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Increased Growth of *Caladium* by Tuber Section and Plant Growth Regulators

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Abstract: *Caladium* is a tuberous plant propagated by the tuber section technique to increase the plant quantity. Gibberellin (GA_3) and indole-3-butyric acid (IBA) have great capability in various agricultural practices, such as growing rapidly and enlargement tuber size. The effects of different tuber section sizes and PGRs levels having the following constituents (GA_3 and IBA) in different levels by 2x5 factorial in a completely randomized design (CRD) with ten replications. The treatments involved 2 factors: The first factor was separating two sizes of tuber section into a squall length of each size 0.5 and 1 cm, and the second factor was drenching the tuber in two different levels of each IBA (100 and 150 ppm) and GA_3 (100 and 150 ppm). The results obtained from this experiment showed that the 1 cm of tuber section size was a higher significant difference in bud germination, tuber size, plant height, canopy width, and the number of leaves than the 0.5 cm of tuber section size. However, IBA at 150 ppm was a higher significant difference in the average survival rate, bud germination, plant height, canopy width, and the number of leaves than others. The interaction between the tuber size at 1 cm and IBA at 150 ppm gave the highest survival rate, bud germination, plant height, canopy width, and the number of leaves. Therefore, the *Caladium* was separated at 1 cm size and immersed in 150 ppm of IBA appropriated to induce growth after the section within two months.

Keywords: IBA; GA_3; *Caladium*; tuber; section size

1. Introduction

Caladium is a member of the Araceae family. It is popular for its colorful foliage and is widely used as a pot plant or for outdoor bedding. It has few complications and is easier to grow. Relatively insensitive to diseases and few pests. Therefore, commercial crops have a lower cost advantage. In Thailand, *Caladium* production was located in the regions around Bangkok, including the provinces of Pathum Thani and Nonthaburi. *Caladium* production is worth around 3 million Thai baht annually [1-4]. Caladium 'Candidum' is generally a potted plant produced as a tuber. Growing *Caladium* was a popular technique for propagation in the landscape or home garden or as a bedding plant for late spring or early summer [1, 5].

The possible techniques for *Caladium* propagation were micropropagation, seeding, or tuber cutting. The tissue culture technique is rarely used due to the

complicated protocol and costs. Seeds are predominantly employed in breeding programs because it is a time-consuming process with laborious that introduces significant variability to the crop. Consequently, tubers cutting are the most widely used technique for commercial purposes for *Caladium* [6]. Reproduction through the tuber section is the most used method among tuber plant production methods. Reproduction through the tuber section is propagation by using a piece taken from the tuber of a plant. The tuber section is put in a suitable environmental light and is forced to form roots and suckers [7]. The new plants obtained in this way retained the entire rootstock gene structure [8]. It was stated that large rhizomes yielded significantly higher yields than smaller ones. Commercial growers typically use plant growth regulators (PGRs) to improve the marketable characteristics of their crops for economic gains. Sarkar et al. [9] explained that using various PGRs could increase the number of tubers per plant, the weight of the bulbs, and the overall bulb yield when applying a dip treatment method in northern India. Singh [10] reported that IBA is a widely used rooting hormone that promotes rooting in stem cuttings or air layering, enhances early establishment, bud formation, vegetative growth, and increases the survival of seedlings. According to Amin et al. [11], the most effective PGRs in tuberose growth is GA_3 at 300 ppm. The effects of PGRs tend to be rather inconsistent because environmental factors also influence them. Under increased humidity or when longer drying times are used, the uptake of PGRs can be increased according to laboratory test results [12].

However, the results of respective scientific research on this *Caladium* plant are inadequate, and the tuber section size and PGRs concentrations in its growth. This study examines the capability of various tuber section sizes and PGRs concentrations with the following constituents (GA_3 and IBA) in different concentrations for *Caladium* quantities and faster sales growth within two months.

2. Materials and Methods

2.1. Area of reserach

The experiment was managed under greenhouse conditions at the Department of Horticulture, King Mongkut's Institute of Technology Ladkrabang (KMITL) in Bangkok, Thailand, between March 2022 and July 2022.

2.2. Treatments

The experimental design was 2x5 factorial in a completely randomized design (CRD) with ten replications. The treatments compose of 2 factors: factor 1 used two sizes of tuber section: 0.5 and 1 cm., and the other factor used four concentrations of each plant growth regulator: IBA (100 and 150 ppm) and GA_3 (100 and 150 ppm), saturated to the tuber of *Caladium* for 30 minutes. The tap water was assigned to be the controlled treatment.

