Effects of Ethephon Application on Growth and Development of *Curcuma alismatifolia* Gagnep.

Thiraporn KHUANKAEW[1], Takuji OHYAMA[1,2]* and Soraya RUAMRUNGSRI[3]

(Received July 1, 2009)

Summary

Rhizomes of *Curcuma alismatifolia* Gagnep. were planted on 24 June 2004 in Chiang Mai University. Aqueous solution of ethephon (100 ml) at four concentrations (0, 100, 300 and 500 mg L^{-1}) were fed twice at 4 weeks (shoot emergence) and 6 weeks after planting (WAP) by drenching. The results showed that the application of ethephon decreased plant height, especially with application at high concentrations (300 mg L^{-1} and 500 mg L^{-1}). At 14 WAP, the average plant heights were 46.5 cm, 43.6 cm, 35.1 cm and 33.9 cm when ethephon is applied at 0, 100, 300 and 500 mg L^{-1}, respectively. Application of ethephon also decreased the quality and quantity of flowers. At a high level of ethephon, flower stalk length and flower length had decreased. Furthermore, the number of pink and green bracts, and the number of flowers per a cluster of whole plant were decreased by ethephon application. The application of ethephon did not affect the rhizome size (width and length of rhizomes, length of storage roots) and the number of storage roots. However, the rhizome weight per a plant cluster tended to decrease when ethephon was applied. The nutrient contents and concentrations (N, P and K) of the aboveground part organs and underground part organs were determined at flowering stage. Results indicate that the highest concentration of ethephon (500 mg L^{-1}) reduced the accumulation of plant nutrient in aboveground part organs (N, P and K) and in under ground part organs (N and P).

Bull.Facul.Agric.Niigata Univ., 62(1):9-15, 2009

Key words : *Curcuma alismatifolia* Gagnep. , ethylene, ethephon, nitrogen, phosphorous, potassium

INTRODUCTION

Curcuma alismatifolia Gagnep., commonly knows as Siam tulip or Pathumma, is a mono cotyledonous perennial, a member of ginger family (Zingiberaceae). Curcuma species have colorful, long-lasting inflorescences with few pest problems. They are used for cut flowers, potted plants and garden plants. The inflorescence has lotus shape and a long post harvest vase-life (Roh *et al*., 2006), comprises a number of pink coma bracts in upper part and green coma bracts in the lower part, with small true flowers (Hagiladi *et al*., 1997). Curcuma plants are commercially propagated from subterranean organs, consisting of a rhizome or stubbed rhizome with several storage roots (Roh and Lawson, 1993; Hagiladi *et al*., 1997). Most curcuma plants grow and flower during a rainy season in Thailand. Rhizome is planted during April to May and flowering occurs during July to September. During December to January, new rhizomes with new storage roots are harvested and exported to the customer during January to March (Vichailak, 2006).

A phytohormone, ethylene is usually classed as an inhibitory hormone. However, ethylene gives a wide range of effects, from stimulatory to inhibitory effects. Its effects on fruit ripening and leaf abscission appear to be due to the stimulation of synthetic processes required for the development of senescence or the formation of the abscission zone (Bidwell, 1979). Ethephon (2-chloroethyl phosphonic acid) is an ethylene-releasing compound, and it is widely used as a plant growth regulator. The effect of the application of exogenous gaseous ethylene or ethepon solution varies with plant species, chemical concentrations, timing and duration of application. Ethephon regulates phases of plant growth and development by application to various growth sites (Kidd and James, 1991). Ethephon is used in the ornamental industry to delay flowering, selective flower abortion, leaf abscision as well as to reduce stem elongation and increase stem strength (Basra, 2000). Briggs (1975) reported that stem and leaf length of narcissus "Carlton" were effectively reduced by application of ethephon. Similar to eight daffodil and ten tulip cultivars, flower stem and leaf length were effectively reduced when ethephon was applied to soil, and a high ethephon concentration delayed flowering for 1-3 days when bulbs were cooled for a short time period (Moe, 1980). Ethephon reduced stem elongation, pistil growth and petal length. However, sugar accumulation is promoted in tepals and pistils of tulip cv. Apeldoorn (Lukaszewska, 1995). In dormant potato tubers (Solanum tuberosum L.), ethylene markedly shortened the duration of rest, but inhibited elongation of sprouts during extended treatment (Rylski *et al*., 1974). However, the effect of ethylene on *Curcuma alismatifolia* have not been fully studied yet (Paz, 2003).

