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THE EFFECT OF GIBBERELIC ACID SOAKING DURATION ON RHIZOME GROWTH OF EDIBLE CANNA (*CANNA EDULIS* KER.)

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ABSTRACT

The objective of this research was to evaluate the soaking duration of Gibberelic Acid (GA₃) on rhizome growth of edible canna. This research was conducted from December 2015 to July 2016 in the experimental field and in the Laboratory of Plant Physiology, Department of Agronomy, Faculty of Agriculture, Sriwijaya University, Indralaya. The method used in this study was Complete Randomized Design consisting of seven treatments and four replications. The treatments were without soaking (control), soaking for 6, 12, 18, 24, 30 and 36 hours. The study used 100 ppm of Gibberelic Acid and a half rhizome. Results showed that by soaking the canna rhizome into GA₃ would significantly affect the time of bud emerging, plant height, leaf number, and seedlings number but did not significantly affect the variable level of leaf greenness, leaf chlorophyll, rhizome and plant fresh weight. Soaking rhizome with GA₃ increased the time of bud emerging in the treatment at the nursery, plant height and the number of tillers in the treatment 24 hours, and the number of leaves on 12 hours treatment. Soaking canna rhizome with GA₃ has the growth ability compared to controls. However, further research is needed with a combination of different growth regulators.

KEY WORDS

Edible canna, rhizome, soaking, gibberellic acid.

Edible canna (*Canna edulis* Ker.) is a potential plant to be developed as an alternative source of food. It is an herbaceous plant that comes from South America and since 2500 BCE has been used as food ingredients before rice and cassava (Koswara, 2014). Edible canna plant is a tuberous plant grown and cultivated in Indonesia, especially in the area of Central Java, East Java and Bali and used as a side dish (Directorate Agriculture of Nuts and Tuberous Cultivation, 2009).

Edible canna can be used in various benefits. Old rhizome is used as a source of starch, the young rhizomes for food or steamed vegetables, and its canopy parts for animal feed. Canna flour can be processed into a variety of traditional foods, such as pastries, breads, crackers, noodles and other processed foods just like wheat (News of Agricultural Research and Development, 2010). In Vietnam, canna starch used as raw material in the manufacture of high quality clear noodle to substitute green beans, while in Hongkong the crushed rhizomes are used to treat acute hepatitis (Center for Agricultural Training in Lembang, 2010).

There are two edible canna cultivars in Indonesia which are red cultivar and white cultivar (News of Agricultural Research and Development, 2010). White canna rhizomes can produce about 25 ton ha⁻¹ fresh weight and 28% of starch content, while the red canna rhizomes about 30 ton ha⁻¹ fresh weight and only 22% of starch content. Edible Canna cultivated in monoculture system can produce up to 23 tons rhizomes ha⁻¹ at the age of 4 months, 45-50 tons ha⁻¹ in 8 months and 85 tons ha⁻¹ after one year (Yulfaet *et al.*, 2012).

Edible canna can be cultivated through both generative and vegetative propagation. Generative propagation using seeds is rarely performed due to the difficulty in obtaining the seed and requires longer time. Vegetative propagation using bulbs/rhizomes is mostly carried out by the farmers, horticulturists or planters for various reasons as it can be obtained in less time and stronger compared to that grown from seeds (Tjitrosomo *et al.*, 1980).

Canna cultivation in Indonesia has faced various constraints including the absence of government subsidies for the development of local crops, less competitive prices and the limited of rhizomes supply as planting material since most of the rhizomes has used for consumption (Grehenson, 2015). The limited supply of rhizome could threaten their sustainability so that it is necessary to find the alternative solution for more efficient use of rhizomes as planting material (News of Agricultural Research and Development, 2010).

Rhizome cutting is one alternative to save the seedlings. The bulbcutting did not show any significant different in production compared to whole bulb in shallot. Shallot bulb was divided into two and four division and the growth percentage is still high at 87.77% and 68.90% respectively with the production of 577.14 g and 399.14 g per plot and without cutting of 937.12 g per plot, or equal to potential yield of 9.4 tons/ha, 5.8 tons/ha and 3.4 t/ha respectively. Though the cutting treatment resulted in lower production, but if compared to bulb seedlings (whole bulb) requirement reaching 1.25 tons/ha, the cutting bulb only required for about 0.625 tons/ha (half bulb) and 0.3125 tons/ha (quarter bulb) which considered more efficient (Deviana, 2014).