2.3 Plant materials

The tuber of Caladium 'Candidum' with an average diameter of a tuber of about 6-8 cm. The tuber was prepared by removing the roots. Then the section was divided into a squall length of each size 0.5 and 1 cm (There will be one side that is the growth point of the buds, and the rest will be accumulated food). Then, the tubers were saturated with the four different plant growth regulator solutions or tap water for 30 minutes, followed by the above treatments. After that, the tubers were dried and planted in a 12 x 17.5 (width x length) cm plastic box using a 1:1 (by volume) sand and coconut coir ratio. After bud germination, planted in a 4.25 x 3.5 (width x length) cm pot using a 2:1 (by volume) ratio of decomposed rain tree leave and soil. The plants were transplanted into the planting material and placed in a greenhouse with 60% shading, average temperature 30-35 °C, relative humidity 60-70%, light intensity 150-220 μmol $s^{-1}m^{-2}$, watering rate 500 ml/pot every 2 days.

2.4 Plant growth analysis

All growth parameters of the Caladium 'Candidum' growth were collected 1 month after planting. The survival rate was evaluated by counting a normal tuber bud germination 30 days after section [4]. The

survival percentage [% survival= (number of survival tubers/number of total tubers) x 100], the days to sprouting was collected after planted at 30 days or the sprouted shoot about 1-2 cm length, and were determined growth at 4 months are as follows: The plant height in a unit of cm was set to be extended from the base of the ground to the tip of the plant, the number of leaf per plant, the canopy width at length and width of the leaf, and color of leaf samples were measured by a Colorimeter Color Reader CR-10 Plus, in the CIE L*, a*, b* (Lightness (L*), redness (a*), and yellowness (b*) values were recorded.

2.5 Statistical analyses

All plant growth parameters were determined using the statistical analysis system IBM SPSS Statistics version 25 and statistix version 10 program. A comparison of treatment methods can be made using Duncan's Multiple Range Test (DMRT) at the 0.05 probability level.

3. Results and Discussion

3.1 The percentage of survival rate and bud germination of Caladium 'Candidum'

The survival rates were non-significant differences ($P<0.05$) after the tuber section in a different size (Table 1), while bud germination showed significant differences after the tuber section in a different size. A 1 cm tuber was the earliest days to bud germination (27.58 days) than a 0.5 cm tuber size, after planting at one month than a 1 cm size (Figure 1). The tuber cutting size at 1 cm has more eyes that are larger with the volume of higher reserve food and may help in cracking shoots in the early stages, as in line with the reported [13]. These results are encouraged by the research literature of Shakh et al. [14], who investigated potatoes that had early days to bud germination with the large-sized tuber, and Satyavir and Singh [15], who investigated gladiolus that had early days to bud germination with the large-sized corms.

Similarly, the growth and development of the *Caladium* when saturated with different concentrations of GA_3 and IBA indicated that survival rate and days to bud germination were significant differences (Table 1). The percentage of survival rate was shown to be the highest at the 150 ppm IBA (91.30 %), the earliest days to bud germination (20.65 days) (Figure 1). These findings concern the research results of Dhiman and Gupt [16]. The highest bud germination levels were reported after treating the seeds with 100 ppm IBA, which can be considered like GA_3 when the concentrations are the same. The improvements in seed germination following treatment with GA_3 could be attributed to the greater levels of hydrolase synthesis diffusion (alpha amylase) of endogenous auxin and gibberellin-like substances. On the other hand, the cause might be the increased metabolic rate during the germination process. The synthesis of specific proteins can lead to more rapid cell division, allowing quicker and more vigorous germination [17-18]. The process of seed metabolism can be assisted during germination by enzyme and coenzyme production, which can then mediate the protein synthesis necessary to promote cell division and the following growth [19].

The interaction between tuber section size and plant growth regulator concentrations affects the survival rate. A 1 cm tuber saturated with 150 ppm IBA gave the highest percentage of survival rate (91.30%), while the 0.5 cm tuber with saturated-in tap water was the lowest rate (67.90%). However, the days to bud germination were found the earliest in the 1 cm tuber with saturated in at 150 ppm IBA (19.00 days), while the 0.5 cm tuber saturated in tap water was the latest days (43.00 days) after planting for one month. This is consistent with the research results of Chaudhary *et al*. [20] that the application of auxin IBA 100 ppm significantly the earliest bud germination of Gladiolus x hybridus Hort. tubers. IBA breaks down and decays rapidly to low concentrations, suitable for converting root tissue into the root [21].

