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Full Length Research Paper

Growth control of kalanchoe cultivars Rako and Gold Strike by application of paclobutrazol and uniconazole as soaking treatment of cuttings

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This study was conducted to test the potential of paclobutrazol and uniconazole used at the propagation stage as a plant growth retardant (PGR) of kalanchoe cultivars Rako and Gold Strike. Three node terminal cuttings were soaked in 500 mL of 0.05, 0.25, or 0.50 mg·L^{-1} paclobutrazol or uniconazole solution for 2 h. After soaking treatment, the cuttings were rooted in a fog tunnel with mean daily air temperature of 18.2°C and RH of 66%. Three replicates per treatment and eight plants per each replicate were used. All cuttings rooted well in all treatments. At all applied concentrations, plant height and stem internode length decreased significantly in both cultivars. Uniconazole was more effective than paclobutrazol at similar concentrations in suppressing stem growth. Both PGRs affected the number of leaves when compared with the control. Leaf area was significantly changed by different cultivars and PGR types, but not by the concentrations of PGR. While leaf chlorophyll concentration increased with an increase in the concentration of PGRs. The number of florets was increased in all PGR treatments when compared with the control. Consequently, soaking cuttings in PGR solutions seems to have a potential to reduce stem elongation of kalanchoe. This method of PGR treatment could become an environmentally friendly method in commercial productions, because of low PGR concentration needed and controlled application.

Key words: Height control, ***Kalanchoe blossfeldiana***, plant growth retardants, triazoles.

INTRODUCTION

Kalanchoe (***Kalanchoe blossfeldiana***) originated from Madagascar and is a member of Crassulaceae family. It is one of the most widely propagated potted ornamentals in the world. Kalanchoe can be produced thoughout the year by controlling lighting and shading, and easily grown and managed because it requires lower amount of fertilizer and less irrigation (Kefu et al., 2003). However, over-growing of the flower stem often causes problems in shipping and handling and consequently deteriorates marketable plant quality.

Methods for controlling stem length in pot plants include breeding of dwarf cultivars, manipulation of flowering time, pinching, and application of plant growth retardants (PGRs). To date, the application of PGRs is the most broadly used method for growth control as foliar spray or soil drench by commercial growers (Lee and Rho, 2000). The effectiveness of triazole PGRs on growth control varies depending on the plant cultivars, PGRs concentration, and application method (Banko and Stefani, 1988; Lee et al., 1998; Schuch, 1994). In foliar spray, PGRs are sprayed at higher concentrations and volumes over entire greenhouse area. This usually causes environment toxication (Ranwala et al., 2002) and stunted growth (Cox and Keever, 1988). On the other hand, soil drench required lower concentrations of PGRs and obtains greater efficacy, but is labor-incentive and often results in excessive height reduction and slow growth (Cox and Keever, 1988; Wilfret, 1987) because of the residual PGRs chemicals in the pot media.

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The problems found in the methods above may be alleviated partly by using soaking treatment of cuttings, since it requires only one-time treatment with relatively low amount of PGRs. Applying plant growth retardant as a dip on cuttings as compared to foliar spray ensures thorough coverage of the stem with the retardant, which is critical for highest efficacy (Barrett and Bartuska, 1982). Soaking the entire unrooted cuttings (Wang and Gregg, 1991) or dipping the cut end of unrooted cuttings (Schuch, 1994) in a growth retardant solution before planting resulted effective height control during production. Adriansen (1989) describes different methods of PGRs treatment of pot kalanchoe in ebb and flood benches. Recently we reported effect of PGRs on growth of pot kalanchoe 'Gold Strike' by recycled subirrigational supply (Hwang et al., 2008). In this paper, we evaluated the efficacy of the soaking treatment of cuttings on growth control of two kalanchoe cultivars, Rako and Gold Strike using paclobutrazol and uniconazole.

MATERIALS AND METHODS

Plant materials and propagation

Three node terminal cuttings of ***K. blossfeldiana*** 'Rako' and 'Gold Strike' were taken from stock plants grown in a greenhouse covered with two layers of shade cloth to get about 30% of full sunlight. Photosynthetic photon flux (PPF) of full sunlight at the experimental location (latitude 35.15° N) was about 1200 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (mean PPF of 10:00, 12:00, 14:00, and 16:00) and maximum/minimum air temperature were 25/10°C. Photoperiod during the experiment was shortened by using black cloth to be less than 11 h during the first six weeks after pinching.