Research results by Ratnasari (2010) showed that potato cutting (*Solanum tuberosum* L.) tubers into two pieces were able to increase plant height (24.22 cm), the number of shoots per clump (5.08 stems/clump) and tubers weight per plant (173 gram/plant). Half tuber would produce the same amount of tubers as the whole tuber treatment with 4.1 tons ha^{-1} . Half tuber was a proper method for tuber saving up to 100% with the potential result of 8.25 ton ha^{-1} in January.

Gibberellic acid is a growth regulator that has a role in germination and cell elongation. The use gibberellic acid would help the plant to accelerate the use of food reserves prior to the damage occurrence in planting materials and improve production (Burton *et al.*, 1989 in Baraniet *et al.*, 2009). Akbari *et al.* (2013) stated that the application of gibberellic acid (GA3) of 50 and 100 ppm before planting would increase the production of potato tubers with 2.23 kg m^{-1} and 2.16 kg m^{-1} . According Shibairo *et al.* (2006), an increase in GA3 concentration led to an increase in the germination percentage, tiller number per bulb, plant height, and improve the performance on potato. GA3 application on potato tubers could enhance tuber effectiveness for 3-7 weeks.

Khuankaew (2009) reported that the application of 100 ppm of GA3 on different durations (0, 3, 6, 12, 24, and 48 h) would significantly increase plant height and leaves number of Tulip Siam (*Curcuma alismatifolia* Gagnep.). The treatment of tuber soaking in GA3 solution for 24 hours could increase the leaves number of Tulip Siam up to 26%. According to Asra (2014), the interaction between GA3 concentration and optimum soaking duration in stimulating the germination of *Calopogonium caeruleum* as obtained at the concentration of 500 ppm with a 24-hour soaking duration resulted in germination percentage of 57.33%. The higher concentration of GA3 and the longer soaking duration would tend to increase germination percentage.

This study was aimed to evaluate the effect of soaking duration in Gibberellic acid solution on the growth of edible canna.

Hypothesis. Allegedly edible canna rhizome soaking for 24 hours in gibberellic acid (GA3) solution would increase the growth of half canna rhizomes.

MATERIALS AND METHODS OF RESEARCH

The study was conducted at the Laboratory of Plant Physiology and Experimental Field of Faculty of Agriculture, University of Sriwijaya, and Indralaya for eight months started from December 2015 to July 2016.

Tools and materials used in this study were 100 ppm of gibberellic acid (GA3) solution, planting box, plastic container, 80% ethanol, camera, 1000 ml flask, gauge, analytical balance, cutter, polybag, half cut edible canna rhizomes Red cultivar, spectrophotometer, SPAD meter, chlorophyll meter 502 and net.

Complete Random Design was used consisted of seven treatments and four replicates. Each unit consisted of five plants, and gibberellic acid (GA3) solution as treatment

as following: T0 = without soaking; T1 = soaking for 6 hours; T2 = soaking for 12 hours; T3 = soaking for 18 hours; T4 = soaking for 24 hours; T5 = soaking for 30 hours; and T6 = soaking for 36 hours. The rhizome used was the half rhizome originated from one bud. The analysis was carried out by comparing the resulted F value with F table at the level of 0.05 and 0.01. When F value was higher than F Table at 0.05 level, it meant that the treatment was significantly different and when it was higher than F table at 0.01 level, the treatment was a very significant different. Non significant occurred when the resulted F value was lower than F Table at 0.05 level. Significant test then was performed using Orthogonal Polynomial Method.

The working steps included the preparation of planting materials, making GA3 solution, seeding media preparation, planting media preparation, treatment application, planting in nursery, seeding, transplanting in the field and maintaining. The observed variables consisted bud emerging time (observed while in nursery), plant height, leaf number, tiller number, leaf greenness level, total chlorophyll, plant fresh weight, and rhizomes weight.