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

[2] Department of Applied Biological Chemistry, Faculty of Agriculture, Niigata University, 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 ethephon application on growth and development of *Curcuma alismatifolia* Gagnep.

Ethephon concentration (mgL^{-1})	DW aboveground parts (g)^{NS}	DW underground parts (g)^{NS}	Plant height at 14 WAP (cm)$^{1/}$	Number of leaves per shoots^{NS}	Number of shoots per cluster^{NS}	Number of days to flower (days)^{NS}
0	5.68	3.56	46.50 a	3.50	2.25	80
100	5.93	3.71	43.63 a	3.25	2.00	82
300	5.84	4.17	35.13 b	3.25	2.25	82
500	4.71	3.69	33.88 b	3.25	1.50	86
$LSD_{0.05}$	-	-	5.62	-	-	-

$^{1/}$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. Effect of ethephon application on quality and quantity of flowers (inflorescence) of *Curcuma alismatifolia* Gagnep.

Ethephon concentration (mgL^{-1})	Flower stalk length (cm)$^{1/}$	Flower length (cm)$^{1/}$	Number of pink bracts$^{1/}$	Number of green bracts$^{1/}$	Number of flowers per cluster^{NS}
0	53.9 a	18.5 a	13.3 a	11.0 a	1.75
100	49.9 a	17.4 a	11.8 a	9.5 b	1.25
300	44.1 b	14.0 b	9.8 b	9.5 b	1.50
500	42.0 b	11.8 b	9.0 b	9.3 b	1.25
$LSD_{0.05}$	5.7	3.0	1.8	1.16	-

$^{1/}$Means with the same letter within column are not significant difference at $p<0.05$ by least significant difference.
^{NS}No significant difference.

Table 3. Effect of ethephon application on quality and quantity of rhizome of *Curcuma alismatifolia* Gagnep.

Ethephon concentration (mgL^{-1})	Rhizomes weight per cluster (g)^{NS}	Rhizome width (cm)^{NS}	Rhizome length (cm)^{NS}	Number of storage roots per rhizome^{NS}	Storage roots length (cm)^{NS}
0	91.4	2.10	2.15	8.0	9.6
100	80.8	2.05	2.21	6.0	9.2
300	79.1	2.13	2.33	6.0	8.8
500	78.4	1.88	2.19	8.7	6.6
$LSD_{0.05}$	-	-	-	-	-

^{NS}No significant difference.

The objective of this research is to investigate the effects of ethephon application on growth and development, the quality and quantity of flowers and rhizomes, and the amounts of nutrients accumulated in aboveground part organs and underground part organs of *Curcuma alismatifolia* Gagnep.

MATERIALS AND METHODS

Rhizomes of *Curcuma alismatifolia* Gagnep. with about 4 storage roots were individually planted on 24 June 2004 in a 6 x 12 (diameter x height) inch pots using soil, rice husk and charcoal ratio 1:1:1 (by volume). The average diameter of stubbed rhizome was about 2.33 cm. The pots were watered daily. After the shoots emerged at 4 weeks after planting (WAP), the plants were supplied with the complete nutrient solution (125 ml a week) containing (in mg L^{-1}) N 200, P 50, K 200, Mg 25, Ca 136, B 0.22, Mn, 0.81, Zn 0.26, Cu 0.025, Mo 0.044 and Fe 0.41. Ethephon solution (100 ml water) at four concentrations: 0, 100, 300 and 500 mg L^{-1} were fed twice at 4 and 6 WAP by drenching. The experimental design was a completed randomized design with five replications per treatment.

