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Promoting side shoot development in *Zantedeschia aethiopica* 'Green Goddess'

Förderung der Seitentriebbildung bei *Zantedeschia aethiopica* 'Green Goddess'

K. Ngamau
(Institut für Zierpflanzenbau, Baumschule und Pflanzenzüchtung, Abteilung Zierpflanzenbau, Universität Hannover)

Summary

Plants as well as rhizomes of 'Green Goddess' were decapitated, pierced or treated with growth regulators BAP and GA_3, singly or combined to attain the outgrowth of the daughter rhizomes which are inhibited during the usual culture conditions. The decapitation of the main shoot led to the immediate outgrowth of the daughter rhizomes and to complete leaf development. The number of visible shoots were, however, less than that of a GA_3+BAP treatment. The piercing of the main shoot on the other hand did not cause the outgrowth of daughter rhizomes.

Treatment with growth regulators BAP, GA_3, KNA, TIBA and ethephon was also carried out. The application of BAP and GA_3 led invariably to earlier emergence and to an increased number of emerged shoots. However, the emerged shoots remained usually small and did not produce leaves. The application of a GA_3+BAP combination was more effective than when either phytohormone was applied exclusively. The application of TIBA alone or in combination with BAP and KNA+BAP could not enhance the emergence, while ethephon application even led to the deterioration of growth.

The culture in larger pots and an increased fertiliser application frequency promoted the outgrowth and the development of side shoots manifestly. While on plants in 8 cm diameter pots, the outgrowth of side shoots was strongly inhibited at first, that of plants in 20 cm diameter pots occurred readily and the side shoots developed quickly and even flowered. An increased fertiliser application frequency speeded up the outgrowth and the further development of the side shoots. However, only side shoots of plants in 20 cm diameter pots flowered.

Zusammenfassung

Pflanzen bzw. Rhizome von *Zantedeschia aethiopica* 'Green Goddess' wurden entspitzt, gepierced (Stechen des apikalen Meristems) oder mit den Wachstumsregulatoren, BAP und/oder GA_3 behandelt, um das Austreiben der Tochterrhizome, das unter üblichen Kulturbedingungen gehemmt ist, zu erzielen. Das Entspitzen des Haupttriebes führte zum sofortigen Austrieb der Tochterrhizome und zur vollständigen Blattentwicklung. Die Anzahl sichtbarer Sprosse war aber niedriger als bei einer GA_3+BAP-Behandlung. Das Piercen des Haupttriebes dagegen rief keinen Austrieb der Tochterrhizome hervor.

Die Applikation von BAP und GA_3 führte stets zum früheren Austreiben und zur erhöhten Anzahl ausgetriebener Sprosse. Jedoch blieben die ausgetriebenen Sprosse meistens klein und brachten keine Blätter hervor. Die Applikation einer GA_3+BAP-Kombination wirkte effektiver als wenn beide Phytohormone ausschließlich appliziert wurden. Die Applikation von TIBA allein oder in Kombination mit BAP und KNA+BAP konnte die Austriebsbereitschaft nicht erhöhen, während Ethephon-Applikation sogar zur Verschlechterung des Wachstums führte.

Die Kultur in größeren Töpfen und eine erhöhte Düngungshäufigkeit förderten das Austreiben und die Entwicklung der Seitentriebe auffallend. Während in Töpfen mit 8 cm Durchmesser der Austrieb anfangs stark gehemmt wurde, trieben die Pflanzen in Töpfen mit 20 cm Durchmesser sofort aus, entwickelten sich schnell und kamen sogar zur Blüte. Eine erhöhte Düngungshäufigkeit konnte ebenfalls das Austreiben und die weitere Entwicklung der Seitentriebe beschleunigen. Dennoch kamen nur die Seitentriebe der Pflanzen in 20-cm-Töpfen zur Blüte.

Introduction

Zantedeschia aethiopica 'Green Goddess' has been observed to have a marked apical dominance, producing daughter rhizomes on the main rhizome, which do not emerge during the early growth period. Ways of inducing the emergence of these rhizomes need to be investigated to further increase the yield of propagation material and cutflowers.