RESULTS AND DISCUSSION

The analysis of variance showed that the treatment of soaking duration in GA3 rhizomes was very significantly different in the parameters of bud emerging time, plant height, leaf number per clump, significantly different in the parameter of tiller number per hill and no significant effect for leaf greenness level, leaf total chlorophyll, plant fresh weight, and rhizome fresh weight.

Table 1 – The analysis of variance in the observed parameters

Parameters	F value	Variability coefficient (%)
Bud emerging time (days after planting)	12.44**	26.4
Plant height (cm)	5.29**	8.02
Leaf number per clump	5.06**	7.09
Tiller number per clump	3.44*	17.79
Leaf greenness level		
a. Age of 4 months	0.76 ^{ns}	9.9
b. Age of 8 months	1.59 ^{ns}	6.3
Leaf chlorophyll (mg l ⁻¹)	2.05 ^{ns}	9.05
Plant fresh weight (g)	0.94 ^{ns}	26.5
Rhizome fresh weight (g)	1.94 ^{ns}	30.8
F Table 0.05	2.57	
0.01	3.81	

Note** = highly significant different; * = significantly different; ns = non significant.

Bud Emerging Time (days after planting). Based on the analysis of variance (Table 1), it showed that soaking duration treatments of edible canna rhizomes into GA3 solution was significantly different in the parameter of shoot appearing time. The result of orthogonal polynomial regression is given in the following figure.

Figure1 – The regression of shoot appearing time in the edible canna

The results of orthogonal polynomial test (Figure 1) showed that the effect of soaking duration of edible canna rhizomes in GA3 solution gave a very significant effect by the quadratic equation $y = 0.0229x^2 - 0.6827x + 10.537$ with $R^2 = 0.733$. The fastest time of emerging buds was found in T1 treatment (6 hours soaking duration) with 4.5 days after planting, while the longest was in T5 treatment (30 hours soaking duration) with 14.875 days after planting.

Plant height (cm). Based on the analysis of variance (Table 1), it was indicated that soaking treatment gave a highly significant impact on plant height. Orthogonal polynomial test on plant height resulted in 26.78 F value (quadratic significantly different), 1.7 F value (non linear significant), 0.7 F value (non cubic significant) and 1.83 F value (non quartic significant) with the value of F Table at 0.05 and 0.01 level were 4.32 and 8.02 respectively. The regression results can be seen in the following figure.

Figure 2 – The regression of plant height in edible canna

The regression results (Figure 2) indicated that the soaking duration of edible canna rhizomes in GA3 solution gave a highly significant impact at the quadratic equation $y = -0.093x^2 + 3.108x + 133.2$ with $R^2 = 0.928$.

Leaf Number. Based on the analysis of variance (Table 1), the effect of soaking duration treatment was significantly different to leaf number. Orthogonal polynomial test also showed significant different linearly (F value = 9.82) and quadratically (F value = 9.72). The regression results can be seen in the following figure.

Figure 3 – The regression of leaf number in edible canna

The regression results (Figure 3) showed that soaking duration gave a highly significant effect with the quadratic equation $y = -0.016x^2 + 0.410x + 30.071$ with $R^2 = 0.643$. Highest number of leaves was found in T2 treatment (12 hours soaking duration) with 34.8 leaves while the lowest number of leaves was in T5 treatment (30 hours soaking duration) and T6 (36 hours soaking duration) with 25 leaves.

Tiller Number per Clump. Based on the analysis of variance (Table 1), it was indicated that soaking duration treatment was significantly different to the number of tillers. Orthogonal polynomial test resulted in linearly significant different (F value = 8.51) and quadratic significant different (F value = 7.08). The regression results can be seen in the following figure.

Figure 4 – The regression of tiller number in edible canna

The regression results (Figure 4) indicated the influence of soaking duration treatment in edible canna rhizomes was highly significant in a quadratic level by the quadratic equation $y = -0.006x^2 + 0.149x + 8616$ with $R^2 = 0.755$. The highest number of tillers was found in T4 treatment (24 hours soaking duration) with 10 tillers while the lowest was in T6 treatment (36 hours soaking duration) with 6.25 tillers.

