

Effects of Rhizome Soaking with Gibberellin Solution Prior to Planting on Growth and Development of *Curcuma alismatifolia* Gagnep.

Thiraporn KHUANKAEW¹, Takuji OHYAMA^{1,2*} and Soraya RUAMRUNGSRI³

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Summary

Rhizomes of *Curcuma alismatifolia* Gagnep. were soaked with 100 mg L⁻¹ GA₃ for 0, 3, 6, 12, 24 and 48 hours prior to planting on 17 March 2005 at Chiang Mai University, Thailand. The results showed that the rhizome soaking with GA₃ solution delayed the emergence of shoot. The GA₃-untreated control plants sprouted at 43 days after planting (6 weeks after planting (WAP)) while rhizomes soaked with GA₃ for 3, 6, 12, 24 and 48 hours prior to planting sprouted at 55 (8 WAP), 57 (8 WAP), 50 (7 WAP), 63 (9 WAP) and 70 days after planting (10 WAP), respectively. The application of GA₃ delayed the sprouting of shoot thus the increase in plant height, the production of leaves and the flowers were also delayed in the early stage. However, after 14 WAP the plant height and the number of leaves per a shoot became constant and those were not significantly different with the control plants. The rhizomes soaked with GA₃ for 48 hours gave the latest flowering at 122 days after planting (17.4 WAP) about 34 days (5 WAP) later than the GA₃-untreated control plants flowered at 88 days (12.5 WAP). The flower stalk and flower were elongated when the rhizomes are soaked in GA₃ solution prior to planting. During flowering stage for each treatment, the N, P and K content of the aboveground part and the underground part organs were determined. Result shows that rhizomes soaking with GA₃ had effect on the amount of K in aboveground part and P in underground part. By soaking rhizomes for 48 hours, the amount of K in the aboveground part was highest at 654 mg, while the amount of P in the underground part is highest at about 120 mg when the rhizomes were soaked for 24 hours.

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Key words : *Curcuma alismatifolia*, flowering, GA₃, nutrient content, rhizome soaking, shoot emergence,

INTRODUCTION

Curcuma alismatifolia Gagnep. or Siam tulip belongs to be a member of the ginger family (Zingiberaceae). The inflorescence is compressed spike of colorful long lasting bracts consist of upper bracts or pink bracts, lower bracts or green bracts and true flowers hide in the axils of bracts (Hagiladi *et al.*, 1997). *Curcuma* species are herbaceous perennials plant with two underground storage organs, rhizomes (stubbed rhizomes), and storage roots. Most *curcuma* plants grow and flower during the rainy season from July to September in Thailand. Thus the products of flowers and rhizomes come to market at the same time resulting in low price. In addition, flowers and rhizomes could not be continuously supplied to the market, because farmers could not produce them all year round (Butploy, 2000). Consequently, sometimes the uproot of *curcuma* rhizomes may not be profitable for farmers. Thus, controlling the flowering time of *C. alismatifolia* is important for the increase in flower quality and quantity which prevents losing money and to increase the profit for producers.

Gibberellins (GAs) are plant hormones that regulate plant growth and influence various developmental processes, including stem elongation, germination, dormancy, flowering, sex expression, enzyme induction and leaf and fruit

senescence. In our previous experiment, application of GA₃ at 300 and 500 mg L⁻¹ by drenching to soil twice at 4 and 6 weeks after planting (WAP) delayed the initial flowering date about 5-8 days. When using GA₃ at 500 mg L⁻¹, the flower stalk was the longest, which was 30 cm higher than GA₃-untreated plants (Khuankaew *et al.*, 2008a). Khuankaew *et al.* (2008b) suggested that the application of GA₃ solution (100 mg L⁻¹) by drenching into soil during 2nd-leaf and 3rd-leaf unfolding stage had increased elongation of leaves and flower stalk than during application at shoot emergence and 1st-leaf unfolding stages. Treatments during shoot emergence, 1st-leaf unfolding and 2nd-leaf unfolding stages had more extended time to flower than during GA₃ treatment at 3rd-leaf unfolding stage. The objective of this research is to investigate the effects of soaking the rhizomes in GA₃ prior to planting on the growth and development of *Curcuma alismatifolia* Gagnep., including the accumulation of nitrogen (N), phosphorous (P) and potassium (K) in aboveground part and underground part organs.