The cuttings were soaked for 2 h in an aqueous solution containing paclobutrazol or uniconazole at 0, 0.05, 0.25, 0.5 mgL^{-1} and planted in 72-cell plug trays containing peatmoss + perlite (1:1, v/v). The cuttings were rooted for 30 days in a mist (10 s every 10 min) propagation bed. After a month, rooted plants were transplanted into pots (one plug per pot) containing peatmoss + perlite (1:1, v/v) and propagated under a short day condition (11 h photoperiod) during the first six weeks after pinching. Plants were pinched 7 days after transplanting. The glasshouse was kept at 18 ± 5°C and cooled by ventilation of an air flow of 1.3 $m.s^{-1}$ at the same temperature. Mean, maximum, and minimum daily air temperatures and mean relative humidity were recorded during the experimental period by digital thermometers (Thermo Recorder TR-71S, T&D Corp., Matsumoto) set at 18.2, 25, 10°C, and 66%, respectively. The nutrient solution formulated separately for each of three growth stages were supplied through over-head irrigation every four days for 72 days (Hwang et al., 2008).

Growth measurement and statistical analysis

Three replicates per treatment and eight plants per each replicate were used. Plant size was calculated as (height + average width)/2 (Million et al., 1999). Average width was determined as the mean of two widths measured at 90º from one another. Flower stem length was measured from the proximal to the distal end of the flower including pedicel. Number of florets was the number of flower cluster per stem. Internode length and stem diameter were measured from the third and fourth node from the shoot tip. Root grade was assigned based on the amount of medium attached to the roots, when plant was pulled out of the pot. The case of the best root system formation was graded as 3 and 1 the worst. Leaf area was determined by measuring with an area meter (LI-3100C, LI-COR Biosciences, USA). For the measurements of chlorophyll concentration, leaf disks from vigorous leaves on second node from the shoot tip were sampled and were extracted with an 80% (v/v) acetone for 24 h. Chlorophyll concentration was determined by measuring absorbance with a spectrophotometer (Uvikon 922, Kotron Instrument, Italy) at 645 and 633 nm, and calculated as described by Arnon (1949).

$$\text{Chlorophyll concentration } (mg \cdot g^{-1}FW) = \frac{(20.29 \times A_{645}) + (8.02 \times A_{663}) \times \text{volume of acetone (ml)}}{\text{Fresh weight (mg)}}$$

Where A_{645} and A_{663} are absorbances at 645 and 663 nm, respectively. Dry weight at harvest was measured after drying at 80°C for 72 h.

Data collected were analyzed for statistical significance by the SAS (Statistical Analysis System, V. 6.12, Cary, NC, USA) program. The experimental results were subjected to an analysis of variance (ANOVA) and Duncan multiple range test.

RESULTS AND DISCUSSION

Effect of paclobutrazol and uniconazole on rooting of cuttings

The terminal cuttings having three nodes were soaked for 2 h in plant growth retardant solution promoted root induction and growth when compared to control. Rooting success was 100% this might be due to the cutting type, rooting substrate, and culture conditions in the greenhouse. Root grades were significantly affected by the types and concentrations of PGR and their interactions, but not by the different cultivars (Table 1 and Figures 1A - D). According to Stang and Weis (1984), triazole PGRs promoted the underground plant growth by suppressing the growth on the ground, increased root diameter, and thereby, enhanced the capacity of nutrient solutions, while limiting the root elongation. Triazoles are known to be gibberellin biosynthesis inhibitors (Barrett, 2001; Rademacher et al., 1984) and gibberellin is known to inhibit strongly the rooting of cuttings (Davis et al., 1985). Hence, it has been reported that triazole can promote root growth due to decrease in endogenous level of gibberellin.

Influence of pruning on growth of kalanchoe

After 30 days rooted cuttings were transplanted into pots containing peat and perlite mixture then allow growing for a week and were pinched (removing apical bud) (Figure 2A). Pinching promoted sprouting of axillary shoot buds (Figure 2B). Hormones located in the terminal bud keep lateral buds dormant. Thus, in general, removal of terminal buds releases lower buds from growth inhibition and permits them to begin branching.

Table 1. Effect of PGRs on plant size, internode length and root grade after soaking treatment of cuttings of kalanchoe.

PGRs (mg·L^{-1})	Plant size (cm)		Internode length (cm)		Root grade	
	Rako	Gold strike	Rako	Gold strike	Rako	Gold strike
Control	9.5 a[z]	13.0 a	1.24 a	1.33 a	2.6 b	2.4 c
Paclobutrazol 0.05	8.9 ab	12.4 a	1.17 ab	1.26 ab	2.9 ab	2.6 b
0.25	9.2 a	11.9 ab	1.20 a	1.21 b	3.0 a	2.8 ab
0.50	8.8 ab	11.6 ab	1.14 b	1.15 bc	3.0 a	3.0 a
Uniconazole 0.05	7.6 b	11.1 c	0.88 c	1.08 b	2.8 ab	2.7 ab
0.25	6.0 c	8.5 d	0.68 d	0.72 c	3.0 a	3.0 a
0.50	5.4 c	7.2 d	0.62 d	0.54 d	3.0 a	3.0 a

[z]Mean separation within columns by DMRT, P<0.05.