Leaf Greenness Level. Non significant different effect of soaking duration was resulted from the analysis of variance (Tabel.1) on leaf greenness level for the plants with both age of 4 months and 8 months. The leaf greenness level at 4 months plant was the highest in T0 (without soaking) with 47.2 and the lowest was in T6 (36 hours soaking duration) with 42.1. While at the age of 8 months, the highest leaf greenness was in T0 (without soaking) with 44.92 and the lowest was in T1 treatment (6 hours soaking duration) with 39.2 as seen in Figure 5 and Figure 6.

Figure 5 – The effect of GA3 soaking duration on leaf greenness level of edible canna at the age of 4 months

Figure 6 – The effect of GA3 soaking duration on leaf greenness level of edible canna at the age of 8 months

Total Leaf Chlorophyll (mg/l). Non significant different effect was resulted from the analysis of variance (Table 1) of GA3 soaking duration on leaf chlorophyll. The highest leaf chlorophyll was resulted in T0 (without soaking) with 10.87 mg l^{-1} and the lowest was in treatment T1 (6 hours soaking duration) with 9.11 mg l^{-1} .

Figure 7 – The effect of GA3 soaking duration on leaf chlorophyll of edible canna

Plant Fresh Weight (g). Non significant different was indicated from the analysis of variance (Table 1) of GA3 soaking duration on edible canna plant fresh weight. The highest fresh weight was in T4 treatment (24 hours soaking duration) with 1512.5 grams and the lowest was in T5 treatment (30 hours soaking duration) with 1075 grams.

Figure 8 – The effect of GA3 soaking duration on plant fresh weight of edible canna

Rhizome Fresh Weight (g). Non significant different was indicated from the analysis of variance (Table 1) of GA3 soaking duration on edible canna rhizome fresh weight. The highest rhizome fresh weight was resulted in T2 treatment (12 hours soaking duration) with 450 grams and the lowest was 262.5 grams in the T6 treatment (36 hours soaking duration).

Figure 9 – The effect of GA3 soaking duration on rhizome fresh weight of edible canna

DISCUSSION OF RESULTS

The application of Gibberellic acid treatment in rhizomes could accelerate the emergence of buds. Gibberellic acid initiated the synthesis of α -amylase, an enzyme hydrolyzing starch into glucose. The resulted glucose was then undergo the glycolysis process changed into pyruvate that later on resulted in producing energy in form of ATP after passing through the Krebs cycle. The energy was used for plant growth (Gupta and Chakrabarty, 2013). Gardner *et al.* (1991) reported that the formation of the alpha amylase enzyme occurred at the beginning of germination stimulated by internal Gibberellin. The addition of an external Gibberellin resulted in increasing amounts of Gibberellin in the seed, so that it would increase the availability and activity of alpha amylase enzyme causing more water in cells and shoots elongation.

The soaking of edible canna rhizome into Gibberellic acid solution affected plant height, with a maximum limit of soaking duration for 24 hours. In accordance to research result of Muchiriet *al.* (2015), the immersion of potato tubers using the single solvent of Gibberellin would be able to produce the highest plant height compared to control. Khuankaewet *al.* (2009) reported that the maximum soaking duration of *Curcuma alismatifolia* Gagnep was 24 hours, with the highest average of plant height by 43.4 cm and decreased in 48 hours treatment to 42.3 cm.

The growth of upper and below surface parts of plants was an interconnected relationship. Root growth was influenced by the growth of shoots. Bud was a place of auxin formation. Auxin was then transported by basipetal towards the root primordia and accelerated root growth. Once the roots were formed, the plant would be able to absorb nutrients from the soil and performed photosynthesis. Photosynthate was used for plant growth. Thus, the maximum growth of shoots from the beginning would generate a complete and faster plant growth reflected by the plants' height (Gardner *et al.*, 1991).

The soaking of edible canna rhizome in gibberellic acid solution increased the leaf number. As reported by Siraj and Al-Safar (2006), the gladiolus bulbs were treated with soaking treatment for 24 hours in gibberellic acid solution of 100 mg/l resulted in the highest leaf number up 38.2 leaves. Similarly, Khuankaewet *al.* (2009) also reported that soaking for 24 hours at a concentration of 100 mg/l GA3 resulted in the highest leaf number with 4.3 leaves on *Curcuma asigmatifolia* Gagnep.

