Kasetsart J. (Nat. Sci.) 41 : 72 - 83 (2007)

Effects of Nitrogen, Phosphorus and Potassium Deficiencies on Growth and Development of *Globba rosae* Gagnep.

Soraya Ruamrungsri[1, 2]*, Watcharaphon Bumphenyoo[1], Rumjuan Sriwichai[2] and Pimchai Apavatjrut[2]

ABSTRACT

The effects of N, P and K deficiencies on growth, development and nutrient status of *Globba rosae* were investigated using soilless culture. Rhizomes of *Globba rosae* Gagnep. were planted in sand medium. After emergence, plants were supplied with nitrogen (N), phosphorus (P) or potassium (K) deficient solutions, compared with a complete nutrient solution (control treatment) and nutrient-free solution (only tap water). Plants were sampled at flowering (7-8 weeks after planting, WAP) and before dormancy stages (12 WAP) to determine the nutrient contents of the aerial and underground parts. Nutrient deficiency symptoms were observed in -N, -P and -K treatments. Leaf of –N treatment was small and yellowish green, the pink bract was pale and had no floret. For P and K deficient symptoms, leaves were small, floral bracts were pale. Plant height, number of leaves per plant, number of plants per cluster, number of racemes per plant in nutrient deficiency treatments were reduced. Days to flower was retarded compared with control treatment. The optimum levels of nitrogen, phosphorus and potassium in nutrient solution for growth of *Globba rosae* were 100, 100 and 200 mg l^{-1}, respectively.

Key words: *Globba rosae*, plant nutrition, nutrient deficiency

INTRODUCTION

Globba is in the tribe Globbeae, family Zingiberaceae (Sirirak, 1996). This genus consists of more than 40 species and several varieties, grown naturally in the northern and central regions of Thailand. It has great potential to use as flowering pot plants, cut flowers or as landscape plants. *Globba* is a monocotyledonous, bulbous plant, bearing a short rhizome with several storage roots. *G. rosea* produces short terminal inflorescences on the leaf shoot, having purplish pink bracts. Bulbil (Figure 1a) is a propagule formed in the leaf axils. Plants grown from big bulbils are taller with longer leaves and a higher number of leaves per plant than those grown from small bulbils (Mongkolrattanasit, 2001). Rhizome size is also affected flowering period, plant height, the number of leaves per plant and the number of plants per cluster. Production of *Globba* in soilless culture has been used to prevent the infection of soil-borne pathogen. Inadequate supply of nutrient in soilless culture was reported to decrease growth, flower quality, rhizome and bulb size in *Hippeastrum* (Silberbush *et al*., 2003), and *Curcuma alismatifolia* Gagnep. (Ruamrungsri *et*

1 Department of Horticulture, Faculty of Agriculture, Chiang Mai University, Chiang Mai 50200, Thailand.
2 H.M. The King's Initiative Centre for Flower and Fruit Propagation. c/o Chiang Mai University, Chiang Mai 50200, Thailand.
* Corresponing author, e-mail: sdosrarn@chiangmai.ac.th

Received date : 08/06/06 Accepted date : 04/10/06

al., 2005). As far as we know, nutrient deficiency symptoms in *Globba rosae* have not been described so far. This research, therefore, was aimed to determine the effects of nitrogen, phosphorus and potassium deficiencies on growth, development, deficiency symptoms and nutrient contents in *Globba rosae* Gagnep. using soilless culture technique.

MATERIALS AND METHODS

Experiment 1 : Effects of nitrogen, phosphorus and potassium deficiencies on *Globba rosae* growth

Rhizomes of *Globba rosae* Gagnep. 0.2-0.3 cm diameter with 2-3 storage roots (Figure 1b) were planted in a 10 × 20 cm plastic bag using sand culture (1 rhizome per container). Different kinds of nutrient solutions were supplied everyday after sprouting. The treatments were : complete solution (treatment 1) was used as control treatment containing NH_4NO_3 140, $NaNO_3$ 60, Na_2HPO_4 100, K_2SO_4 100 and $CaCl_2$ 100 mg l^{-1} plus microelement fertilizer (Mn 0.1, Zn 0.005, Cu 0.003, Mo 0.055, B 0.2 and Fe 2 mg l^{-1}). Distilled water was used to prepare nutrient solutions. In -N, -P, and -K treatments (treatment 2 - 4), plants were fed everyday with 50 ml of nutrient solutions lacking N, P and K, respectively. Only distilled water was used in nutrient free solution (treatment 5). Leaching of accumulation salts was done once a week using 300 ml of distilled water. Plant height, number of plants per cluster were measured every two weeks after planting (WAP), days to flowering, number of racemes per plant and plant dry weight were measured at flowering stage. The experimental design was a completely randomized design with 4 replications (2 containers for one replication). The concentrations of nitrogen and phosphorus were determined in aerial and underground plant parts at flowering and before dormancy stage using colorimetry as described in Ohyama *et al*. (1985). Potassium, calcium and magnesium concentrations were determined using an atomic adsorption spectrophotometer (PERKIN ELMER 3100, The Perkin Elmer Cooperation, Norwalk, USA).