Figure 1. Effect of paclobutrazol and uniconazole on rooting of cuttings. A) Cuttings were soaked in PGRs solutions for 2 h. B) PGRs treated cuttings were planted in 72-cell plug trays containing peatmoss + perlite (1:1, v/v). C) Rooted cuttings 'Gold Strike' after 30 days. D) Rooted cuttings 'Rako' after 30 days.

Effect of paclobutrazol and uniconazole on growth characteristics of kalanchoe

The effects of PGR on the suppression of stretchiness and growth changes were investigated depending on kalanchoe cultivars, different types and concentrations of PGR after soaking treatment of cuttings. Plant size and internode length weight were significantly changed by the types or concentrations of PGR. Uniconazole treatment inhibited plant size and internode length of both cultivars while, paclobutrazol had no effect when cuttings were soaked in a plant growth retardant solution (Table 1). An increase in uniconazole concentration from 0.05 to 0.5 mg·L^{-1} resulted in a significant decrease in the plant size

Figure 2. Influence of pruning on growth of kalanchoe. A) Removal of apical bud. B) Lateral shoots were developed after pinching.

and internode length after 15 weeks of cultivation. The effect of triazoles on growth inhibition varied depending on their structure and concentration, and also kalanchoe cultivars. In the present study, uniconazole was more effective than paclobutrazol in reducing plant size and stem elongation. Similar results have been reported by other researchers (Barrett et al., 1986; Wang and Blessington, 1990; Wang and Gregg, 1991). PGRs did not significantly affect stem diameter however, at high concentration of uniconazole (0.5 $mg \cdot L^{-1}$) resulted in increased stem diameter when compared with the control (Table 2). The significant differences in fresh and dry weight were observed from different cultivars and different types or concentrations of PGR. In 'Rako' fresh and dry weight were decreased at all treatments however, at 0.25 $mg \cdot L^{-1}$ paclobutrazol increased dry weight. In 'Gold Strike' high concentration of paclobutrazol and low concentration of uniconazole increased fresh and dry weight when compared with the control (Table 2). Both PGRs affected the number of leaves when compared with the control. In 'Rako' lower concentrations of paclobutrazol resulted in increased the number of leaves while, the same concentrations of paclobutrazol decreased the number of leaves in 'Gold Strike'. The number of leaves were increased in 'Rako' and 'Gold Strike' when uniconazole applied at 0.25 and 0.05 $mg \cdot L^{-1}$, respectively. Leaf area was significantly changed by different cultivars and PGR types, but not by the concentrations of PGR (Table 3). In 'Rako' chlorophyll concentration was not significantly affected by both PGRs. In 'Gold Strike' chlorophyll content was significantly increased when uniconazole applied at higher concentrations. Table 4 showed the changes in flower stem length, and the number of florets depending on the cultivars, which were affected by the interaction between the types and concentrations of PGR. The number of florets was increased in all PGR treatments when compared with the control. The highest number of florets was observed in 'Rako' and 'Gold Strike' when cuttings were soaked in a solution containing paclobutrazol 0.25 $mg \cdot L^{-1}$ and uniconazole 0.5 $mg \cdot L^{-1}$, respectively. Fletcher et al. (1986) reported that triazole PGRs enhanced the plant adaptability to the environmental stress and yield by suppressing the stem elongation, and by influencing rooting morphological and biochemical. Significantly different effects on the days to flower were observed among the cultivars, PGR types, and the concentrations of PGR, but there was no affection by the interaction. In 'Rako' no significant differences in days to first flowering were recorded. In 'Gold Strike' days to first flowering were increased from 75.7 to 81.7 when paclobutrazol applied at 0.5 mgL^{-1}. The results from those studies support the potential of the PGR soaking treatment of cuttings as an effective method for growth control (Steffens and Wang, 1984; Sankhla et al., 1985; Kim and Kwack, 1991).