Data on plant growth and development (Table 1), quantity and quality of flowers (Table 2) and rhizomes (Table 3) were collected. At flowering stage (12 WAP), curcuma plants were sampled and divided to aboveground and underground part. Samples were washed with tap water and deionzied water then dried and ground into a fine powder. To determine N and P concentration, dried samples were digested by using Kjeldahl digestion solution (Ohyama *et al.*, 1985: 1991). The solutions thus obtained were used to determined N concentration by a modified indophenol method

Table 4. Effects of ethephon application on N, P and K concentrations in aboveground part and underground part of *Curcuma alismatifolia* Gagnep. at flowering stage (12 WAP).

Ethephon concentrations (mgL^{-1})	Nutrient concentrations ($mg\ g^{-1}$ DW)					
	Aboveground parts			Underground parts		
	$N^{1/}$	P^{NS}	K^{NS}	$N^{1/}$	P^{NS}	K^{NS}
0	18.4 b	10.6	60.4	22.7 b	21.6	45.3
100	18.7 b	10.0	62.6	28.2 a	20.4	47.5
300	19.7 a	9.4	57.1	28.6 a	22.1	47.7
500	20.1 a	9.3	59.2	26.5 a	19.6	48.1
$LSD_{0.05}$	0.85	-	-	4.14	-	-

[1/]Means with the same letter within column are not significant difference at $p<0.05$ by least significant difference.
[NS]No significant difference.

and P concentration by the ammonium molybdate method (Davidescu and Davidescu, 1972). K concentration was determined by atomic absorption spectrophotometry using a $HClO_4$-HNO_3 modified digestion method (Mizukoshi *et al*., 1994).

RESULTS

Plant growth and development

Plants were supplied with four concentrations of ethephon solution at 0, 100, 300 and 500 mg L^{-1} twice at 4 WAP and 6 WAP by drenching to soil. The sprouting of a new shoot is visibly observed at 4 WAP. Just 2 weeks (6 WAP) after application of ethephon, plant height of untreated plants is relatively high compared with ethephon treated plants (Fig. 1). The application of ethephon decreased the plant height, especially with application at high levels (300 mg L^{-1} and 500 mg L^{-1}) (Fig. 1). At 14 WAP, plant heights were 46.5 cm and 43.6 cm when ethephon was applied with 0 mg L^{-1} and 100 mg L^{-1}, while at 300 mg L^{-1} and 500 mg L^{-1}, plant heights were 35.1 cm and 33.9 cm, respectively (Table 1). Figure 2 shows the effects of ethephon application on the morphological changes of curcuma at 12 WAP. The size of plant applied with 500 mg L^{-1} of ethephon was smaller than the untreated plant (Fig. 2). At flowering, the dry weight of aboveground parts and underground parts were 4.71 to 5.93 g and 3.56 to 4.27 g, respectively (Table 1). Application of ethephon did not affect the dry weight (aboveground and underground parts), the number of leaves per shoots and number of shoots per a plant cluster but tended to delay flowering. Flowering started at 80, 82, 82 and 86 day after planting for the untreated, and the treatment of 100 mg L^{-1}, 300 mg L^{-1} and 500 mg L^{-1} ethephon, respectively.

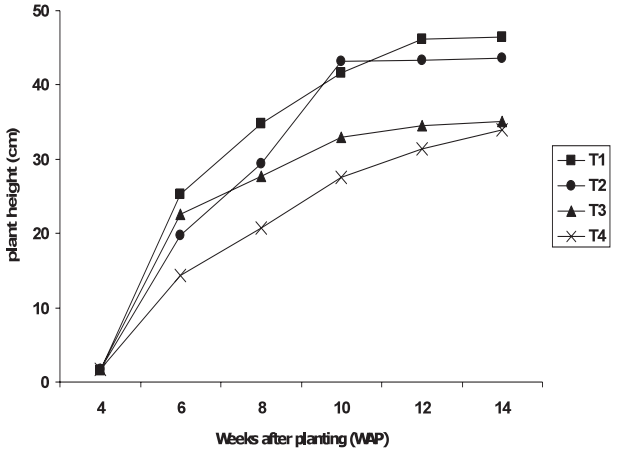

Fig.1 Effects of different concentration of ethephon application on plant height during plant growth and development of *Curcuma alismatifolia* Gagnep.
T1: untreated plants, T2: 100 mg L^{-1} ethephon, T3: 300 mg L^{-1} ethephon, T4: 500 mg L^{-1} ethephon.