Experiment 2 : Effects of nitrogen, phosphorus and potassium levels in nutrient solution on growth and development of *Globba rosae* in soilless culture

Rhizomes of one cm diameter (Figure 1c) were grown in soilless media comprised sand : rice husk charcoal (1:1 v/v). Plants were supplied with different nutrient solutions comprising of the combination of three nitrogen levels (100, 200 and 300 mgN l^{-1}), two levels of phosphorus (50 and 100 mgP l^{-1}) and two levels of potassium (200 and 300 mgK l^{-1}). Each treatment also contained Ca 65, Mg 20, B 0.22, Mn 0.54, Zn 0.26, Mo 0.04 and Fe 0.45 mg l^{-1}. Experimental design was in 3 × 2 × 2 factorials with completely randomized design, 10 replications per treatment. Plant height, number of plants per cluster were measured at 12 WAP when the first floret open, rhizome fresh weight were measured at harvest and nutrient concentration in aerial and underground parts were determined at 14 WAP during full bloom.

RESULTS AND DISCUSSION

Experiment 1 : Effects of nitrogen, phosphorus and potassium deficiencies on growth and development of *Globba rosae*

Plant Growth and Development

The control treatment, plant height and number of leaves per cluster were gradually increased up to 12 WAP (Figure 2a and 2b). Distilled water, -N, -P and -K treatments severely depressed plant height and number of leaves per cluster comparing with the control. Flowering of *G. rosae* generally took place during August to September in Thailand. Flower blooming within 7-8 WAP was observed in this experiment.

Phosphorus and potassium deficiency did not affect the number of days to flowering compared with the control, however, -N and distilled water treatment retarded flowering date about 10 days.