MATERIALS AND METHODS

Rhizomes of *Curcuma alismatifolia* Gagnep. with average diameter of stubbed rhizome about 1.82 cm and 6-7 storage roots were soaked in water for 3 days before planting. The

¹ Graduate School of Science and Technology, Niigata University, Japan

² Department of Applied Biological Chemistry, Faculty of Agriculture, Niigata University, Niigata, Japan

³ Department of Horticulture, Faculty of Agriculture, Chiang Mai University, Chiang Mai 50200, Thailand

* Corresponding author: ohyama@agr.niigata-u.ac.jp

Table 1. Effects of different time period to soaking rhizomes with 100 mg L⁻¹ GA₃ solution prior to planting on the number of days to shoot emergence and number of days to flower of *Curcuma alismatifolia* Gagnep.

Time to GA ₃ soaking (hours)	Number of days to emergence (days) ^{1/}	Number of days to Flower (days) ^{1/}
0	43 e	88 d
3	55 cd	100 c
6	57 c	107 b
12	50 d	100 c
24	63 b	117 a
48	70 a	122 a
LSD _{0.05}	5.8	5.9

^{1/}Means with the same letter within column are not significant difference at p<0.05 by least significant difference.

^{NS}No significant difference.

Table 2. Effects of different time period to soaking rhizomes with 100 mg L⁻¹ GA₃ solution prior to planting on growth and development of *Curcuma alismatifolia* Gagnep.

Time to GA ₃ soaking (hours)	DW of aboveground part (g) ^{NS}	DW of underground part (g) ^{NS}	Plant height at 18 WAP (cm) ^{NS}	Number of leaves per shoot ^{NS}	Number of shoots per cluster ^{1/}
0	7.49	5.03	40.0	3.6	2.8 a
3	7.33	5.18	42.1	3.0	2.6 ab
6	7.84	5.04	40.9	3.4	2.2 ab
12	7.91	5.26	43.4	3.4	2.2 ab
24	8.58	6.05	42.7	4.3	2.2 b
48	7.89	5.90	42.3	3.2	1.6 b
LSD _{0.05}	-	-	-	-	0.6

^{1/}Means with the same letter within column are not significant difference at p<0.05 by least significant difference.

^{NS}No significant difference.

water was changed every day. After that, rhizomes were divided into six groups and soaked in 100 mg L⁻¹ GA₃ solution at different soaking time periods.

Treatment 1 (T1): rhizomes were not soaked with GA₃ (Control)

Treatment 2 (T2): rhizomes were soaked with 100 mg L⁻¹ GA₃ for 3 hours

Treatment 3 (T3): rhizomes were soaked with 100 mg L⁻¹ GA₃ for 6 hours

Treatment 4 (T4): rhizomes were soaked with 100 mg L⁻¹ GA₃ for 12 hours

Treatment 5 (T5): rhizomes were soaked with 100 mg L⁻¹ GA₃ for 24 hours

Treatment 6 (T6): rhizomes were soaked with 100 mg L⁻¹ GA₃ for 48 hours

Rhizomes were dried and planted on 17 March 2005 in a 6 x 12 (diameter x height) inch pot using 1:1:1 (by volume) ratio of soil, sand, rice husk and rice husk charcoal. Plants were watered daily. After shoot emerged, the plants were supplied with a nutrient culture solution (125 mL a week) containing (in mg L⁻¹) N 200, P 50, K 200, Mg 25, Ca 136, B 0.22, Mn, 0.8, Zn, 0.26, Cu, 0.025; Mo, 0.044, Fe, 0.41. The

experiment was a completed randomized design with 10 replications per treatment.