Table 1. Effect of tuber section size and the different concentrations of GA_3 and IBA on the percentage of survival rate and days to the bud germination of Caladium 'Candidum' after planting at 1 month.

Tuber size	Survival rate (%)	Bud germination (day)
Tuber size		
0.5 cm	81.84	31.24 a
1 cm	80.58	27.58 b
PGRs		
Tap water	69.35 e	39.00 a
GA_3 100 ppm	77.00 d	35.85 b
GA_3 150 ppm	80.80 c	28.85 c
IBA 100 ppm	87.75 b	22.70 d
IBA 150 ppm	91.15 a	20.65 e
Tuber size x PGRs (ppm)		
0.5 cm + Tap water	67.90 d	43.00 a
1 cm + Tap water	70.80 d	35.00 c
0.5 cm + GA_3 100	76.10 c	38.00 b
1 cm + GA_3 100	77.90 c	33.70 d
0.5 cm + GA_3 150	79.80 bc	30.50 e
1 cm + GA_3 150	81.80 b	27.20 f
0.5 cm + IBA 100	88.10 a	22.40 gh
1 cm + IBA 100	87.40 a	23.00 g
0.5 cm + IBA 150	91.00 a	22.30 h
1 cm + IBA 150	91.30 a	19.00 i
F-test		
Tuber size	ns	*
PGRs	*	*
Tuber size x PGRs	*	*
CV (%)	9.10	2.50

1/ Means with the same letter within a column are not significantly different at $P<0.05$ by the least significant difference by using the DMRT test.
ns= non-significant.