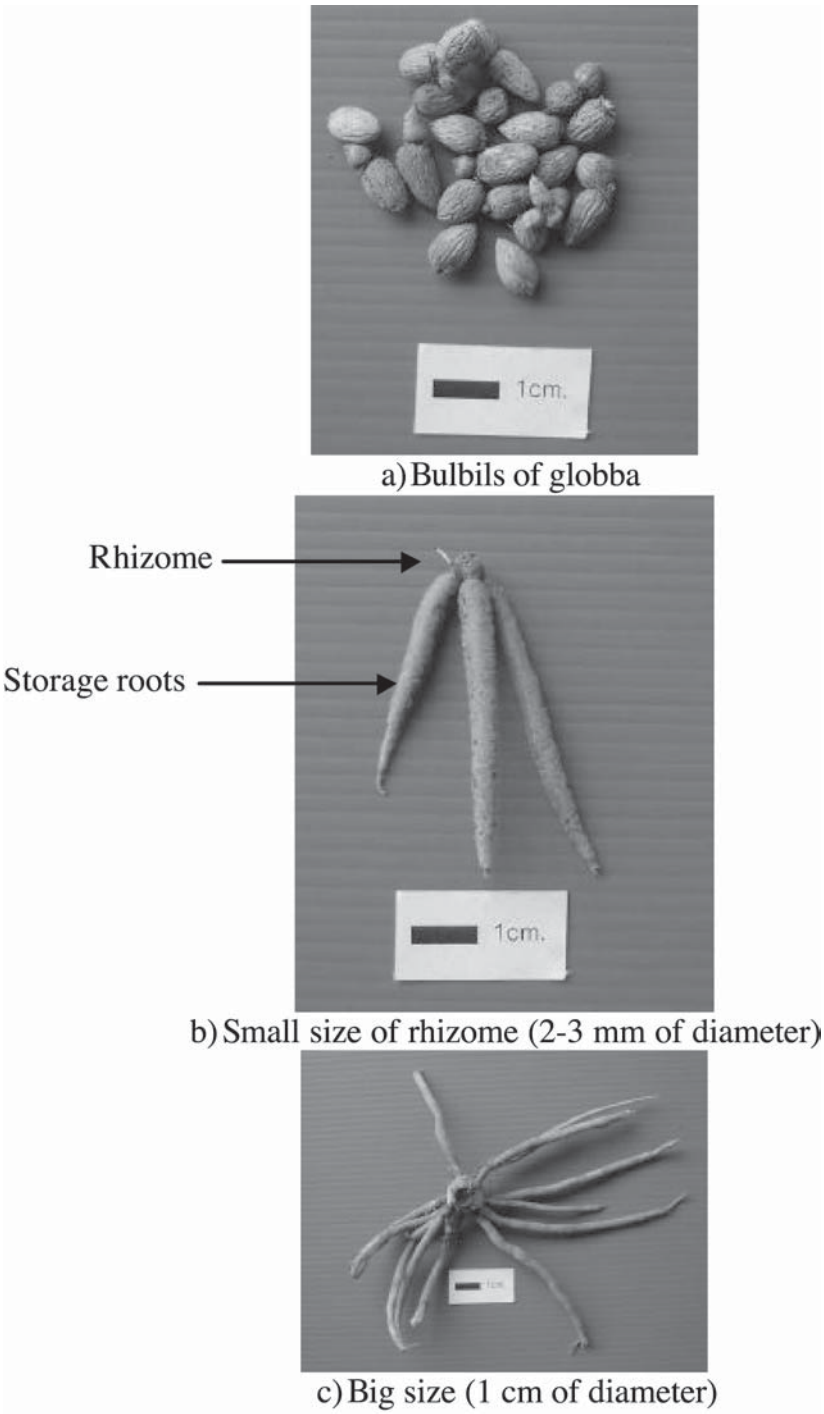
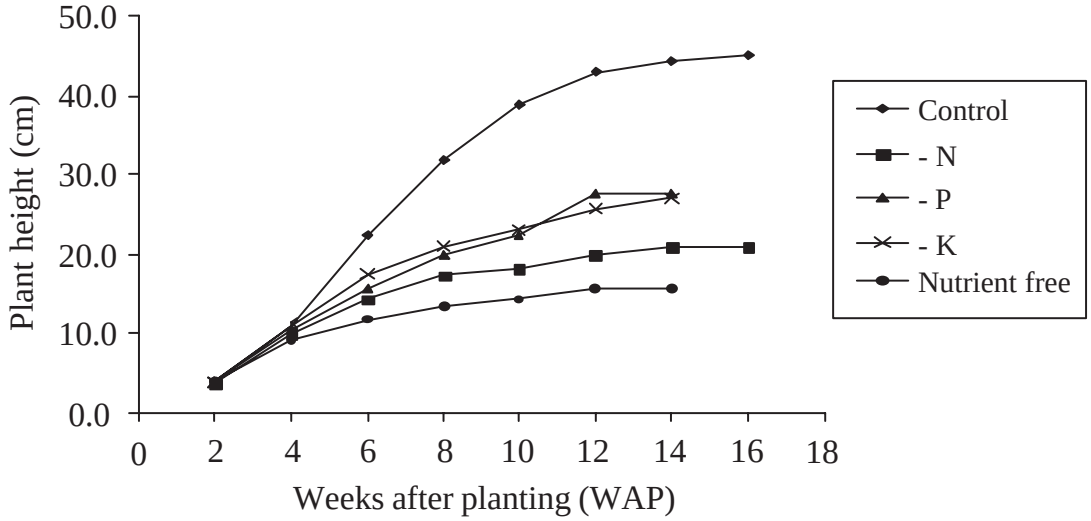
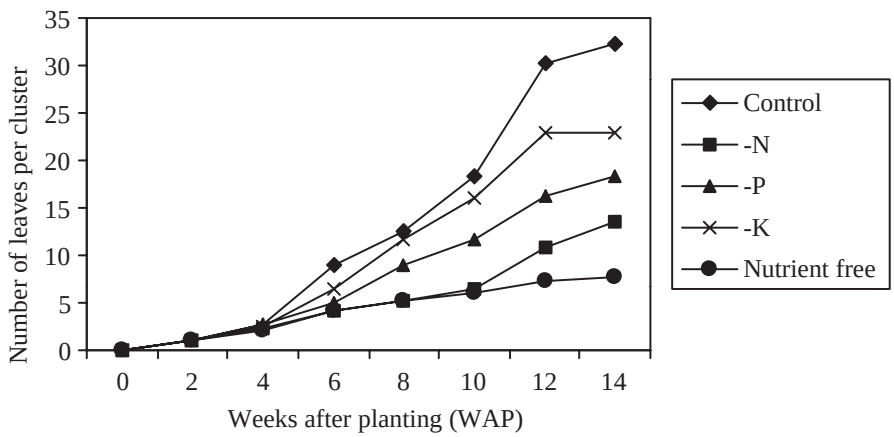


Figure 1 Rhizomes with storage roots and bulbils of *Globba rosae*.



a) Plant height at different stages of growth



b) Number of leaves per cluster at different stages of growth

Figure 2 Growth of *Globba rosae* plants at different stages under nutrient deficiency treatments.

In control treatment, plant height, number of leaves and number of racemes per cluster were greater than the other treatments (Table 1). Plants grown in nutrient-free, -N and -P treatments produced 0.62, 1.00 and 1.25 racemes per plant, respectively (Table 1). Deficient K solution did not affect plant dry weight at flowering stage while it subsequently decreased plant dry weight at dormancy stage (Table 2). The dry weight of plants in -N, -P and nutrient free solution were severely depressed at flowering and harvest stages (Figure 3).

Previously, we reported that *Curcuma alismatifolia* grown in P and K treatments did not show clear visible symptoms on plant growth, only shorter spikes were observed (Ruamrungsri and

Table 1 Effect of nutrient deficiencies on plant height, number of leaves per cluster, number of plants per cluster and number of racemes/plant of *Globba rosae* (every table) at 12 weeks after planting (WAP).