In pilot experiments the removal of the apical shoot was observed to enable the outgrowth of the daughter rhizomes. Application of growth regulators, if effective, offers a rapid method of overcoming apical dominance. Very few reports have been found in literature that relate the influence of growth regulator application to the outgrowth of side shoots in *Zantedeschia*. This is possibly because many cultivated varieties produce numerous shoots spontaneously. Certain *Z. rehmannii* and *Z. aethiopica* cultivars have several dominant buds on the corms/rhizomes that produce several shoots on planting, giving a multibranching growth

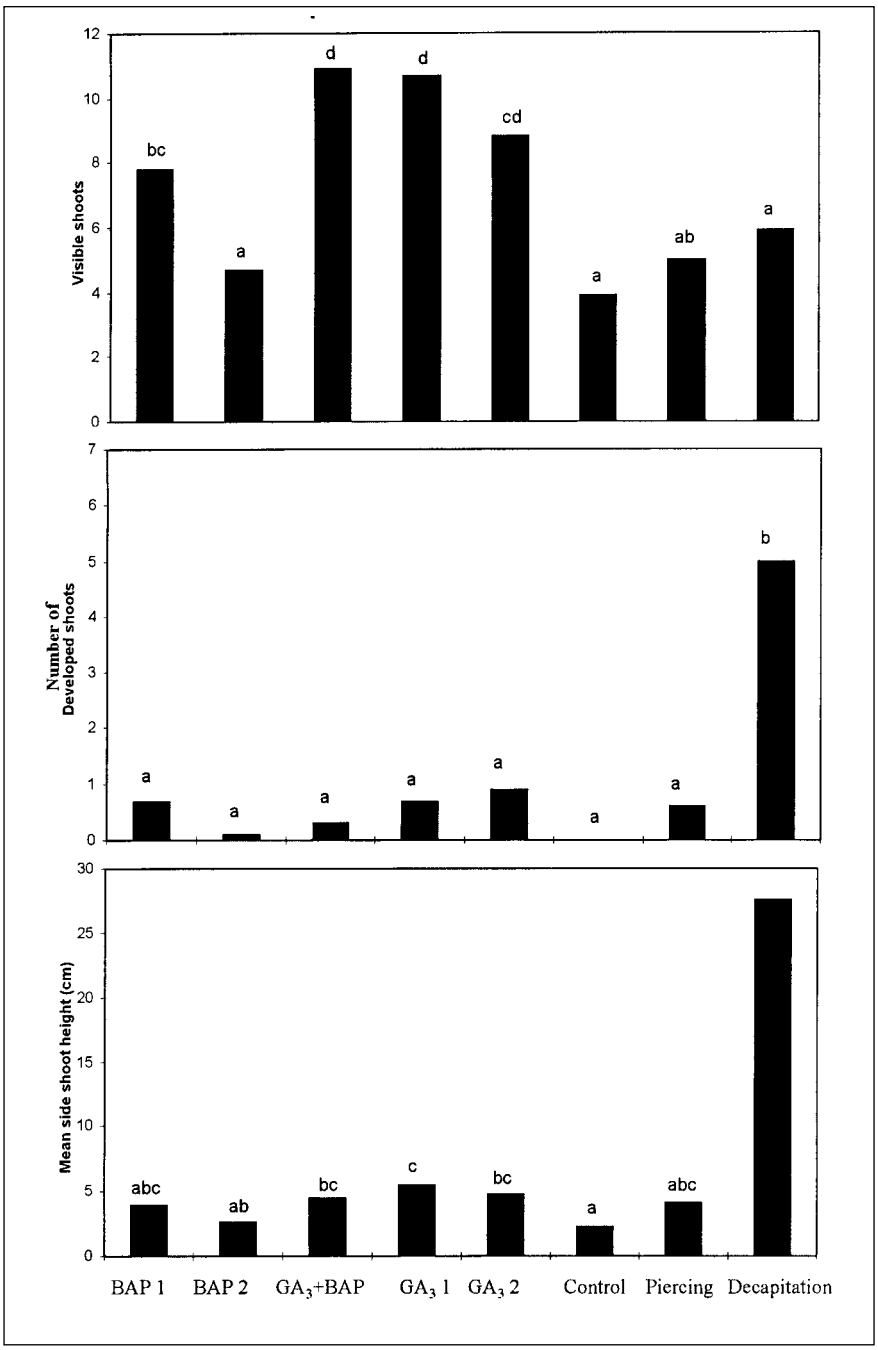


Fig. 1. Influence of treatments on the outgrowth and development of *Z. aethiopica* 'Green Goddess' side shoots at 16 weeks
Einfluß verschiedener Behandlungen auf den Austrieb und die Entwicklung von Z. aethiopica ‚Green Goddes's Seitentrieben in der 16. Woche

BAP 1 – 150 mg/l BAP (3x/wk, 6wk);
BAP 2 – 150 mg/l BAP (1x/2 wk, 8 wk);
GA_3+BAP – 250 mg/l GA_3+150 mg/l BAP (3x/wk, 6 wks);
$GA_3$1 – 250 mg/l GA_3 (3x/wk, 6 wks);
$GA_3$2 – 250 mg/l GA_3 (1x/2wk, 8wks);
Decapitation, Entspitzen;
Piercing, Stechen;
Control, Kontrolle;
n = 10
Means having common letter are not significantly different at Tukey's HSD (5 %)
Mittelwerte mit gleichen Buchstaben sind nicht signifikant abweichend bei HSD (5 %) nach Tuckey

habit (FUNNELL, 1993). Tubers of *Z. elliottiana* on the other hand have one dominant bud, exhibiting a monopodial growth habit and consequently low flowering potential (TJIA, 1985).