Quality and quantity of flowers (inflorescences)

C. alismatifolia flowered during 80 to 86 days after planting. Application of ethephon decreased quality and quantity of flowers (Table 2). At high levels of ethephon (300 mg L^{-1} and 500 mg L^{-1}), the flower stalk length and flower length have decreased (Table 2). The flower stalk length was reduced to 44.1 and 42.0 cm by the application of 300 mg L^{-1} and 500 mg L^{-1} ethephon, respectively, compared that of the untreated and 100 mg L^{-1} ethephon-treated plants, which have 53.9 cm and 49.9 cm of flower stalks, respectively. Furthermore, the number of pink bracts and green bracts were decreased by ethephon application and tends to decrease the number of flower per a plant cluster (Table 2) due to lower number of new shoots per a plant cluster. Figure 3 shows the structure of inflorescence of *Curcuma alismatifolia* Gagnep. after treatment with various ethephon concentrations at 12 WAP. From this figure, application at 500 mg L^{-1} gave the smallest size of inflorescence.

Quality and quantity of rhizomes

The new rhizomes of curcuma were harvested at 32 WAP when aboveground part withered and dried. Rhizomes were cleaned and the size and weight were measured. The application of ethephon did not affect rhizome size (width and length of rhizomes, length of storage roots) and number of storage roots. However, rhizome weight per a plant cluster tends to decrease when ethephon was supplied (Table 3).

Fig.2 Effects of ethephon application on visual morphological changes at flowering stage of *Curcuma alismatifolia* Gagnep. (12 WAP).
T1: untreated plants, T2: 100 mg L^{-1} ethephon, T3: 300 mg L^{-1} ethephon, T4: 500 mg L^{-1} ethephon.

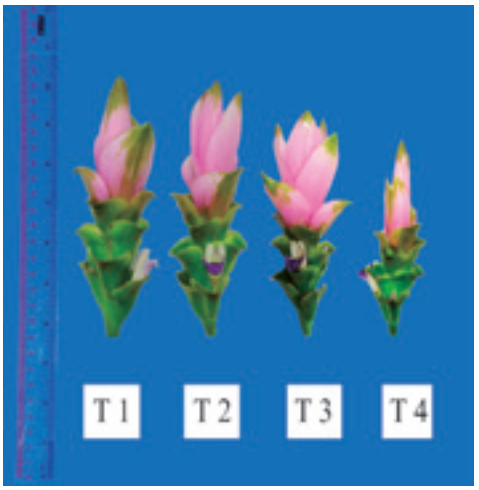

Fig.3 Structure of inflorescence of *Curcuma alismatifolia* Gagnep. after treated with various ethephon concentrations (12 WAP).
T1: untreated plants, T2: 100 mg L^{-1} ethephon, T3: 300 mg L^{-1} ethephon, T4: 500 mg L^{-1} ethephon.

N, P, K concentrations and N, P, K contents in aboveground and underground organs at flowering stage