Treatment	Height (cm)[1/]	Number of leaves per cluster[1/]	Number of plants per cluster[1/]	Number of racemes per cluster[1/]
1. Control	42.90a	30.13a	5.50a	3.00a
2. N- deficiency	19.76c	10.75d	2.75c	1.00bc
3. P-deficiency	27.59b	16.25c	3.00c	1.25b
4. K-deficiency	25.68b	22.38b	4.13b	2.75a
5. Nutrient-free	15.49c	7.38e	1.13d	0.62c
LSD.(0.05)	1.27	0.91	0.22	0.18

[1/] Mean followed by the different letter within the same column was significantly different by LSD at $P < 0.05$

Table 2 Effect of nutrient deficiencies on dry weight of aerial parts at different stages of growth.

Treatment	Dry weight (g) [1/]	
	Flowering stage	Harvest stage
1. Control	1.64a	2.90a
2. N-deficiency	0.24c	0.37c
3. P-deficiency	0.67b	0.61c
4. K-deficiency	1.74a	1.16b
5. Nutrient-free	0.21c	0.22c
LSD (0.05)	0.22	0.40

[1/] Mean followed by the different letter within the same column was significantly different by LSD at $P < 0.05$

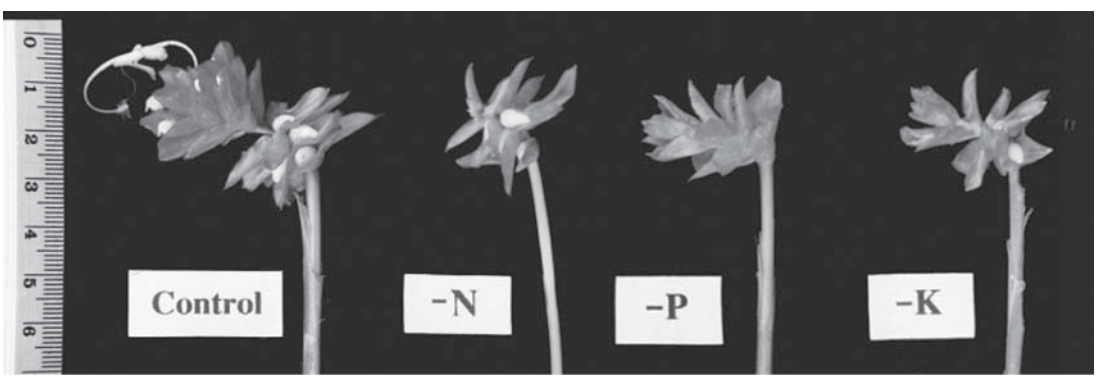


Figure 3 Deficiencies symptoms in inflorescence of *Globba rosae*.

Apavatjrut, 2003). In *G. rosae*, deficiency symptoms in -N, -P, and -K treatments were determined. -N, -P, -K symptoms were noticed first in mature leaves. Leaves of -N treatment were small, yellowish green and gradually turned yellow, leaf tip was brown and dry (Figure 4). It is because N deficiency induced proteolysis in leaves and results in a collapse of the chloroplasts and decline of the chlorophyll content (Mengel and Kirkby, 1987). The shoot growth was retarded and

roots had few ramifications, floral bracts were pale. In -P and -K treatments, the size of mature leaves were reduced, the leaf tip was yellowing and dry and floral bracts were pale similar to those shown in -N treatment (Figure 4). Leaves color of –P treatment were dark green.

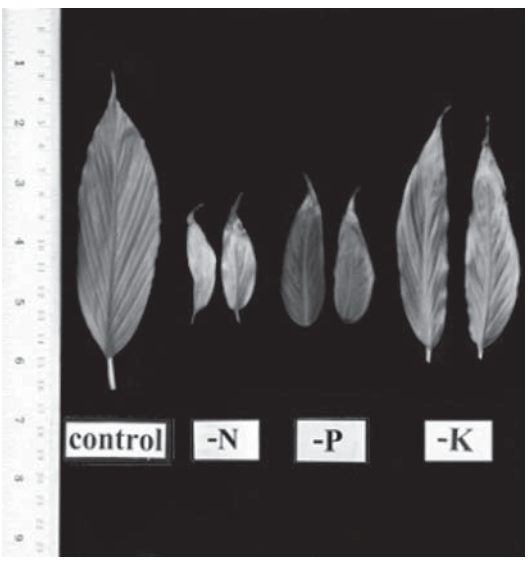


Figure 4 Deficiency symptoms in leaves of *Globba rosae*.