CORR and WIDMER (1987) reported that sprays of GA_3 significantly increased the number of developed shoots in *Z. rehmannii* but not in *Z. elliottiana*. TJIA (1985) reported that GA treatment suppressed apical dominance and caused multiple stems to develop on *Z. elliottiana* and increased the number of multiple stems on *Z. rehmannii*. FUNNELL *et al.* (1992) obtained a significant increase in the number of shoots in treatments with Promalin™ on *Zantedeschia* 'Galaxy' but not with GA_3. CORR and WIDMER (1991) also reported that GA_3 treatments did not significantly affect the number of shoots in *Z. rehmannii* and *Z. elliottiana*.

In other Aroids, various treatments have been used in promoting the lateral shoot production such as GA treatments in Tannia (*Xanthosoma sagittifolium*) (ALAMU and MCDAVID, 1978), BA and GA_3 in *Anthurium andreanum* 'Andre' (IMAMURA and HIGAKI, 1988), BA in *Spathiphyllum* (HENNY and FOOSHEE, 1985) and BA in *Dieffenbachia* (HENNY, 1986; WILSON and NELL, 1983). Dikegulac and ethephon had no effect (WILSON and NELL, 1983).

Ethylene promoted lateral shoot production in Bromeliads (VAN DIJCK, *et al.* 1988). Application of the ethylene-generating agent, ethephon, to a wide range of ornamental and rhizomatous species led to the outgrowth of lateral buds (MORGAN *et al.*, 1969; DE WILDE, 1971). Ethephon applications of 100 to 5000 ppm inhibited terminal growth and increased lat-

eral branching of many ornamentals such as Azalea, *Cotoneaster*, *Hydrangea*, *Petunia*, Poinsettia, *Zinnia*, Rose and Pine (DE WILDE, 1971).

Materials and Methods

Influence of decapitation, piercing and phytohormone GA_3 and BAP

Treatments involving high and low frequencies of BAP (Benzylaminopurine) and GA_3 (Gibberellic acid), a combination of GA_3+BAP (all as soil drench), decapitation or piercing through the apical bud were conducted to determine their influence on the emergence and further development of side shoots of *Z. aethiopica* 'Green Goddess'. Details of the experiment are presented with the results.

Influence of phytohormone application

Six-month old seedling plants of *Z. aethiopica* 'Green Goddess' received the phytohormone treatments of BAP, GA_3, GA_3+BAP, ethephon, KNA+BAP (Potassium-α-naphthylacetate) as well as a control (de-ionised water) 4 times at 2 week intervals as either foliage spray or soil drench.

Influence of pot size and fertiliser application frequency

Young rhizomes were planted either in 8, 14 or 20 cm diameter pots and received fertiliser treatments (0,2 % Wuxal® Super NPK 8.8.6 (Aglukon Spezialdünger GmbH)) at either once/2wk, once/wk and twice/wk. Additionally phytohormone treatments (with or without) were applied as soil drench (see details in Table 2).

Results

Influence of decapitation, piercing and phytohormone GA_3 and BAP application

Application of phytohormones generally led to significantly increased number of visible shoots (side shoots emerging from buds located on daughter rhizomes which become visible at medium surface) at the end of 16 weeks from the beginning of treatments (Figure 1). Application of GA_3+BAP gave the highest number of visible shoots followed by high and low GA_3 frequency (see details in Figure 1). The visible side shoot number in these three treatments was not significantly different, but it was significantly higher than all other treatments. High BAP frequency of application yielded significantly more visible side shoots than low frequency. Decapitation led to significantly increased developed side shoot number (side shoots developing further to the unfolding of leaves), while that of phytohormone treatments was not significantly higher than the control. Thus phytohormone treatments were unable to induce further growth and development of side shoots to bring about the unfolding of leaves. The phytohormone treatments except the high and low BAP frequency led to significantly higher mean height of side shoots. However, the mean plant height was much less than in decapitated plants. BAP and GA_3 singly or combined promoted the outgrowth of buds on daughter rhizomes as observed from the increased number of visible shoots, but were unable in many cases to promote the further development of the side shoots to the unfolding of leaves. Piercing did not lead to a significant increase in the number of visible shoots, developed side shoots or mean height of side shoots.