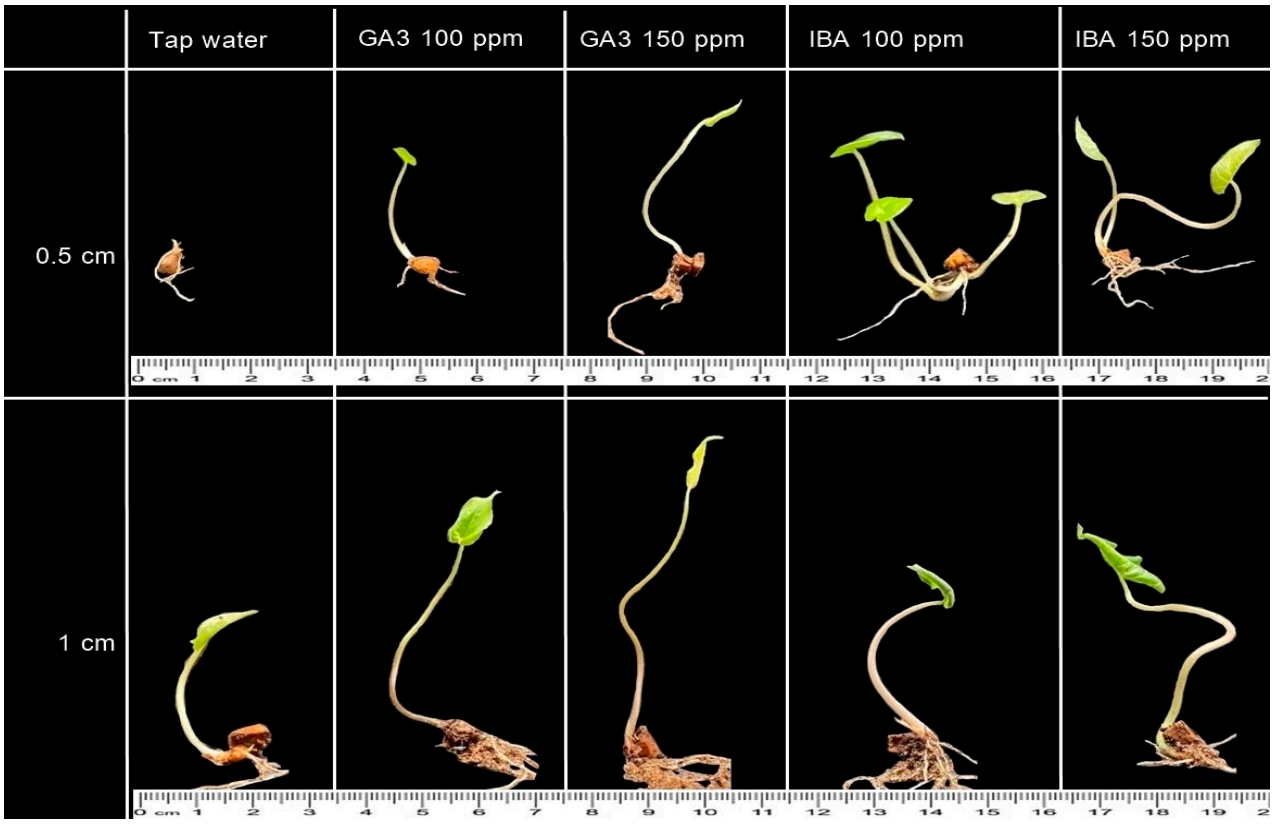

Figure 1. The bud germination of Caladium 'Candidum' after section and saturated within the different concentrations of GA_3 and IBA at 2 months**.**

3.2 Plant height, the canopy width, and the number of leaves of Caladium

The growth and development of the tuber section size differences were indicated by the plant height and the canopy width significant differences ($P<0.05$). The 1 cm tuber was the highest of the plant height (17.88 cm) and the canopy width (15.65 cm), while the number of leaves showed nonsignificant differences after planting at 2 months (Table 2).

The various concentrations of plant growth regulators were significantly different ($P<0.05$). The plant height, the canopy width, and the number of leaves were highest at 100 and 150 ppm IBA. There were 15.09 and 16.07 cm in height, respectively, 15.01 and 14.28 cm in width, respectively, and the highest number of leaves was shown in the tap water, and both IBA levels (100 and 150 ppm) were 2.75, 2.85, and 3.05 leaves/plant, respectively, after planted at 2 months (Table2).

The interaction between tuber section size and plant growth regulator concentrations on the plant height, canopy width, and the number of leaves after planting at 4 months resulted that a 1 cm tuber saturated within IBA at 150 ppm giving the highest plant height (20.81 cm) while the 0.5 cm tuber with saturated with tap water was the lowest height (5.99 cm).

While, the canopy width found that the highest canopy width 14.86, 15.16, 15.34, 15.42, 15.78, and 16.58 cm in a 1 cm tuber and saturated with IBA 100 ppm, IBA 150 ppm, tap water, GA_3 100 ppm, IBA 150 ppm, and GA_3 150 ppm, respectively, while the 0.5 cm tuber and saturated with tap water was the lowest (8.83 cm) in a 1 cm tuber and saturated with at tap water, 100 and 150 ppm IBA, respectively. Besides, the number of leaves showed the highest number of leaves, 2.90, 3.20, and 3.30 leaves/plant in a 0.5 cm tuber and saturated with at an IBA 150 ppm, 1 cm tuber and saturated with at an IBA 150 ppm and 0.5 cm tuber and saturated with at IBA 100 ppm, respectively. In comparison, the 0.5 cm tuber saturated with GA_3 at 100 ppm was the lowest leaf number (2.00 leaves /plant) (Table 2). Generally, Auxin plays a critical role in the growth characteristics because it can rapidly stimulate cells inside tubers, while higher levels of auxin in tissues

support the conversion of tryptophan to IAA, leading to the promotion of cell division and elongation. This can be attributed to IBA, leading to the formation of root initiation and, thus, root formation and, eventually, the uptake of a greater amount of nutrients from the soil, resulting in higher plant height and canopy width [11, 22]. While GA could not stimulate plant height because of the later germination time than IBA, the growth was lower than in the IBA treatment. These findings concurred with the results reported by Bhattacharjee [23] in the context of gladiolus, Jana, and Biswas [24] and Mukhopadhyay and Bankar [25] in the case of tuberose. The use of plant growth regulators to enhance both cell division and cell elongation can potentially lead to plant height in tuberose, according to Shanker et al. [26] and Tiwari and Singh [27] in tuberose. This is consistent with the research results of Chaudhary et al. [20] that the application of auxin IBA 100 ppm the highest plant height, leaf length, leaf width, and number of leaves of tubers of Gladiolus x hybridus Hort. (Figure 2)

Table 2. Effect of tuber section size and the different concentrations of GA_3 and IBA on the plant height, the canopy width, and the number of Caladium 'Candidum' leaves after planting at 2 months.