Nutritional status of the plants

Nutrient accumulations in control plants

Before planting, a rhizome of *Globba rosae* contained 5.83 mg of N, 4.47 mg of P, K 1.64 mg, Ca 0.18 mg and Mg 0.26. Mineral nutrients in plant tissue continuously increased at flowering stage. At harvest, control plants accumulated a large amount of nutrients, i.e. 198 mg of N, 99.2 mg of P, K 27.6 mg, Ca 13.6 mg and Mg 2.44 mg (Figure 5). This showed that one plant was able to accumulate more than 190 mg of N, 90 mg of P, 25 mg of K, 13 mg of Ca and 2 mg of Mg from nutrient solution within one growth cycle. Therefore fertilizer application, especially nitrogen fertilizer should be continuously supplied at flowering stage until 12 WAP.

Nutrients contents in aerial parts (leaves and inflorescence)

Aerial parts of *Globba* grown in complete solution (control treatment) contained an average of 46.21 mg N per plant, 24.91 mg P per plant, 8.83 mg K per plant, 4.43 mg Ca per plant and 1.25 mg Mg per plant at flowering stage (8 WAP). -N, -P and nutrient-free treatments, nitrogen, phosphorus, potassium, calcium and magnesium contents of aerial parts were

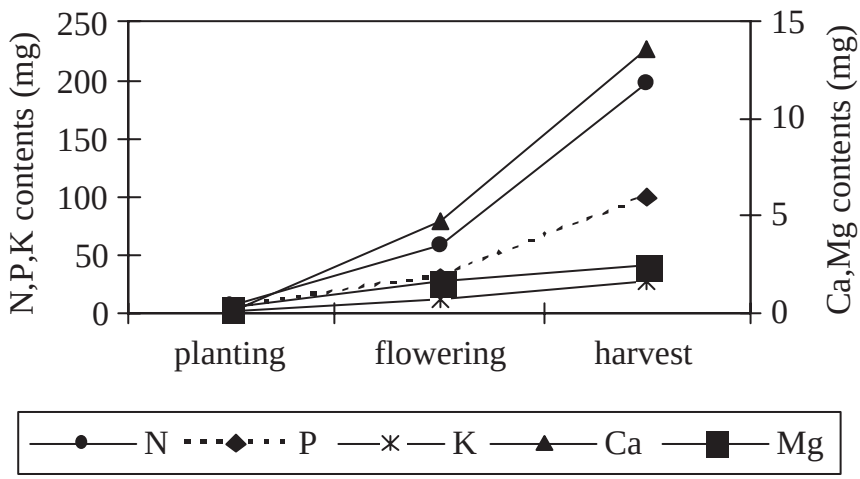


Figure 5 Nutrient accumulation of *Globba rosae* at different stages of growth.

decreased, however –K treatment was not affected compared with the control (Table 3a). At harvest, the content of each mineral in the plant was lower than in control plant (Table 3b, underlined). Similar results has been found in *Narcissus* 'Garden Giant' (Ruamrungsri *et al*., 1996).

Nutrient contents in underground part (roots and rhizome)

Underground part (root and rhizome) of control plants contained 12.8 mg of N, 5.94 mg of P, 2.09 mg of K, 0.40 mg of Ca and 0.37 mg of Mg at the flowering stage. -N and -P treatments, nitrogen and phosphorus contents in underground parts were reduced, but not in K treatment. -K and nutrient-free treatments, Ca and Mg content in plant were increased (Table 4a). At harvest, underground parts of control plant contained a large amount of mineral elements, especially nitrogen and phosphorus content. N, P and K deficiency treatments, accumulation of N, P, K, Ca and Mg in new roots and rhizome at dormancy stage were decreased (Table 4b).

It should be mentioned that this experiment was done for a long period so contamination of deficient solution with N, P or K from chemical reagents or from environment have been occurred. Therefore, K-deficiency did not affect nutrition content except for K in the other treatments at flowering stage and the total content of N, P and K in the deficient treatments markedly increased at harvest (Table 3b and 4b).

Nutrient contents in bulbils

Bulbils of *G. rosae* contained 26.3 mg of N, 12.7 mg of P, 3.1 mg of K, 1.2 mg of Ca and 0.3 mg of Mg per bulbils in control treatment at harvest. -N, -P or –K and nutrient-free treatment, N, P, K, Ca and Mg contents of the bulbils were decreased (Table 5). Mongkolrattanasit (2001) reported that bulbil size affected plant growth and development. This may be due to the different amount of food reserves in each size bulbil. Therefore, bulbils grown in nutrient deficient condition may affect growth and development of the next crop.

Table 3 Effect of nutrient deficiencies on contents of N, P, K, Ca and Mg in aerial parts (leaves and raceme) at flowering stage and before dormancy stage.