Every 2 week, data about plant growth and development (number of days to sprouting, plant height, number of leaves per a shoot, number of shoots per a cluster and number of days to flower) (Table 1 and Table 2) were monitored. Moreover, during flowering stage (time of flowering depends on each treatment), the quality and quantity of flowers or inflorescence (flower stalk length, flower stalk wide, flower length, number of pink and green comma bracts and number of flowers per a cluster) (Table 3) were evaluated. Four replications in each plant treatment were sampled at flowering stage and the nutrient content was determined. Aboveground and underground parts were separated and washed with a tap water and deionized water then dried at 60°C and ground into a powder. To determine N and P concentrations, the dried samples were digested by using Kjeldahl digestion solution (Ohyama *et al.*, 1985: 1991). The solution thus obtained were used to determine N concentration by a modified indophenol method and P concentration by ammonium molybdate method (Davidescu and Davidescu, 1972). K concentration was determined by

Table 3. Effects of different time period to soaking rhizome with 100 mg L⁻¹ GA₃ solution prior to planting on flower (inflorescence) quality and quantity of *Curcuma alismatifolia* Gagnep.

Time to GA ₃ soaking (hours)	Flower stalk length (cm) ^{1/}	Flower stalk wide (cm) ^{NS}	Flower length (cm) ^{1/}	Number of pink bracts ^{NS}	Number of green bracts ^{NS}	Number of flowers per cluster ^{NS}
0	42.0 b	0.71	14.1 c	13.2	13.2	2.2
3	49.6 a	0.69	15.7 ab	13.4	13.4	2.2
6	49.9 a	0.67	15.7 ab	14.0	14.0	1.8
12	46.8 a	0.69	16.3 a	13.6	13.6	1.8
24	48.7 a	0.70	15.0 abc	14.0	14.0	2.4
48	47.0 a	0.68	14.5 bc	12.6	12.6	2.2
LSD _{0.05}	4.8	-	1.4	-	-	-

^{1/}Means with the same letter within column are not significant difference at p<0.05 by least significant difference.

^{NS}No significant difference.

atomic absorption spectrophotometry using a HClO₄-HNO₃ modified digestion method (Mizukoshi *et al.*, 1994).

RESULTS

Plant growth and development

Rhizomes of curcuma were soaked in GA₃ solution at 100 mg L⁻¹ with 0 (T1), 3 (T2), 6 (T3), 12 (T4), 24 (T5) and 48 hours (T6). Soaking rhizomes with GA₃ prior to planting delayed the sprouting of new shoot. The sprouting of new shoot of rhizomes untreated with GA₃ was initially observed at 43 days (6 WAP), while the GA₃-soaked rhizome for 48 hours gave the longest sprouting time of about 70 days (10 WAP), which is about 27 days (4 WAP) later than the GA₃-untreated control plants (Table 1). Since the sprouting of curcuma shoot depended on the time of soaking rhizome with GA₃, the development of the plant height was also delayed. Figure 1 shows the effect on plant height of *Curcuma alismatifolia* when the rhizomes were soaked with 100 mg L⁻¹ GA₃ at

different durations. The plant height of GA₃-untreated plant was highest from 6 to 10 WAP. At 12 WAP, the average plant height of 48-hour soaked rhizomes was the lowest compared to other treatments. However, during 14 to 18 WAP, the plant height was similar for all treatments. At 18 WAP, the average plant height was 42 cm (Table 2). A similar trend was observed on the number of fully exploding leaves (Fig. 2). From 6 to 12 WAP, the number of leaves per a shoot of the GA₃-untreated plant continuously increased and is the highest compared with other treatments, although it is not significantly different at 14 and 16 WAP among treatments. Soaking rhizomes with GA₃ solution also decreased the number of shoots per a cluster of whole plant. At 18 WAP, the total number of shoots per a cluster on GA₃-untreated plant was 2.8 shoots per a cluster, while the rhizomes soaked with GA₃ for 3, 6, 12 and 24 hours were about 2.2 to 2.6 shoots per a cluster, and the lowest of shoot production was 1.6 shoots per a cluster when the rhizomes