Tuber size	Plant height (cm)	Canopy width (cm)	Number of leaves
Tuber size			
0.5 cm	8.33 b	11.44 b	2.66
1 cm	17.88 a	15.65 a	2.54
PGRs			
Tap water	11.24 b	12.68 bc	2.75 a
GA_3 100 ppm	11.12 b	12.12 c	2.10 b
GA_3 150 ppm	12.00 b	13.64 ab	2.25 b
IBA 100 ppm	15.09 a	15.01 a	2.85 a
IBA 150 ppm	16.07 a	14.28 a	3.05 a
Tuber size x PGRs (ppm)			
0.5 cm + Tap water	5.99 e	8.83 c	2.80 bcd
1 cm + Tap water	16.50 c	15.34 a	2.70 cde
0.5 cm + GA_3 100	6.71 e	10.02 c	2.00 f
1 cm + GA_3 100	15.54 c	15.42 a	2.20 f
0.5 cm + GA_3 150	6.70 e	10.70 c	2.30 ef
1 cm + GA_3 150	17.31 bc	16.58 a	2.20 f
0.5 cm + IBA 100	10.94 d	14.86 a	3.30 a
1 cm + IBA 100	19.25 ab	15.16 a	2.40 def
0.5 cm + IBA 150	11.34 d	12.78 b	2.90 abc
1 cm + IBA 150	20.81 a	15.78 a	3.20 ab
F-test			
Tuber size	*	*	ns
PGRs	*	*	*
Tuber size x PGRs	*	*	*
CV (%)	17.65	16.50	19.02

1/ Means with the same letter within a column are not significantly different at $P<0.05$ by the least significant difference by using the DMRT test.
ns=non-significant.

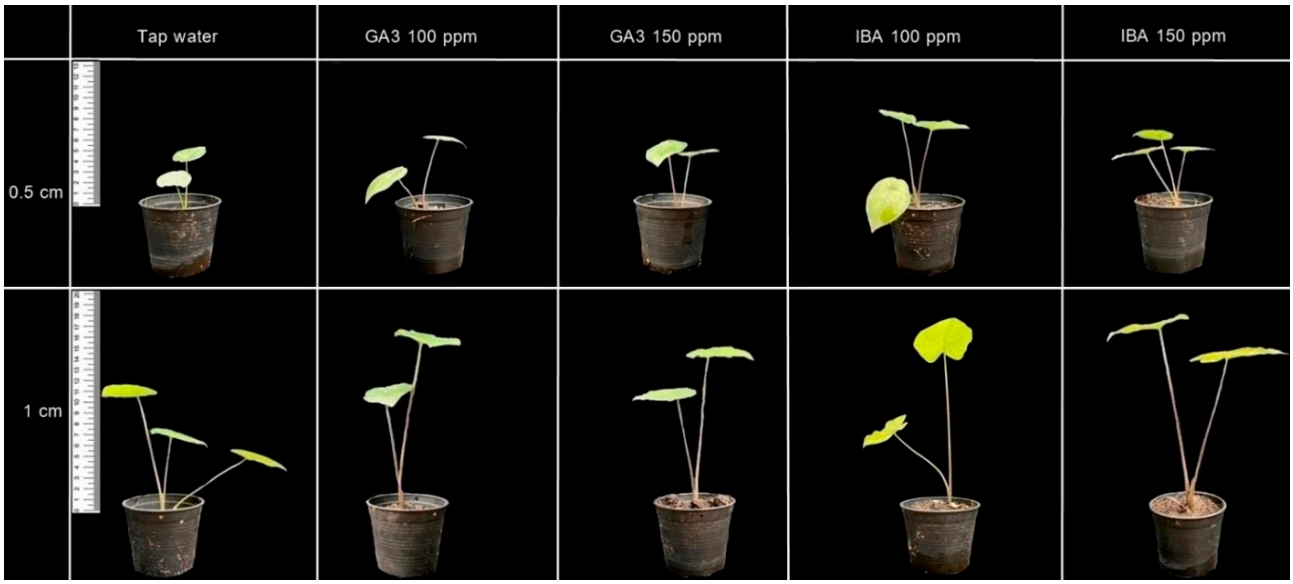

Figure 2. Effect of tuber section size and the different concentrations of GA_3 and IBA on the plant height, the canopy width, and the number of Caladium 'Candidum' leaves after planting at 2 months.