Treatment	Content (mg/plant part) [1/]				
	a) Flowering stage				
	N	P	K	Ca	Mg
1. Control	46.21a	24.91b	8.83a	4.43a	1.25b
2. N- deficiency	5.14c	4.81c	1.18c	0.66bc	0.22c
3. P-deficiency	20.37b	5.05c	3.25b	1.48b	0.32c
4. K-deficiency	45.85a	28.77a	7.62a	4.14a	1.50a
5. Nutrient-free	2.79c	1.74c	0.66c	0.57c	0.35c
LSD.(0.05)	1.86	1.10	0.46	0.28	0.07
	b) Before dormancy stage				
1. Control	55.56a	31.46a	13.69a	9.48a	1.06a
2. N- deficiency	5.96cd	7.46c	2.08bc	1.44c	0.28b
3. P-deficiency	14.48c	4.19d	3.00b	1.90c	0.18b
4. K-deficiency	25.98b	19.53b	1.19c	5.62b	1.08a
5. Nutrient-free	1.76d	1.98d	0.73c	0.69c	0.16b
LSD.(0.05)	2.63	0.98	0.52	0.61	0.05

[1/] Mean followed by the different letter within the same column of the same stage was significantly different by LSD at $P < 0.05$

Table 4 Effect of nutrient solutions on contents of N, P, K, Ca and Mg in underground parts (roots and rhizome) at flowering stage and before dormancy stage.

Treatment	Content (mg/plant part) 1/				
	a) Flowering stage				
	N	P	K	Ca	Mg
1. Control	12.82a	5.94ab	2.09ab	0.40ab	0.37bc
2. N- deficiency	2.77b	4.42bc	1.20c	0.43a	0.25c
3. P-deficiency	6.11b	2.50c	1.32bc	0.22b	0.19c
4. K-deficiency	11.76a	6.99a	2.35a	0.46a	0.46b
5. Nutrient-free	5.97b	4.08bc	1.37bc	0.34ab	0.82a
LSD.(0.05)	1.56	0.74	0.29	0.06	0.07
	b) before dormancy stage				
1. Control	142.79a	67.71a	13.89a	4.11a	1.38a
2. N- deficiency	9.91c	7.59c	1.98c	0.83b	0.24cd
3. P-deficiency	56.04b	12.30c	5.67b	1.35b	0.48c
4. K-deficiency	56.42b	23.09b	3.27c	1.40b	0.84b
5. Nutrient-free	10.01c	7.33c	2.51c	1.00b	0.14d
LSD.(0.05)	6.39	2.37	0.59	0.28	0.10

1/ Mean followed by the different letter within the same column of the same stage was significantly different by LSD at $P < 0.05$

Table 5 Effect of nutrient deficiencies on total contents of N, P, K, Ca and Mg in bulbils of *G. rosae*.

Treatment	Bulbils dry weight (g)	Total Content (mg/plant) 1/				
		N	P	K	Ca	Mg
1. Control	0.91	26.27a	12.68a	3.14a	1.24a	0.30a
2. N- deficiency	0.18	4.46c	2.39c	1.12b	0.41b	0.13b
3. P-deficiency	0.34	11.80bc	3.75c	1.47b	0.47b	0.14b
4. K-deficiency	0.55	16.45b	7.89b	1.48b	0.54b	0.20b
5. Nutrient-free	0.30	6.23c	1.93c	1.22b	0.22b	0.18b
LSD.(0.05)		2.73	1.37	0.36	0.14	0.04

1/ Mean followed by the different letter within the same column was significantly different by LSD at $P < 0.05$

Experiment 2: Optimum nitrogen, phosphorus and potassium levels in nutrient solution for *Globba rosae* culture in soilless culture

Plant Growth and development

This experiment was carried out using the bigger size of rhizome than those in the experiment 1. The result showed that nitrogen concentration at 100 mg l^{-1} gave higher inflorescence width and rhizome fresh weight than the others, however plant height and number of leaves per plant were not affected (Table 6, Figure 6a). Phosphorus concentrations did not affect plant growth, except for number of leaves per plant (Table 6). It was found that 100 mg of phosphorus slightly increased number of leaves per plant (Figure 6b). Potassium concentration at 200 mg l^{-1} gave greater number of leaves per plants, inflorescence width and rhizome fresh weight than using 300 mg l^{-1} . The response of *G. rosae* to N, and K concentrations in present experiment was different from *Curcuma alismatifolia* in our

Table 6 Effect of nutrient levels on growth and development of *Globba rosae* at 14 weeks after planting (WAP).

Factors	Plant height (cm)	Number of leaves per plant	Inflorescence width (cm)	Rhizome fresh weight g/plant
N-levels (mg l^{-1})				
100	40.43 a[1/]	6.32 a	3.50 a	43.68 a
200	41.23 a	6.42 a	3.34 ab	32.81 b
300	43.51 a	5.76 a	3.21 b	35.15 b
P-levels (mg l^{-1})				
50	39.45 a	5.79 b	3.30 a	37.15 a
100	44.00 a	6.54 a	3.24 b	37.28 a
K-level (mg l^{-1})				
200	39.58 a	6.44 a	3.46 a	42.14 a
300	43.87 a	5.89 b	3.24 b	32.29 b

[1/] Mean followed by the different letter within the same column in each factor was significantly different by LSD at $P < 0.05$
ns: not significantly different

previous report. *C. alismatifolia* preferred N concentration at 200 mg l^{-1} to promote plant height, number of plants per cluster, flower quality, number of new rhizomes, number of storage roots and length of storage roots and different concentrations of K (50, 100 and 200 mg l^{-1}) did not affect to these parameters except for number of green bracts (Ruamrungsri *et al*., 2005). The levels of N-nutrition required for optimum growth during the vegetative period must also be balanced by the presence of other plant nutrients in adequate amounts (Mengel and Kirkby, 1987).