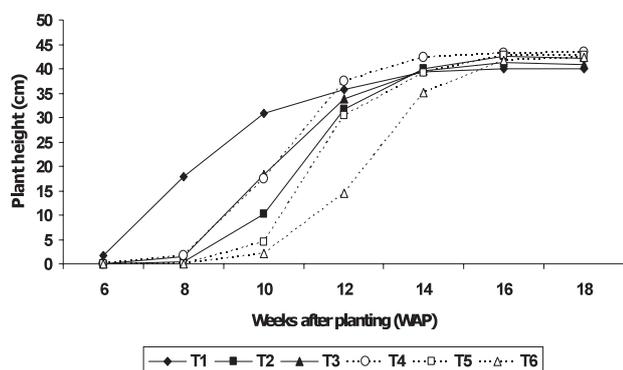


Fig.1 Effects on plant height of *Curcuma alismatifolia* Gagnep. when soaking rhizomes with 100 mg L⁻¹ GA₃ solution at different time period during plant growth and development.

T1: GA₃-untreated rhizome, T2: GA₃-soaked rhizome for 3 hours, T3: GA₃-soaked rhizome for 6 hours, T4: GA₃-soaked rhizome for 12 hours, T5 GA₃-soaked rhizome for 24 hours, T6: GA₃-soaked rhizome for 48 hours

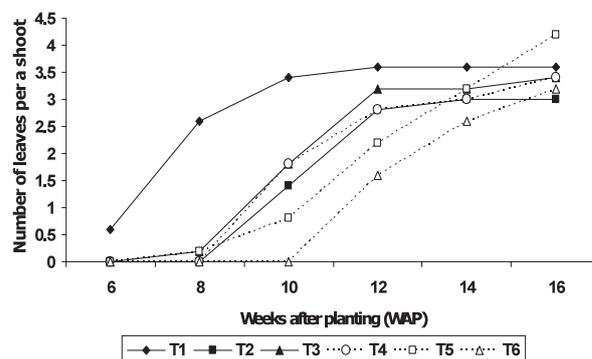


Fig.2 Effects on the number of leaves per a shoot of *Curcuma alismatifolia* Gagnep. when soaking rhizomes with 100 mg L⁻¹ GA₃ at different time period during plant growth and development.

T1: GA₃-untreated rhizome, T2: GA₃-soaked rhizome for 3 hours, T3: GA₃-soaked rhizome for 6 hours, T4: GA₃-soaked rhizome for 12 hours, T5 GA₃-soaked rhizome for 24 hours, T6: GA₃-soaked rhizome for 48 hours

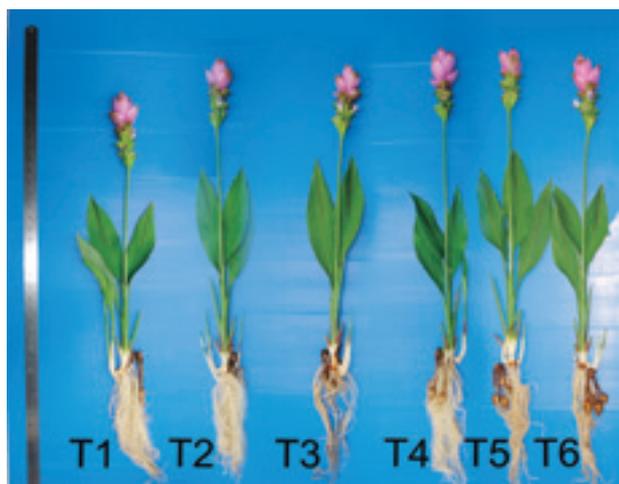


Fig.3 Effects of different time period to soaking rhizomes with 100 mg L⁻¹ GA₃ solution before planting on visual morphological changes at flowering stage when 1-2 of the true flower fully open (T1, T2, T3, T4, T5 and T6 flower at 12, 14, 15, 14, 17 and 17 WAP, respectively) of *Curcuma alismatifolia* Gagnep.