Towards the end of the experiment, numerous side shoots began to emerge in all the treatments including control, developing beyond the unfolding of leaves such that, after 38 weeks there was no significant difference in the number of developed side shoots in the various treatments over control (data not shown). Decapitated plants still had significantly greater mean side shoot height than all other treatments.

In the second experiment, application of GA_3+BAP resulted in significantly higher number of emerged side shoots, giving the highest number of side shoots among all the treatments (Table 1). Highest side shoot numbers were observed at the 2nd and 4th GA_3+BAP levels, which corresponded to a GA_3 concentration of 500 mg/l combined with 50 and 150 mg/l BAP, respectively. The GA_3 treatment at 500 mg/l also yielded significantly increased number of emerged side shoots than the control. Application of BAP, ethephon, KNA+BAP did not significantly influence the number of emerged side shoots.

GA_3+BAP gave significantly higher percentage of emerged daughter rhizomes than the other treatments (Table 1). Highest percentage daughter rhizome sprouting was obtained at the 2nd and 4th level, corresponding to a GA_3 concentration of 500 mg/l. Application of GA_3 exclusively also gave a significant increase in the percentage sprouted daughter rhizomes than the control. BAP and ethephon did not significantly influence this parameter, while KNA+BAP resulted in significantly lower percentage sprouted daughter rhizomes.

The number of daughter rhizomes greater than 1,0 g significantly decreased following ethephon and KNA+BAP treatment (Table 1). Ethephon concentration of 1000 mg/l and above significantly reduced the number of daughter rhizomes as compared to control. The 2nd and 4th levels of KNA+BAP, which contained higher levels of KNA, were responsible for the decline in daughter rhizome number. The other phytohormone treatments did not significantly influence this parameter.

The plant height of main shoots generally increased with time. This was due to the continual production of new leaves with increased peduncle lengths to replace old dying leaves, giving higher plant heights. However, application of ethephon led to production of leaves with reduced peduncle lengths, leading to plants that were significantly shorter than the other treatments at week 12 (Table 1). Nevertheless, this situation later changed, such that by the end of the experiment after18 weeks, there was no significant difference in the plant height from the other treatments. The recovery was possibly due to the detrimental effect of ethephon declining after the completion of the phytohormone treatments. Control treatments on the other hand, were significantly taller than the other treatments at the end of the experiment. Ethephon treatments resulted in plants showing foliage damage.

Table 1. Influence of phytohormone type and level on side shoot growth in *Z. aethiopica* 'Green Goddess' seedling plants
Einfluß von Phytohormonetyp und -konzentration auf das Seitentriebwachstum in Sämlingspflanzen von Z. aethiopica 'Green Goddess'

		Phytohormone						
Parameter	**Level**	**GA_3**	**BAP**	**Ethephon**	**GA_3+BAP**	**KNA+BAP**	**Control**	**Mean**
No. of shoots	0						1,3 a-e	1,3 a
(18 wap) [s]	1	0,9 abc	0,8 abc	1,1 a-d	2,0 d-g	0,8 ab		1,1 a
	2	2,0 d-g	0,9 abc	0,7 ab	3,8 h	0,6 a		1,6 ab
	3	2,1 efg	0,3 a	0,6 a	1,9 c-f	1,0 a-d		1,2 a
	4	2,7 fgh	1,7 b-f	0,7 ab	3,4 gh	0,5 a		1,8 b
	Mean	1,9 b	0,9 a	0,8 a	2,8 c	0,7 a	1,3 b	
Percent	0						20,0 a-d	20,0 ab
sprouted	1	13,4 ab	13,7 ab	15,7 ab	30,2 bcd	11,5 a		16,8 a
daughter	2	35,7 cd	10,9 a	13,3 ab	60,0 f	8,3 a		25,6 b
rhizomes [r]	3	37,3 cd	14,3 ab	15,0 ab	37,0 de	21,4 abc		25,0 b
	4	56,8 ef	21,1 a-d	14,2 ab	65,9 f	9,6 a		33,5 d
	Mean	35,8 c	15,0 ab	14,6 ab	48,3 d	12,6 a	20,0 b	
No. of	0						5,5	5,5 b
daughter	1	6,1	5,9	4,8	5,8	5,4		5,6 b
rhizomes	2	5,4	5,9	3,3	6,1	3,9		4,9 a
	3	5,6	5,8	2,2	5,9	4,6		4,8 a
	4	6,0	5,9	1,1	5,9	3,8		4,5 a
	Mean	5,8 c	5,9 c	2,8 a	5,9 c	4,4 b	5,5 c	
								$HSD^c = 1,3$
Plant height	0						59,0	59,0 c
(cm)	1	56,1	54,4	57,1	54,5	58,0		56,0 b
15 weeks	2	54,5	57,3	45,9	56,8	55,0		53,9 ab
	3	56,2	52,0	44,5	56,3	56,3		53,1 a
	4	57,0	55,9	36,0	56,5	55,9		52,3 a
	Mean	56,0 b	54,9 b	45,9 a	56,0 bc	56,3 bc	59,0 c	
								$HSD^c = 6,2$