In conclusion, our present study proved the efficacy of PGR soaking treatment of cuttings for suppressing stretchiness in kalanchoe. The growth suppression by 30%, which was the level aimed in this experiment of soaking treatment of cuttings, was achieved by the treatment of uniconazole 0.25 and 0.5 $mg \cdot L^{-1}$ in kalanchoe, 'Rako', and by uniconazole 0.5 $mg \cdot L^{-1}$ in 'Gold Strike' (Figure 3A and B). Flower stem length was not reduced by the treatment of paclobutrazol in both kalanchoe cultivars, but significantly reduced by uniconazole 0.25 and 0.5 $mg \cdot L^{-1}$. At the same level of concentration, uniconazole showed the greater on the growth suppression, compared to paclobutrazol. The number of florets in both cultivars increased as the concentration of paclobutrazol increased. For uniconazole, the number of florets in 'Rako' increased only at 0.5 $mg \cdot L^{-1}$ while in 'Gold Strike', it increased significantly at all concentrations. Further examinations for the optimal concentration of PGRs will enable us to use PGRs more efficiently and more eco-friendly for the growth control divers cutting pot plants.

Figure 3. Effect of PGRs on growth of kalanchoe after soaking treatment of cuttings. A) Kalanchoe 'Rako' at 15 weeks after soaking treatment of PGRs. B) Kalanchoe 'Gold Strike' at 15 weeks after soaking treatment of PGRs.

Table 2. Effect of PGRs on stem diameter, fresh and dry weight after soaking treatment of cuttings of kalanchoe.

PGRs (mg·L^{-1})	Stem diameter (cm)		Fresh weight (g)		Dry weight (g)	
	Rako	Gold strike	Rako	Gold strike	Rako	Gold strike
Control	0.41 b^z	0.30 b	23.1 a	40.6 ab	1.25 a	1.79 ab
Paclobutrazol 0.05	0.41 b	0.31 ab	22.6 a	38.5 b	1.21 ab	1.70 b
0.25	0.43 a	0.33 a	23.2 a	39.0 b	1.31 a	1.71 b
0.50	0.44 a	0.33 a	22.0 ab	41.9 a	1.16 b	1.83 ab
Uniconazole 0.05	0.43 a	0.32 ab	19.2 b	42.5 a	1.00 b	1.94 a
0.25	0.45 a	0.35 a	19.1 b	38.2 b	0.97 c	1.74 b
0.50	0.47 a	0.36 a	18.3 bc	36.3 c	0.95 c	1.69 b

^{z}Mean separation within columns by DMRT, P< 0.05.

Table 3. Effect of PGRs on number of leaves, leaf area and chlorophyll content after soaking treatment of cuttings of kalanchoe.

PGRs (mg·L^{-1})	No. of leaves		Leaf area (cm^2)		Chlorophyll content (ug·mg^{-1}fw)	
	Rako	Gold strike	Rako	Gold strike	Rako	Gold strike
Control	48.0 c^z	49.3 b	143.8 b	196.9 c	0.42 a	0.89 b
Paclobutrazol 0.05	55.3 b	34.3 e	131.8 c	190.1 d	0.45 a	0.86 b
0.25	52.0 bc	39.0 d	130.9 c	211.9 a	0.46 a	0.95 ab
0.50	46.7 c	45.7 c	149.9 a	213.8 a	0.47 a	0.86 b
Uniconazole 0.05	45.3 cd	53.0 a	118.5 d	200.9 b	0.45 a	0.87 b
0.25	59.3 a	44.0 c	114.1 d	207.2 b	0.46 a	1.05 a
0.50	43.0 d	51.3 ab	95.5 e	203.2 bc	0.43 a	1.12 a

^{z}Mean separation within columns by DMRT, P< 0.05.

Table 4. Effect of PGRs on flower stem length, number of florets and days to flower after soaking treatment of cuttings of kalanchoe.

PGRs (mg·L^{-1})	Flower stem length (cm)		No. of florets		Days to flower	
	Rako	Gold strike	Rako	Gold strike	Rako	Gold strike
Control	5.1a^z	7.6 a	3.4 c	3.2 c	68.7 ab	75.7 bc
Paclobutrazol 0.05	4.9 ab	6.9 ab	4.6 a	4.2 b	67.2 b	74.7 c
0.25	4.8 ab	6.7 b	5.3 a	4.6 ab	67.4 b	75.3 bc
0.50	4.4 b	6.4 b	4.5 ab	4.9 ab	67.3 b	77.5 b
Uniconazole 0.05	4.7 ab	6.1 bc	4.1 b	4.7 ab	67.8 b	78.1 b
0.25	3.8 c	5.3 c	4.3 b	5.2 a	69.2 a	80.7 a
0.50	3.6 c	5.0 c	4.5 ab	5.3 a	70.3 a	81.7 a

^{z}Mean separation within columns by DMRT, P< 0.05.

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