T1: GA₃-untreated rhizome, T2: GA₃-soaked rhizome for 3 hours, T3: GA₃-soaked rhizome for 6 hours, T4: GA₃-soaked rhizome for 12 hours, T5 GA₃soaked rhizome for 24 hours, T6: GA₃-soaked rhizome for 48 hours

were soaked for 48 hours. As described above, the soaking of rhizomes with GA₃ not only delayed the shoot emergence, the plant growth and reduced number of shoots per a plant cluster but also delayed the days to flower (Table 1). In this experiment, the average number of flower per a cluster of whole plant was 2 (Table 3). The GA₃-untreated plants flowered at 88 days after planting, while the rhizomes soaked with GA₃ for 3, 6 and 12 hours flowered at 100, 107 and 100 days after planting, respectively. Moreover, the rhizomes soaked with GA₃ for 24 and 48 hours were the latest to flower at 117 and 122 days after planting, respectively.

This indicates that the rhizome soaked with GA₃ at 100 mg L⁻¹ can delay the emergence of curcuma plant which leads to delay the plant growth, the production of leaves and the flowering time.

Quality and quantity of flower (inflorescence)

At the flowering stage (depending on each treatment), data on curcuma plants were collected. The results showed that the rhizomes soaked with GA₃ for 3 to 48 hours increased the elongation of flowers and flower stalks, however the flower stalk width, the number of pink and green comma bracts and the number of flowers per a cluster were not affected (Table 3). The average length of flower stalks of GA₃-untreated plant was 42 cm, while the GA₃-treated plants were about 46.8 to 49.6 cm. The flower length of rhizomes soaked with GA₃ (14.5 to 16.3 cm) is slightly longer than GA₃-untreated control plants (14 cm). The number of pink bracts and green bracts were between 13 to 14 bracts and 10 to 11 bracts, respectively. Figure 3 shows the effects of different time in soaking rhizomes with GA₃ solution (100 mg L⁻¹) before planting on visual morphological changes at flowering stage (0, 3, 6, 12, 24 and 48 hours of soaking rhizome with GA₃ at 12, 14, 15, 14, 17 and 17 WAP, respectively) of *Curcuma alismatifolia* Gagnep. From this figure, the plant size of all treatment is relatively the same. The flower stalk of the GA₃-untreated plant, however, is shorter than the GA₃-treated plants.

N, P, K content in aboveground organs and underground organs

During flowering (1-2 of the true flower fully open), four plants from each treatment were sampled and the amount of nitrogen, phosphorous and potassium were determined in the aboveground and underground organs. Results show that the K content in both part of curcuma plant is higher than N and P content (Table 4). Rhizomes soaked with GA₃ solution for 3, 6, 12, 24, and 48 hours prior to planting did not affect the N content, on the average 117 mg N for the aboveground

Table 4. Effects of different time period to soaking rhizomes with 100 mg L⁻¹ GA₃ solution prior to planting on N, P and K content in the aboveground and underground organs of *Curcuma alismatifolia* Gagnep. at flowering stage (soaking rhizomes with GA₃ solution for 0, 3, 6, 12, 24 and 48 hours flower at 12, 14, 15, 14, 17 and 17 WAP, respectively) .

Time to GA ₃ soaking (hours)	Nutrient content (mg per plant)					
	Aboveground organs			Underground organs		
	N ^{NS}	P ^{NS}	K ^{1/}	N ^{NS}	P ^{1/}	K ^{NS}
0	120	81.3	522 bc	75.7	104.9 b	389
3	117	68.4	502 c	97.3	99.7 bc	383
6	111	73.2	531 bc	84.1	92.7 c	371
12	116	74.6	561 b	74.8	100.0 bc	372
24	114	79.8	574 b	105.5	120.2 a	414
48	126	85.7	654 a	107.6	99.0 bc	383
LSD _{0.05}	-	-	52.9	-	10.9	-

^{1/}Means with the same letter within column are not significant difference at p<0.05 by least significant difference.