Mean separation according to Tukey's $HSD_{(0,05)}$. Means of main effects bearing a common letter in respective row or column are not significantly different at $HSD_{(0,05)}$. [s] analysis on $\log_{(x+1)}$ transformed values. [r] analysis on arcsine transformed values. (Spray and immersion treatments summarised together). HSD^c = HSD for combinations. BAP at 50, 100, 150 and 250 mg/l; GA_3 at 50, 100, 250 and 500 mg/l; Ethephon at 500, 1000, 2000 and 5000 mg/l; GA_3+BAP at 50:50, 500:50, 50:150 and 500:150 mg/l; KNA+BAP at 50: 50, 150:50 50:150 and 150:150 mg/l; Control (de-ionised water). Application at 20 ml/plant. n = 15
Mittelwertsvergleich nach Tukey's $HSD_{(0,05)}$. Mittelwerte der Hauptwirkungen mit gleichem Buchstabe in jeweiliger Zeile bzw. Spalte sind nicht signifikant abweichend nach $HSD_{(0,05)}$. [s] Analyse an $\log_{(x+1)}$ transformierten Werten. [r] Analyse an winkel- transformierten Werten. (Sprüh- und Tauchbehandlungen zusammengefasst). HSD^c = HSD für Kombinationen. BAP bei 50, 100, 150 und 250 mg/l; GA_3 bei 50, 100, 250 und 500 mg/l; Ethephon bei 500, 1000, 2000 und 5000 mg/l; GA_3+BAP bei 50:50, 500:50, 50:150 und 500:150 mg/l; KNA+BAP bei 50: 50, 150:50 50:150 und 150:150 mg/l; Kontrolle (entionisiertes Wasser). Applikation bei 20 ml/Pflanze. n = 15

Influence of pot size and fertiliser application frequency

Phytohormone application led to a significant increase in the number of visible side shoots at week 38 (Table 2). The increase was significant in 8 and 14 cm diameter pots, but not in 20 cm diameter pots. Plants in 8 cm pots had significantly more visible side shoots than those in 14 and 20 cm pots. Increasing the fertiliser application frequency from once/2 weeks to twice/week significantly increased the number of visible side shoots in 20 cm pots.

Phytohormone treatment resulted in significantly higher developed side shoot number than untreated plants. An increase in pot size also led to significant increase in the number of developed shoots. Similarly, increasing the fertiliser application frequency from once/2 weeks to twice/week significantly increased the number of developed shoots in 14 and 20 cm pots, but not in 8 cm pots.

The application of phytohormones resulted in significantly greater mean side shoot height. The pot size also significantly influenced the mean side shoot height, with side shoots in 20 cm pots having significantly greater plant height than those in 8 and 14 cm diameter pots. Increasing the fertiliser application frequency from once/week to twice/week also led to significantly greater mean side shoot height of plants in 14 and 20 cm diameter pots. By contrast, the fertiliser application frequency did not significantly influence the mean side shoot height of plants in 8 cm diameter pots.

Many developed side shoots of plants in 20 cm pots were observed to flower, while those in smaller pot sizes (8 and 14 cm diameter) did not flower by the end of the experiment. Photograph 2 shows *Z. aethiopica* 'Green Goddess' plants in 20 cm pots with side shoots bearing flowers.

Discussion

Influence of piercing and decapitation

Decapitation of the main shoot led to the emergence and development of daughter rhizomes as side shoots. The shoots attained greater plant size than those in-

Table 2. Influence of phytohormone application, pot size and the fertiliser application frequency on the growth and flowering of *Z. aethiopica* 'Green Goddess'
Einfluß von Phytohormon, Topfgröße und Düngunghäufigkeit auf das Wachstum und Blühen von Z. aethiopica 'Green Goddess'