Gibberellin is a growth regulator required by the plants during vegetative growth. In the vegetative growth, the development of plants was depended on the division, enlargement

and cell differentiation. Gibberellin influence on vegetative growth was by stimulating cell division activity in the stem meristem and cambium area. Besides, Gibberellin also stimulated the activity of cell enlargement to accelerate the growth of stems and leaves of the plant (Salisbury and Ross, 1985).

The soaking of edible canna rhizome in gibberellic acid solution could increase the tiller number. Similar result was reported by Shibairo *et al.* (2006) where the highest number of buds on potato was obtained by the soaking treatment of gibberellic acid solution. Research result by Muchiri *et al.* (2015) also showed that GA₃ was able to increase the rate and number of buds formed on potato due to GA₃ role in plant cell division in the vegetative phase. Number of tillers per plant clump affected the density of stems per unit area. According to Ratnasari (2010), gibberellin treatment and cleavage of potato tubers gave different results where it was highly significant for stem number per clump and no interaction between the two.

The soaking of edible canna rhizome in gibberellic acid did not give any significant impact on leaf greenness and leaf total chlorophyll. Research results by Parvin (2015) on Black Walnut (*Juglans nigra* L.) also indicated similar result in which the application of GA₃ did not affected leaf total chlorophyll with the average of 25.17 mg/g. According to Wahyurini (2011), leaf chlorophyll of lily (*Lilium longiflorum*) would be significantly different among cultivars, however, by applying GA₃, no significant different on leaf chlorophyll was resulted. The soaking of edible canna rhizome on gibberellic acid solution would tend to decrease leaf greenness and leaf total chlorophyll compared to control due to plant metabolism disruption. The application of gibberellic acid would allocate more photosynthate for cell division on the growing apicals causing the shrink on leaves (Zimmerman, 1961).

The highest fresh weight of edible canna plant was resulted in the 24 hours soaking treatment. Plants with soaking treatment would resulted higher weight compared with control. Plant weight was closely related to plant tiller number, leaf number and rhizome number. Ameen and Al-Iman (2007) investigated the soaking of *Pistacia vera* L. on GA₃ solution for 24 hours, resulted in the highest total plant weight with 21.73 g. The application of GA₃ indicated a significant result in increasing plant growth. Gardner *et al.* (1991) discovered that gibberellic acid was often related to the increase on stem growth. Growth was essentially the increase on plant weight. While plant weight was the accumulation of plant materials through cell division activities portrayed in plant height and stem development.

The soaking of edible canna rhizome on gibberellic acid solution did not significantly affect rhizome fresh weight. This was similar with research result by Wahyuniri (2010) indicating that single application of gibberellic acid did not affect rhizome fresh weight, the increase on rhizome diameter and length would increase the weight of rhizome. Based on Kratzleand Palta (1992) in Wahyuruni (2010), rhizome development was essentially carbohydrate and water penetration to the rhizome through phloem. The greater of accumulated carbohydrate stimulated by the stolon length, the greater volume and diameter of the formed rhizome.

One clump of plant consisted of more than one stem would increase the competition on environmental factor, such as for the mineral nutrients, water, lights and air. The competition would result in a higher stem density causing a less yield of rhizome. However, the rhizome yield on each stem from one clump with a higher density would still be higher than the ones with a lower density. Consequently, higher number of stem per clump still could produce higher rhizome weight compared to the ones with less stems per clump. Nevertheless, rhizome size would be smaller in a high density clump due to fair photosynthate translocation resulting in smaller photosynthate accumulation on each rhizome (Gardner *et al.*, 1991).

CONCLUSION

Based on the results, it was concluded that:

The soaking duration of 24 hours was the best treatment for edible canna rhizome propagation for Morados variety originated from half cut rhizome.

The soaking duration of rhizome for 24 hours would result in the highest plant height, tiller number and plant fresh weight.

The soaking of rhizome on GA₃ solution would fasten bud emerging time on T1 treatment, increase plant height and tiller number on T4 treatment, and also leaf number on T2 treatment.

The soaking of rhizome on GA₃ solution would improve growth ability compared to control.

Further research was required to investigate the effect of different combinations of plant growth regulators.

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