^{NS}No significant difference.

organs and 90.8 mg N for the underground organs, respectively. The P content in the aboveground organs was not significantly different among treatments, which is 77 mg P per a plant on the average. However, the P content was significantly different for the underground organs. Soaking rhizomes with GA₃ solution for 24 hours gave the highest amount of P at 120 mg P in the underground part, while for 6 hours it gave the lowest at 92.7 mg P per a plant part (Table 4). Amount of K in the underground part did not significantly differ in all treatments, which is about 385 mg K per a plant part. Meanwhile, the K content in the aboveground part differs depending on the time period of GA₃ soaking. Rhizomes soaked for 12, 24, and 48 hours gave higher amount of K in the aboveground parts with 561, 574 and 654 mg K per a plant part, respectively (Table 4).

DICUSSION

Effects of rhizome soaking with GA₃ solution prior to planting on plant growth and development of *Curcuma alismatifolia*.

From this experiment, it was found out that the rhizome soaking with GA₃ solution from 3 to 48 hours can delay the emergence of shoot. The longest time for shoot to emerge was 10 WAP when the rhizomes were soaked for 48 hours, while the GA₃-untreated rhizome sprouted at 6 WAP. This led to delay of plant growth and development such as the average plant height, the production of leaves and the production of next shoots. However, from 14 WAP, the plant height and the number of leaves per a shoot became similar for all treatments.

As mentioned above, the time of dormancy on curcuma rhizomes was extended when they were soaked with GA₃ solution at 100 mg L⁻¹. Dormancy is induced by two general types of conditions a) an external condition, such as unfavorable environmental conditions; and b) an internal condition, which prevents the growth even through the external conditions are favorable (Samish, 1954). In this experiment, feeding the exogenous GA₃ by rhizome soaking might affect the internal condition, which tended to delay shoot emergence. In contrast, the natural hormones, GA is the most potent germination promoter, breaking seed dormancy in a wild range of species (Louis, 1982). Kuehny et al. (2002) reported that soaking rhizomes of *Curcuma alismatifolia* for 10 min in a GA₄₊₇ at 200, 400 and 600 mg L⁻¹ delayed shoot emergence. GA at 400 mg L⁻¹ delayed flowering but did not increase the number of inflorescences. Okagami and Tanno (1993) suggested that dormancy of tubers or rhizomes of *Dioscorea spp.* (Yam) is distinctly prolonged by application of GA₃.

Soaking rhizomes in just 3 hours with GA₃ solution at 100 mg L⁻¹ delayed the flowering about 12 days while soaking for 48 hours delayed about 34 days in comparison to GA₃-untreated plant. However, the number of inflorescences was not increased. Kuehny et al. (2002) also reported that GA₄₊₇ applied by soaking at 400 mg L⁻¹ for 10 min delayed flowering

but did not increase the number of inflorescences. In addition, application of GA₃ solution at 300 mg L⁻¹ and 500 mg L⁻¹ by drenching twice at 4 WAP (after shoot emergence) and 6 WAP delayed the flowering about 5-8 days (Khuankaew *et al.*, 2008a). Moreover, the application of GA₃ solution (100 mg L⁻¹) by drenching into soil at different stages also delayed the flowering. Application during shoot emergence, 1st-leaf and 2nd-leaf unfolding stages prolonged the onset of flowering as compared to that when GA₃ was applied at 3rd-leaf unfolding stage (Khuankaew *et al.*, 2008b). Kuehny et al. (2002) suggested that GA₃ could be used to prolong storage of ornamental ginger rhizome prior to planting. It should not be used to promote or increase flowering.