		Fertiliser application frequency						
Parameter	**Pot size**	**Once/2 weeks**		**Once/week**		**Twice/week**		
	Phyto-hormone	**With**	**Without**	**With**	**Without**	**With**	**Without**	**Mean**
No. of visible shoots	8 cm	17,2	10,8	15,0	9,0	14,5	9,0	12,6 b
	14 cm	11,5	6,7	11,5	6,0	12,9	10,7	9,9 a
	20 cm	8,8	6,2	9,7	9,2	11,7	11,3	9,5 a
	Mean	15,6	9,6	12,0	7,8	10,1	8,9	$HSD^{fp} = 1,6$
								$HSD^{c} = 3,4$
No. of developed shoots	8 cm	3,9	2,1	2,8	0,6	5,3	0,9	2,6 a
	14 cm	1,7	0,3	3,0	0,2	7,8	7,0	3,3 a
	20 cm	7,8	5,7	8,4	7,1	11,0	10,3	8,4 b
	Mean	4,5	2,7	4,7	2,6	8,0	6,1	$HSD^{fp} = 1,3$
								$HSD^{c} = 2,8$
Mean side shoot height (cm)	8 cm	8,5	6,2	8,6	3,7	11,9	3,7	7,1 a
	14 cm	4,9	3,1	6,1	3,3	12,8	11,9	7,0 a
	20 cm	22,2	17,9	19,8	18,9	37,0	35,8	25,3 b
	Mean	11,9	9,1	11,5	8,6	20,6	17,1	$HSD^{fp} = 2,2$
								$HSD^{c} = 4,7$
Total no. of flowers/plant	8 cm	0,6	0,5	0,3	0,1	1,6	0,8	0,7 a
	14 cm	3,5	2,2	4,5	4,0	7,5	6,8	4,8 b
	20 cm	7,4	8,2	9,1	10,0	20,2	22,2	13,2 c
	Mean	3,8	3,6	4,6	4,7	9,8	9,9	$HSD^{fp} = 1,0$
								$HSD^{c} = 2,2$

Mean separation according to Tukey's $HSD_{(0,05)}$. Means of main effects bearing a common letter in respective row or column are not significantly different at $HSD_{(0,05)}$. HSD^{fp} = HSD for combinations of fertiliser application frequency and phytohormone treatments. HSD^{c} = HSD for all combinations. Phytohormone treatment = 150 mg/l BAP + 250 mg/l GA_3. Fertiliser application 0,2 % Wuxal® Super NPK 8.8.6 (Aglukon Spezialdünger GmbH) at 40, 120 and 240 ml for 8, 14 and 20 cm diameter pots, respectively. n = 10
Mittelwertsvergleich nach Tukey's $HSD_{(0,05)}$. Mittelwerte der Hauptwirkungen mit gleichem Buchstabe in jeweiliger Zeile bzw. Spalte sind nicht signifikant abweichend nach $HSD_{(0,05)}$. HSD^{fp} = HSD für Kombinationen von Düngungshäufigkeit und Phytohormonbehandlungen. HSD^{c} = HSD für alle Kombinationen. Phytohormonbehandlung = 150 mg/l BAP + 250 mg/l GA_3. Düngung 0,2 % Wuxal® Super NPK 8.8.6 (Aglukon Spezialdünger GmbH) bei 40, 120 und 240 ml für 8, 14 und 20 cm Durchmesser Töpfe. n = 10

duced to emergence using phytohormone treatments. Decapitation eliminated the inhibiting influence and enabled the daughter rhizomes to emerge as side shoots.

Decapitation has been used in many plant species to promote the sprouting of lateral buds by overcoming the apical dominance. Imamura and HIGAKI (1988) obtained an increased number of lateral shoots following topping of *Anthurium andreanum* 'Andre'. Although reports on the influence of decapitation on lateral meristems located on the shoots are common, that on buds located on subterranean organs are not. BOOTH (1959) and MCINTYRE (1977) reported that when disbudded plants of the ancestral potato *Solanum andigena* were decapitated, natural underground stolons lost their diageotropic growth habit and became orthotropic leafy shoots. WOOLLEY and WAREING (1972b) reported that the conversion of stolons to leafy shoots may be mediated by cytokinins produced by the roots.

Decapitation removes the source of the inhibiting influence through auxin, thereby enabling the outgrowth of lateral meristems. CHEN *et al.* (1997) observed decreased endogenous IAA and increased endogenous cytokinin content in side shoots following decapitation in azalea (*Rhododendron obtusum*). Axillary bud swelling and lateral bud outgrowth followed decapitation. BANGERTH (1994) also reported that the level of endogenous cytokinins increased tremendously following decapitation in *Phaseolus vulgaris* L. Application of NAA on the decapitated stem eliminated this increase, showing that cytokinin build-up may be under the control of polar auxin transport. Decapitation eliminates the apical control and may thus be utilised to produce plants with a „multibranching growth habit".

Piercing, on the other hand, achieved no positive effect. This may have been due to the difficulty of reaching the apical bud to destroy it. The apical bud of *Zantedeschia* is well protected, being enclosed in several layers of leaf sheaths. Also, axillary buds surrounding the apical meristem located at the leaf bases take-over the apical control when the apical bud is incapacitated thereby restoring the dominance. The re-establishment of apical control by axillary buds below the apex following the death of the apical bud has also been reported in other plants. ARGALL and STEWART (1984) reported that in cowpeas *Vigna unguiculata*, one branch took over the lead of the main apex following decapitation.