At flowering stage, the aboveground organs (leaves, flower, flower stalk, new shoots) and underground organs (old stubbed rhizome, old storage roots, new stubbed rhizome, old storage roots and roots) were sampled, digested and the nutrient contents and concentrations of N, P and K were determined. In terms of nutrient concentrations, the average concentration of K in both parts is high, which is 60 mg K g^{-1} DW in aboveground part and 47 mg K g^{-1} DW in underground part, in comparison to N and P concentrations (Table 4). The concentration of N and P in underground part (26.5 mg N g^{-1} DW and 20.9 mg P g^{-1} DW) is higher than in aboveground part (19.2 mg N g^{-1} DW and 9.8 mg P g^{-1} DW). Application of ethephon had no effect on P and K concentrations in both aboveground part and underground part organs (Table 4). However, in the aboveground part, N concentration is higher in plants treated with ethephon at 300 mg L^{-1} and 500 mg L^{-1} in comparison to that in plants that are untreated and treated with only 100 mg L^{-1} ethephon (Table 4). In the underground part organs, ethephon treated plants has higher N concentration than untreated plants (Table 4).

In Table 5, the application of ethephon at 500 mg L^{-1} gave the lowest of N, P and K contents in aboveground organs, and similarly, N and P contents in underground organs. Amount of K in both aboveground and underground organs is higher than the amount of N and P. The accumulation of K in aboveground part is higher than underground part. Results showed that K contents were between 276 to 371 mg K in aboveground part and between 162 to 198 mg K in underground part. Application with 300 mg L^{-1} ethephon gave the highest amount of N and P in underground parts (122 mg N and 92 mg P per plant part, respectively) in comparison to all other treatments.

Table 5. Effects of ethephon application on N, P and K content in aboveground part and underground part of *Curcuma alismatifolia* Gagnep. at flowering stage (12 WAP).

Ethephon concentrations (mgL^{-1})	Nutrient contents (mg per plant part)					
	Aboveground parts			Underground parts		
	$N^{1/}$	$P^{1/}$	$K^{1/}$	$N^{1/}$	$P^{1/}$	K^{NS}
0	112 a	66.8 a	342 ab	81.6 b	77.9 ab	162
100	100 a	60.0 ab	371 a	99.1 ab	76.0 ab	177
300	112 a	54.7 ab	331 ab	122.4 a	92.0 a	198
500	75 b	43.3 b	276 b	82.1 b	70.5 b	177
$LSD_{0.05}$	19	14.8	73	22	14.4	-

[1/]Means with the same letter within column are not significant difference at $p<0.05$ by least significant difference.
[NS]No significant difference.

DISCUSSION

Effects of ethephon on plant growth and development in curcuma

In this experiment, the rhizomes of curcuma were planted on 24 June 2004. The results confirmed that ethephon has effectively reduced plant height, flower stalk length and flower size. Sebanek et al. (1976) reported that applying ethrel by spraying on sprouting hyacinth decreased flower stalk length and leave length, similar as in narcissus "Carlton" when applied with ethephon by drenching in soil (Briggs, 1975). In impatients plant cv. Tempo Pink (Sultanii) and Aruba (New Guineal), ethrel had increased ethylene production, and growing of stem has stopped but led to increase of roots in cutting-root (Guy *et al*., 1998). This study showed that ethephon delayed the flowering day and decreased the quality of flowers such as number of pink bracts and green bracts and flower length. Moe (1980) reported that a high ethephon concentration delayed the flowering. Ethylene causes the increase in respiration where glucose is broken down and metabolic energy (ATP) is synthesized. In tulip cv. Apeldoorn, ethephon promoted sugar accumulation in tepals and pistils (Lukaszewska, 1995). In this experiment, ethephon application at high concentrations (300 mg L^{-1} and 500 mg L^{-1}) in curcuma reduced plant growth and flower quality. Ethylene affects many plant metabolism and consequently, plant growth. Ethylene increases respiration rate leading to decrease in carbon accumulation and to loss of energy (ATP) which are important for other plant metabolism such as photosynthesis and amino acid synthesis. This eventually inhibits plant growth. In addition, plant growth at the cellular level requires a coordinated balance of cell division and cell expansion. A high concentration of ethylene may play a role in the reduction of cell division and cell expansion. In Arabidopsis, growth-inhibiting effect of high ethylene concentration was due to a reduction of cell expansion (Stepanova and Alonso, 2005). Furthermore, ethylene also had interaction with other hormones such as ABA (abscisic acid), GA (Gibberellin) and auxin (Pierik *et al*., 2006). In the study of ethylene, it is difficult to separate its effects from those of auxin. IAA (indolacetic acid) causes ethylene production in tissue, and many of supposed IAA effects are really secondary effects caused by ethylene produced due to IAA stimulation (Bidwell, 1979). However, in this experiment we can not identify the possible factors that had effects on plant growth in curcuma plants when ethephon is applied.