Nutrient status in plant parts at flowering stage

Nutrient concentration in aerial parts (leaves and inflorescence)

The results showed that highest concentration of nitrogen supply to the plant, nitrogen, iron and manganese concentration in aerial parts of plant were increased, while calcium concentration was decreased (Table 7). However, phosphorus, potassium, magnesium and zinc concentrations in the plant were not affected. Higher concentration of phosphorus (100 mg l^{-1}) resulted in increased phosphorus and manganese concentrations but not magnesium concentration (Table 7). 300 mg l^{-1} of potassium supplied to the plant did not promote the uptake of potassium in aerial part but it was found that magnesium concentration was decreased (Table 7) due to the competitive absorption of cation between K^+ and Mg^{2+}.

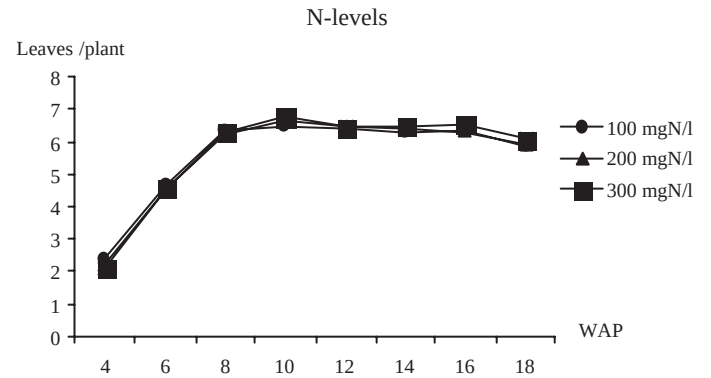
Nutrient concentrations in underground parts (rhizome and storage roots)

Nitrogen in nutrient solution did not affect nitrogen concentration in underground parts of *Globba*. Furthermore, it decreased K concentration in underground part (Table 8). Higher concentration of N promoted the accumulation of Ca, Fe, Mn and Zn in underground part. At 100 mg l^{-1} phosphorus did not increased P concentration in the plant, but reduced K, Mg and Zn concentrations (Table 8). At high level of K (300 mg l^{-1}), P, Fe and Mn levels in the plant were increased (Table 8).

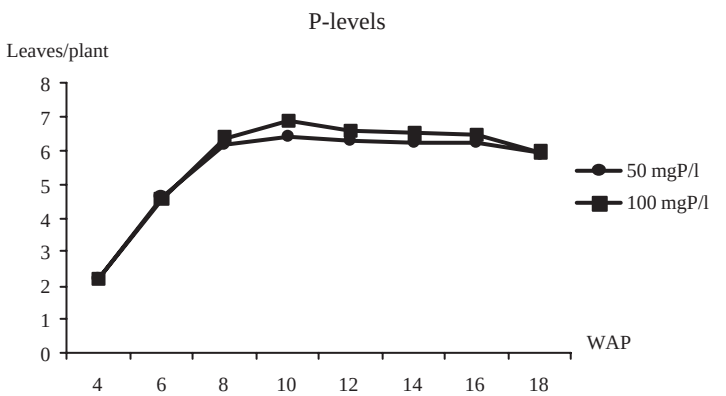
CONCLUSION

N, P or K deficiency nutrient solutions strongly reduced plant height, number of plants per cluster, number of racemes per cluster, flower quality, and nutrient content of this plant. The

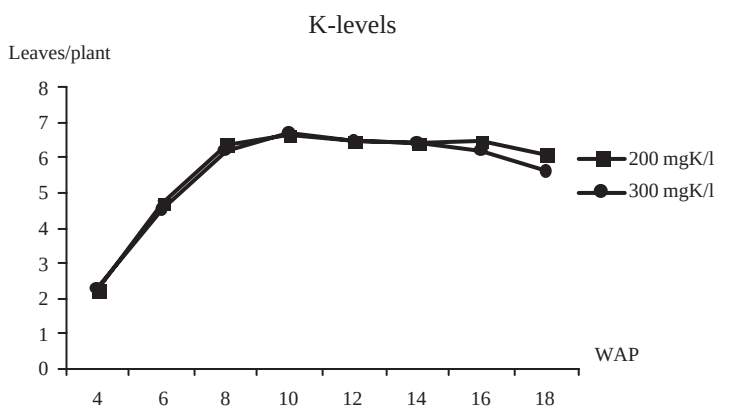
results in experiment 2 indicated that the optimum amount of nitrogen, phosphorus and potassium in nutrient solution for promoting growth and development of *Globba rosae* grown in soilless medium was 100, 100, 200 mg l^{-1}, respectively.



a) Effect of nitrogen on number of leaves per plant



b) Effect of phosphorus on number of leaves per plant



c) Effect of potassium on number of leaves per plant

Figure 6 Number of leaves per plant of *G. rosae* under different N, P and K levels.