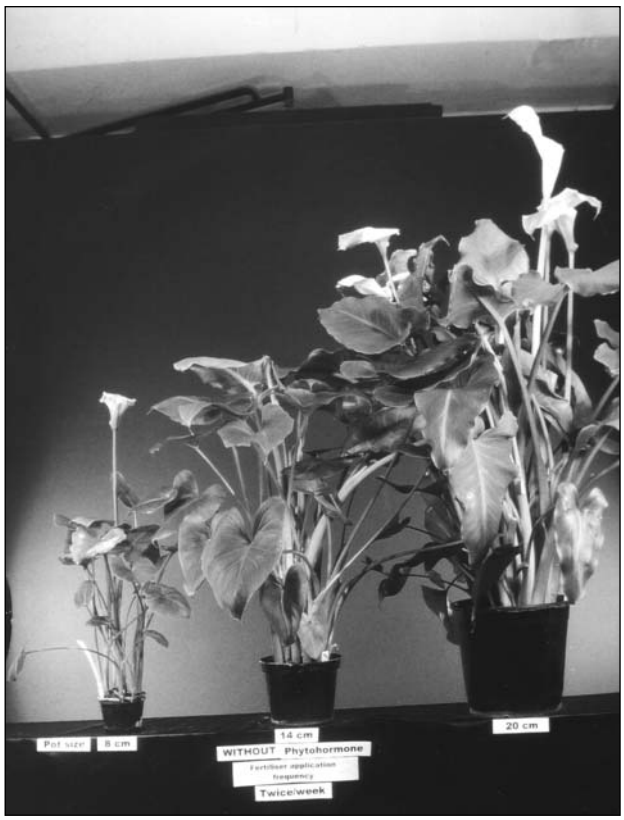


Photo 1. Zantedeschia plants after 54 weeks; Left, 8 cm; middle, 14 cm and right 20 cm diameter pot
Zantedeschia Pflanzen nach 54 Wochen; Durchmesser der Töpfe (von Links nach Rechts): 8 cm, 14 cm, 20 cm.



Photo 2. Zantedeschia plants in 20 cm pots after 54 weeks; Left to right: Fertiliser application frequency; once/2 wk, once/wk and twice/wk
Zantedeschia Pflanzen in 20 cm Töpfe nach 54 Wochen (von Links nach Rechts): Düngungshäufigkeit; Einmal/2 Woche, Einmal/Woche, und Zweimal/Woche.

Influence of BAP and GA_3

Application of BAP and GA_3 alone or combined enhanced both the emergence and the outgrowth of the side shoots, leading to earlier emergence and to an increased number of visible side shoots and developed shoots. The mean and total height of side shoots was also positively influenced. However, the complete emergence of all daughter rhizomes as side shoots could not be attained. The outgrowth of buds terminated or slackened before the unfolding of leaves or shortly thereafter in many cases. This may be due to the apical dominance being reimposed before the complete outgrowth of the buds.

Combined application of BAP and GA_3 improved side shoot development than when either was applied exclusively. The higher GA_3 level was responsible for the improved effect of the combined treatment. Similarly, FUNNELL *et al.* (1992) obtained a significant increase in the number of shoots in treatments with Promalin™, which contains $GA_{(4+7)}$ and the cytokinin, BA, on *Zantedeschia* 'Galaxy'.

The influence of the applied phytohormones, BAP and GA_3 was short-lived possibly as the factors responsible for inhibition at this stage could not be completely overcome by their application alone and required other factors or conditions. HILLMAN (1984) and PHILLIPS (1969) reported that the stimulatory effects of cytokinins were commonly short-lived. HILLMAN (1984) also reported that gibberellins had dramatic stimulatory effects on the growth of released buds, but may not play a major role in the release from correlative inhibition.

SACHS and THIMANN (1967) reported that buds released from apical inhibition by kinetin elongated much less than control buds on decapitated plants and that even addition of gibberellin to kinetin added only a minor improvement in elongation. They concluded that there was a residual type of apical inhibition which was not overcome by kinetin. BEßLER (1995) investigated the possibility of using cytokinin BAP as a branching agent in two different perennials *Coreopsis grandiflora*, 'Early sunrise' and *Physostegia virginiana*, 'Schneekrone'. He obtained visible outgrowth of axillary leaf buds on *Physostegia virginiana*, 'Schneekrone' plants at the first treatment week at all BAP levels, but not in the control. After the completion of the phytohormone application, no further outgrowth was observed, showing that the apical dominance had been immediately reinstated. On the other hand, normal outgrowth of lateral buds following cytokinin application has been obtained in some plants. ROUSSAUX (1970) reported that repeated BAP application to axillary buds of pea seedlings resulted in a bud outgrowth equivalent to that obtained by decapitating the apical bud.