Nutrient accumulation

At flowering stage, plants were harvested and separated to aboveground and underground part organs, after which the amount of N, P and K in samples were determined. The highest level of ethephon application (500 mg L^{-1}) gave the lowest amount of N, P and K contents in aboveground part organs, and N and P contents in underground part organs. From the previous results, ethephon can decrease aboveground part growth such as plant height, flower stalk, flower length and producing new shoot. It can be assumed that the reduction of plant size by the highest concentration of ethephon (500 mg L^{-1}) might be caused by low absorption, translocation and accumulation of nutrients. In contrast, the accumulation of N and P content in underground part organs was promoted with the application of 300 mg L^{-1} ethephon. In mung beans, the accumulation N in roots was highest during the application of ethephon at low concentration (100 mg L^{-1}) while a high ethephon level (400 mg L^{-1}) gave low N content (Techapinyawat *et al*., 1995).

CONCLUSSION

The application of high concentration of ethephon (300 mg L^{-1} and 500 mg L^{-1}) in curcuma plants inhibited plant growth and development, such as plant height and the quality of flowers. The highest concentration of ethephon (500 mg L^{-1}) reduced the accumulation of plant nutrients in aboveground part organs (N, P and K) and in under ground part organs (N and P). For more understanding about the effects of ethylene on plant growth and development in curcuma plants, the interaction between ethylene and other metabolism (e.g. respiration, photosynthesis) as well as other plant hormones would be studied.

REFERENCES

Basra, A.S. (Ed). 2000. *Plant Growth Regulators in Agriculture and Horticulture: Their Role and Commercial Uses*. p. 264. Food Products Press, New York.

Bidwell, R.G.S. (Ed.). 1979. *Plant Physiology, Second Edition*. p. 726. Collier Macmillan Publishers. London.

Briggs, J.B. 1975. The effects on growth and flowering of the chemical growth regulator ethephon on narcissus and ancimidol on tulip. *Acta Hort*., **47** : 287-296.

Davidescu, D., and Davidescu, V. 1972. *Evaluation of fertility by plant and soil analysis*. Abacus Press. London.

Guy, T., P. Lamprini, Z. Tamar and B. Amihud. 1998. Effects of ethrel and gibberellin on impatiens plants. *Sci. Hortic*., **76(1-2)** : 29-35.

Hagiladi, A., N. Umiel, Z. Gilad and X.-H. Yang. 1997. *Curcuma alismatifolia*. I. Plant morphology and the effect of tuberous root number on flowering date and yield of inflorescences. *Acta Hort*., **430 :** 747-754.

Kidd, H. and D. R., James (Eds.). 1991. *The Agrochemicals Handbook, Third Edition*. Royal Society of Chemistry Information Services. Cambridge, UK. 10-2 (AS update)

Lukaszewska, A. J. 1995. Distribution of sugars in tulip flower parts as affected by Ethrel and GA_3 in the holding solution. *Acta Hort*., **405** : 351-355.

Mizukoshi, K., T. Nishiwaki, N. Ohtake, R. Minagawa, K. Kobayashi, T. Ikarashi and T. Ohyama. 1994. Determination of tungstate concentration in plant materials by HNO_3-$HClO_4$ digestion and colorimetric method using thiocyanate. *Bull. Facul. Agri., Niigata Univ*., **46** : 51- 56.

Moe, R. 1980. The use of ethephon for control of plant height

and daffodils and tulips *Acta Hort*., **109** : 197-204.

Ohyama, T., T. Ikarashi and A. Baba. 1985. Nitrogen accumulation in the roots of tulip plants (*Tulipa gesneriana*). *Soil Sci. Plant Nutr*., **31** : 581-588.