Quality and quantity of flower

As seen from Table 3, GA₃ application prior to planting increased elongation on flower stalk and slightly on flower length. Khuankaew et al. (2008a) suggested that GA₃ application at 300 and 500 mg L⁻¹ increased flower stalk length. Further more, application of GA₃ at 3rd-leaf unfolding stage gave the highest flower stalk (Khuankaew et al., 2008b). Soaking rhizomes in GA₃ solution might affect the endogenous GAs hormone level in curcuma plants. Davies (2004) suggested that bioactive GAs are endogenous hormones that regulate the natural development processes including stem growth of plants. An increase of both cell elongation and cell division occurs during stem growth. GA induces transcription of gene involved in these processes.

Nutrient content

At flowering, amounts of N, P and K in the aboveground part and underground part were determined. The rhizomes soaked with GA₃ solution for 12, 24 and 48 hours increased the K content in the aboveground part. Furthermore, the amount of K was higher than those of N and P in both plant parts. This result is similar to the previous report, where the application of GA₃ solution by drenching into soil at 100, 300 and 500 mg L⁻¹ increased the amount of K in the aboveground part organs, and the K content in both plant parts are higher than those of N and P (Khuankaew *et al.*, 2008a). Devlin and Karczmarczyk (1977) suggested that the uptake of K by wheat is accelerated by gibberellin. The accumulation of N and K in the aboveground part during flowering stage is relatively higher than the underground part. This is because N and K may be used to support plant growth in the aboveground part. At the same time, the new stubbed rhizomes and new storage roots start to form in the underground part, which results to low accumulation of N and K.

CONCLUSION

Soaking rhizomes in GA₃ solution (100 mg L⁻¹) for 3 to 48 hours before planting can be used to extend the time of shoot emergence and flowering. This treatment did not reduce the plant size and the flower quality and quantity but it could

not be used to increase the number of plant and flower per a cluster.

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クルクマ・アリスマティフォリア Gagnep. の生長と分化に対する塊茎のジベレリン溶液浸漬の影響

ティラポン クアンカエウ¹・大山 卓爾^{1,2*}・ソラヤ ラムランスリー³

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要 約

クルクマ・アリスマティフォリア Gagnep. の塊茎を、植え込み0、3、6、12、24、48時間前に濃度100mg L⁻¹のジベレリン (GA₃) 水溶液100mLに浸漬し、2005年3月17日にタイ、チェンマイ大学で植え込んだ。塊茎のGA₃水溶液浸漬処理で萌芽が遅れた。GA₃未処理の対照植物では、植え込み後43日(6週間)で萌芽したが、3、6、12、24、48時間前にGA₃水溶液に浸漬した植物では、55日(8週間)、57日(8週間)、50日(7週間)、63日(9週間)、70日(10週間)に萌芽した。同時に、塊茎のGA₃水溶液浸漬処理で、生育初期の植物の草丈伸長が促進され、葉と花の形成も遅くなった。しかしながら、植え込み14週間以降は、草丈およびシュートあたりの葉数は、対照区と処理区で差がなくなった。クルクマ塊茎を植え込み前48時間浸漬した処理では、植え込み後122日後(17.4週間後)に最初に開花し、対照区の88日後(12.5週間後)に比べて、34日間(5週間)開花が遅くなった。花茎と花は、GA₃水溶液に浸漬することで長くなった。開花期における地上部、地下部各器官の、窒素、リン、カリウム濃度と株当たり含有量を測定した。GA₃水溶液に浸漬した区では、地上部のカリウム含有量と地下部のリン含有量に影響を与えた。地上部のカリウム含有量は、GA₃水溶液に塊茎を48時間浸漬した区で654mgと最高値を示し、地下部のリン含有量と濃度は、GA₃水溶液に塊茎を24時間浸漬した区で120mgと最高値を示した。

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¹ 新潟大学自然科学研究科

² 新潟大学農学部

³ チェンマイ大学農学部

*代表著者：ohyama@agr.niigata-u.ac.jp