Table 7 Effect of NPK levels on the concentration of nutrient in aerial parts of *Globba rosae* at flowering stage.

Factors	Nutrient concentrations (mg gDW^{-1})							
	N	P	K	Ca	Mg	Fe	Mn	Zn
N-levels (mg l^{-1})								
100	30.85 b[1/]	18.19 a	73.39 a	13.14 a	4.55 a	0.31 c	0.96 b	0.05 a
200	30.17 b	18.22 a	72.61 a	10.91 b	4.13 a	0.45 b	1.26 ab	0.05 a
300	34.46 a	16.47 a	66.06 a	11.91 a	3.81 a	0.60 a	1.48 a	0.05 a
P-levels (mg l^{-1})								
50	32.54 a	16.00 b	70.85 a	12.84 a	4.59 a	0.43 a	0.97 b	0.05 a
100	31.11 a	19.25 a	70.52 a	10.81 a	3.74 b	0.49 a	1.49 a	0.05 a
K-levels (mg l^{-1})								
200	30.48 b	17.47 a	71.48 a	12.09 a	4.61 a	0.44 a	1.02 b	0.05 a
300	33.17a	17.78 a	69.89 a	11.56 a	3.72 b	0.48 a	1.44 a	0.05 a

[1/] Mean followed by the different letter within the same column in each factor was significantly different by LSD at $P < 0.05$
ns: not significantly different

Table 8 Effect of NPK levels on the concentration of nutrient in underground parts of *Globba rosae* at flowering stage.

Factors	Nutrient concentrations (mg gDW^{-1})							
	N	P	K	Ca	Mg	Fe	Mn	Zn
N-levels (mg l^{-1})								
100	20.50 a[1/]	18.08 a	52.72 a	9.04 b[1/]	3.71 a	1.25 b[1/]	0.58 b[1/]	0.07 b[1/]
200	21.40 a	18.88 a	37.80 b	12.38 a	3.87 a	1.45 ab	0.84 a	0.07 b
300	22.54 a	18.40 a	37.00 b	11.94 a	3.99 a	1.61 a	0.93 a	0.09 a
P-levels (mg l^{-1})								
50	21.75 a	18.08 a	46.69 a	10.95 a	3.99 a[1/]	1.41 a	0.76 a	0.08 a[1/]
100	21.21 a	18.83 a	38.32 b	11.29 a	3.72 b	1.46 a	0.81 a	0.07 b
K-levels (mg l^{-1})								
200	21.14 a	17.29 b	45.31 a	10.67 a	3.89 a	1.30 b[1/]	0.69 b[1/]	0.08 a
300	21.82 a	19.62 a	39.70 a	11.57 a	3.82 a	1.57 a	0.88 a	0.08 a

[1/] Mean followed by the different letter within the same column was significantly different by LSD at $P < 0.05$
ns: not significantly different

ACKNOWLEDGMENTS

We thank H.M. the King's Initiative Centre for Flower and Fruit Propagation for supporting plant materials and chemicals in this experiment.

LITERATURE CITED

Mengel, K and E.A. Kirkby. 1987. **Principles of Plant Nutrition**. International potash institute, Burn. 687 p.

Mongkolrattanasit, N. 2001. **Growth and Development of Two *Globba* Species**. MS Thesis. Chiang Mai University, Chiang Mai.

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.

Ruamrungsri, S., T. Ohyama, T. Konno and T. Ikarashi. 1996. Deficiency of N, P, K, Ca, Mg, or Fe mineral nutrients in *Narcissus* cv.' Garden Giant'. **Soil Sci. Plant Nutr**. 42(4): 809-820.

Ruamrungsri, S. and P. Apavatjrut. 2003. Effect of nutrient deficiency on the growth and development of *Curcuma alismatifolia* Gagnep, pp. 98-104. *In* **Proceedings of the 3rd Symposium on the Family Zingiberaceae**. Khon Kaen, Thailand. 7-12 July, 2002.

Ruamrungsri, S., C. Suwanthada, N. Ohtake, K. Sueyoshi, T. Ohyama and P. Apavatjrut. 2005. Effect of Nitrogen and Potassium on Growth and Development of *Curcuma alismatifolia* Gagnep. **Acta Hort**. 673: (443-448)

Sirirak, P. 1996. **A Taxonomic Survey of Zingiberaceous Species in Southern Thailand**. Department of Biology, Faculty of Science, Songklanakarin University. Songkla. 30 p.