)	Yellow group 6A	Yellow orange 17A (Upper) Yellow group 13D	Yellow green 144B (Upper) Yellow green 150D (Bottom)	Red group 36A
<b>Spathe color</b>	Yellow green 145C	Yellow green 150D	Green yellow 1D	Yellow group 8D	Yellow green 154D	Yellow green 150D

These colors are inherited from the combination of the colors of both parent plants, A. Midori which is green, and A. Angel which is white (Figure 1). The white spathe color is caused by the downregulation of AaMYB2 expression. This downregulation results in the upregulation of AaLAR (leucoanthocyanidin reductase) and AaANR (anthocyanidin reductase). The green color is associated with the presence of AaMYB124 which enhances AaHemB a (porphobilinogen synthase) (Li *et al.*, 2023).

#### 3.6.2. Color of Spadix

The hybrids resulting from the cross of Anthurium Midori  $\times$  Angel exhibit variations in the color of the spadix, including yellowish-green, greenish-yellow, yellow, orange-yellow, and red (Figure 1; Table 1). The spadix color is more strongly inherited from the combination of the spadix colors of both parent plants. The color of the spadix is significant as it complements the beauty by forming a harmonious combination with the spathe. The attractiveness of anthurium flowers lies in the compatibility of this combination.









3.6.3. Shape and Size of Spathes

Variations in the shape and size of the spathe were also obtained from the crossing of Anthurium Midori x Angel (Figure 6). According to the anthurium plant characterization guidelines (PPVTPP, 2021), the shape of the spathe is classified into 5 types: elliptic, broad elliptic, almost round, ovate, and broad ovate. Based on this classification, the shapes of the spathe resulting from the Midori × Angel cross are categorized into four types: 1) Elliptic (6d), 2) Almost round (c, e & f), 3) Broad elliptic (6b), and 4) Broad ovate (6a). According to the presence of lobes, they are categorized into two groups: with lobes and without lobes. Clone MA 26 does not have lobes (Figure 6a), while clones MA 18, MA 28, MA 14, MA 4, and MA 27 have lobes (Figures 6b, c, d, e, and f).



Figure 6. Variations in the shape and size of the spathe and spadix of anthurium hybrids from the Midori x Angel cross.

Table 2. Position of lobes on the spathe of MA hybrids based on the Anthurium characterization guidelines (PPVTPP, 2021).

Shape		Category	MA Clones
a.		incurved but not touching	 MA-28, MA-14, and MA-27.
b.		free	 MA-26
c.		touching	 MA-18 and MA-4
d.		over lapping	--
e.		adpressed	--



### 3.6.4 Position of Lobes on Spathe

The hybrids resulting from the cross of *Anthurium* Midori × *Angel* are categorized into three groups based on the position of the lobes: 1) incurved but not touching (Table 2a); 2) free (Table 2b); and 3) touching (Table 2c). These three categories show the diversity in the lobe position character on the spathe.

### 3.6.5 Shape of Spathe Base

Characterization of the spathe base shape based on the anthurium characterization guidelines (PPVTPP, 2021) is grouped into three shapes: acuminate, obtuse, and rounded. The selected hybrids from the *A. Midori* × *A. Angel* cross consist of two shapes: acuminate (Figure 7.1) and obtuse (Figure 7.2).

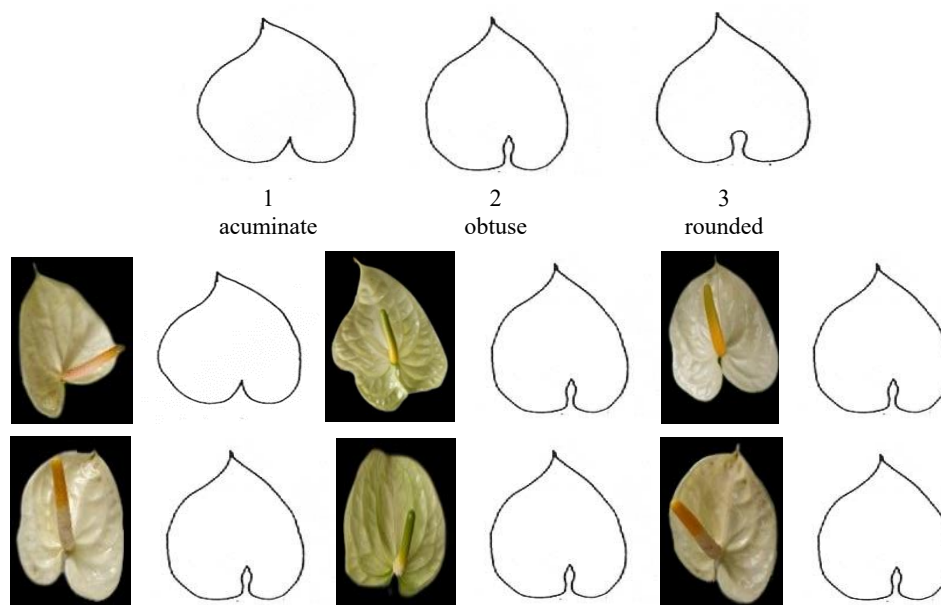


Figure 7. Base shapes of *Anthurium* MA clones.

Generally, the shape of the spathe base is not a primary consideration for consumers and market demand; however, it becomes a criterion in the characterization and selection of anthurium as cut flowers. Consumer and market criteria typically focus more on the color, shape, and size of the spathe.

## 4. CONCLUSION

The selection of anthurium hybrids is based on the superior morphological characteristics of the flowers, market needs, and consumer preferences. The selected MA clones include MA16 and MA27. The description of the hybrid anthurium flowers is characterized based on standardized characterization guidelines. The shape, color, and size of the flowers are adjusted to consumer needs. White anthurium flowers remain dominant in market and consumer demand for decorations and arrangements as they are easier to match. Green color is becoming a new trend required by the market as an alternative color.

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