Ohyama, T., M. Ito, K. Kobayashi, S. Araki, S. Yasuyoshi, O. Sasaki, T. Yamazaki, K. Sayoma, R. Tamemura, Y. Izuno and T. Ikarashi. 1991. Analytical procedures of N, P, K content in plant and manure materials using H_2SO_4-H_2O_2 Kjeldahl digestion Method. *Bull. Facul. Agric. Niigata Univ*., **43** : 111-120.

Paz, M. D. P.P. 2003. *Rhizome manipulation affects growth and development of ornamental gingers*. Thesis. p. 100. Department of Horticulture. Louisiana state University.

Pierik, R., D. Tholen, H. Poorter, E. J.W. Visser and L. A.C.J. Voesenek. 2006. The Janus face of ethylene: growth inhibition and stimulation. *Trends in Plant Science*., **11(4)** : 176-183.

Roh, M.S. and R.H., Lawson. 1993. *Curcuma*. Grower Notebook. A step-by-step guide to success. *Greenhouse Manager*, **12** : 10.

Roh, M.S., R. Lawson, J.S. Lee, J.K. Suh, R.A. Criley and P. Apavatjrut. 2006. Evaluation of Curcuma as potted plants and cut flowers. *J. Hort. Sci. Biol*., **81(1)** : 63-71.

Rylski, I., L. Rappaport and H.K. Pratt. 1974. Dual effects of ethylene on potato dormancy and sprout growth. *Plant Physiol*., **53** : 658-662.

Sebanek, J., F. Kopecky and K. Slaby. 1976. Effect of gibberellin, cytokinin and Ethrel on the growth and development of tulips and hyacinths. *Acta Universitatis Agriculturae,* Brno, **24(3)** : 387-396.

Stepanova, A.N. and J.M., Alonso. 2005. Ethylene signaling and response pathway: a unique signaling cascade with a multitude of inputs and outputs. *Physiol. Plant*., **123** : 195-206.

Techapinyawat, S., M. Na Nakorn, and N. Sinbuathong. 1995. Effects of ethephon and paclobutrazol on growth and yield of Mungbean cv Kamphaeng Sean 1. *Kasetsart J. (Nat. Sci.)*, **29** : 193-204.

Vichailak, O. 2006. *Amazing Thai Curcuma*. Horticultural research institute. Bangkok. Thailand.

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エテフォン施用の影響

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*]

（平成21年７月１日受付）

要　約

クルクマ･アリスマティフォリア Gagnep. の塊茎を2004年６月24日にチェンマイ大学で植え込んだ。植え込み４週間後（萌芽）と、６週間後に、濃度０、100、300、または、500 mg L^{-1}のエテフォン水溶液100mL を土壌に施用し、クルクマの生長と分化に及ぼすエテフォンの施用効果を調べた。エテフォン300 または 500 mg L^{-1}区では、草丈が低下した。植え込み14週間後には、０、100、300、500　mg L^{-1}区で草丈はそれぞれ、46.5 cm、43.6 cm、35.1 cm、33.9 cm であった。また、エテフォンの施用は、花の数と品質を低下させた。特に高濃度のエテフォン施用では、花茎と花が短くなった。さらに、エテフォン施用で、ピンクと緑の苞の数、および株あたりの花の数が減少した。エテフォンの施用は、塊茎の大きさ（長さと幅）、貯蔵根の長さには影響を与えなかった。しかしながら、株あたりの塊茎の重さは、エテフォン施用で低下する傾向がみられた。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。高濃度エテフォン（500 mg L^{-1}）区では、地上部の株当たり窒素、リン、カリウム含有量と濃度、および地下部の窒素とリン含有量と濃度は、対照区より低下した。

新大農研報, 62(1):9-15, 2009

キーワード：クルクマ、エチレン、エテフォン、窒素、リン、カリウム

[1] 新潟大学大学院自然科学研究科

[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