Influence of KNA, TIBA and ethephon application

Application of ethephon, KNA and TIBA, on the other hand, did not positively influence side shoot development. SACHS and THIMANN (1967) reported no elongation when auxin and kinetin were applied on whole buds of 'Radio' pea plants. Auxin treatment only resulted in bud elongation when it was carefully localised only on the bud apices. On *Zantedeschia* rhizomes, that may not be technically possible as the buds on daughter rhizomes are underground.

Similarly, application of TIBA alone or combined with BAP failed to improve side shoot emergence and development. TIBA is a known auxin transport inhibitor whose application releases axillary buds from inhibition (TUCKER, 1978). However, its application did not lead to the outgrowth of buds on *Z. aethiopica* 'Green Goddess' daughter rhizomes. The mode of TIBA application possibly hindered its effectiveness, as the reported effective treatments involved the application of TIBA below the shoot apex. The *Zantedeschia* shoot apex is located at the base of the plant and is protectively covered by the surrounding leaf sheaths, hence such an application is practically impossible. The soil drench applications of TIBA carried out may not have been able to inhibit the auxin transport.

Ethephon treatments resulted in significantly lower plant height, number of daughter rhizomes and in plants showing foliage damage. The reduction in side shoot number with increased ethephon application was possibly due to the lower number of daughter rhizomes produced on the main rhizome with increasing ethephon application. The later recovery of the ethephon treated plants leading to an insignificant difference in plant height by the time of the last observation may have been as a result of the injurious effects of ethephon diminishing after the treatments were completed.

Ethephon has been found to cause negative effects in Tulips (BRAGT and GELDER, 1979; MOE and HAGNESS, 1975), *Begonia* x *tuberhybrida* (TONECKI, 1986), *Narcissus* (BRIGGS, 1975) and Chrysanthemums 'Polaris' and 'Bright Golden Anne' (STANLEY and COCKSHULL, 1989), reducing the length of flowering stem, total weight of daughter bulbs, reduced plant height and delayed flowering. Thus as in a wide range of other ornamental plants, ethephon application in *Z. aethiopica* 'Green Goddess' led to unfavourable effects.

As satisfactory side shoot production was not attained using phytohormone applications tested, this may not be an effective method for promoting side shoot development in these plants and decapitation is preferential in cultural methods.

Influence of fertiliser application

Increased fertiliser application frequency (0,2 % Wuxal® Super NPK 8.8.6) led to significantly increased number of developed side shoots, mean height of developed side shoots and plant height of main shoots. This was probably by providing vital nutrients for growth.

Differences in the reaction to the various fertiliser application frequencies indicates that mineral nutrition may be important in the development of daughter rhizomes, possibly playing a part in release of side shoots from correlative inhibition by the apical meristem. Nutrient levels, especially nitrogen, have been reported to be a major factor influencing apical dominance (MCINTYRE, 1977). MCINTYRE (1964) reported that varying the nitrogen level could quite precisely control the inhibiting influence of the rhizome apex on the growth of lateral buds in *Agropyron repens*. MCINTYRE (1977) found that in *Agropyron repens*, increased nitrogen and water supply led to the transformation of rhizome buds into leafy shoots. MCINTYRE (1973) showed that the growth of cotyledonary buds of *Phaseolus vulgaris* 'Red Kidney' was very responsive to nitrogen supply, with bud growth completely arrested at low N levels, but increased with increasing N levels until 210 ppm. WOOLLEY and WAREING (1972a) suggested that low N levels depress the levels of endogenous cytokinins.

Flowering was only observed on developed side shoots of plants in 20 cm pots and was earliest and most prolific in treatments receiving the fertiliser treatments twice/week and lowest in treatments receiving fertiliser once/week.

Nitrogen application also plays an important role in flowering and has been reported to increase the number of flowers per plant in *Brunfelsia calycina* (FINGER, 1971; PREISSEL, 1978) and flower production in Kalanchoe-Hybrids, Fuchsia-Hybrids and *Campanula isophylla* (PREISSEL, 1978) as well as dry mass of flowers in *Petunia* (PAWLOWSKI, 1965). This was attributed to a decrease in apical dominance through N providing favourable conditions for flower induction in lateral shoots.

The cultivation in larger pots and with higher fertiliser application frequency thus leads to „multibranching" plants with multiple flowers that suit the preference of buyers and increases production of flowers. However, such plants require much greenhouse space due to their size, which may increase the production costs.

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Anschrift des Verfassers: Dr. K. NGAMAU, Horticulture Dept. Jomo Kenyatta University of Agriculture and Technology, P.O. Box 62000, Nairobi, Kenya.