3.3 Leaf shapes and Leaf color of Caladium

The interaction between tuber section size and plant growth regulator concentration affects leaf shape 2 months after planting (Figure 3). Tubers size of 1 cm and saturated with IBA or GA_3 gave the larger leaf than saturated in tap water. Moreover, IBA increased leaf width and length more effectively than GA_3. This could possibly be due to IBA leading to root initiation and thus root formation and eventually uptake of a greater amount of nutrients from the soil, resulting in greater leaf area. Jawanda *et al.* [22] and Diwakar and Katiyar [28] also reported that IBA promotes leaf area.

The interaction between tuber section size and plant growth regulator concentrations on the leaf color changes after planting at 2 months resulted in a 1 cm tuber and drench in GA_3 at 100 ppm had lower L* values (brightness) and lower yellow components (b* values) of the control plants. As a result, the plants are darker and less bright. This results in darker and less bright colors. These results adapted with results of Mynett et al. [29] in *Freesia perennis* about the effect of GA_3 on the increase of the greenness index. GA_3 has a structural role in the membrane of chloroplasts and stimulates photosynthesis [30].

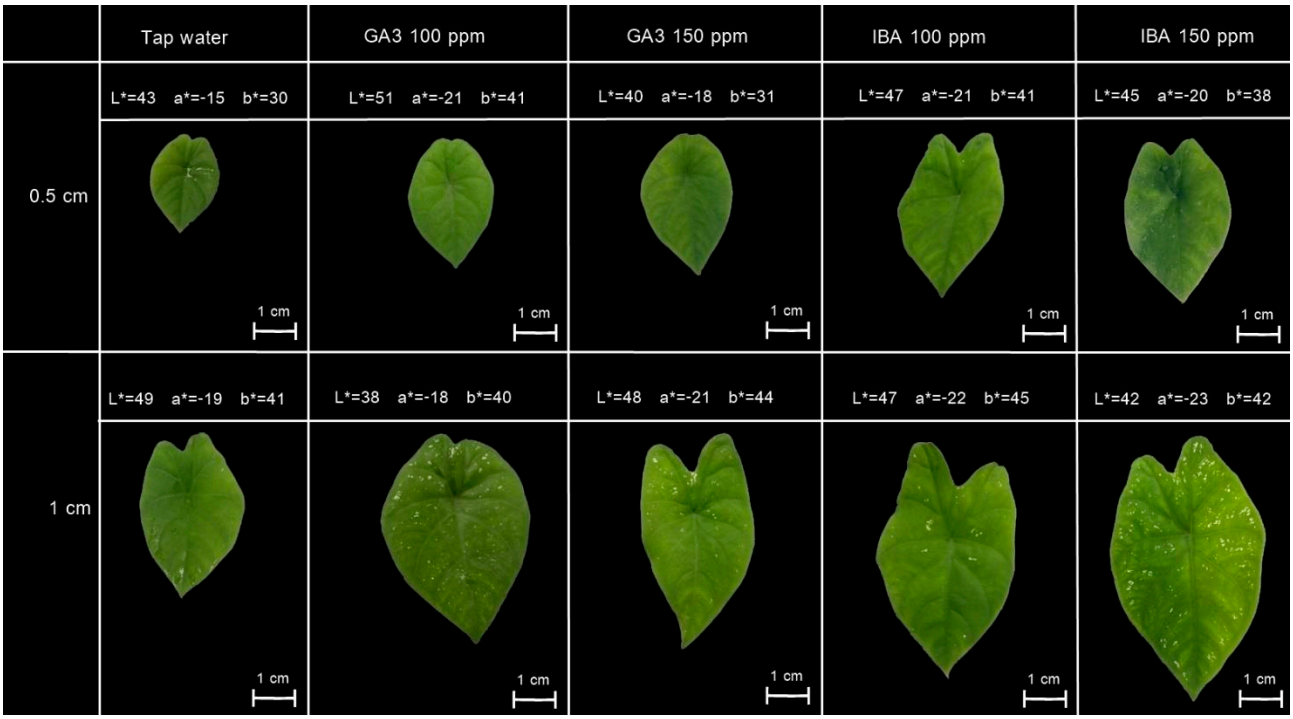

Figure 3. Leaf shapes and color (L*, a*,b*) of Caladium 'Candidum' after planting at 2 months.

4. Conclusions

The result showed that a 1 cm of tuber section size with drenched in IBA at 150 ppm was shown the highest effect on days taken for bud germination, tuber size, plant height, canopy width, and the number of leaves than other treatments and control. Therefore, the Caladium 'Candidum' was cut at 1 cm size and drenched in 150 ppm of IBA appropriated to induce growth after section within four months.

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Conflicts of Interest: The authors declare no conflict of interest.

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