Research Reports

Flurprimidol and Paclobutrazol Substrate Drenches on Potted Pineapple Lily

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SUMMARY. When grown in containers, pineapple lily (*Eucomis* sp.) can produce excessively long foliage and tall scapes, particularly in cultivars with tall pineapple lily (*Eucomis comosa*) parentage. Height control, through the use of plant growth regulators (PGRs), is necessary to improve crop quality of potted pineapple lily. In year 1 of these trials, bulbs of cultivars Reuben, Tugela Jade, and Tugela Gem were given substrate drenches of flurprimidol or paclobutrazol, each at 2, 4, or 6 mg per 6-inch pot. Drenches were applied at the “visible inflorescence” stage. As concentration increased, scapes were generally shorter in all cultivars for both PGRs, but there was no effect on foliage length or production time. At the rates tested, the reduction in scape length was insufficient to produce marketable plants of the three cultivars. In the second year, substrate drenches were applied at an earlier stage than in year 1, at “leaf whorl emergence,” when shoots were about 7 cm tall. The PGR treatments were notably more effective at controlling plant height in the second year. As concentration increased, scape and foliage length was reduced relative to the controls in all three cultivars for both PGRs. For all cultivars, inflorescence leaning and toppling were sharply reduced at all application rates compared with untreated controls. The reduction in plant height observed in year 2, particularly in plants treated with 4 or 6 mg/pot, resulted in plants with compact scapes and foliage proportional with their 6-inch containers.

Pineapple lily, a South African flowering bulb, is grown for its showy, pineapple-shaped inflorescences. Traditionally grown as a specialty cut flower, recent interest in pineapple lily as a potted greenhouse crop is because of the same factors that make it an attractive cut flower crop, namely, a unique growth habit and long-lasting

inflorescences. The inflorescences of pineapple lily are top-heavy and the scape has a tendency to bend, topple, or break during production or transport (De Hertogh and Le Nard, 1993). This phenomenon is most common and problematic in the large cultivars developed for cut flower production, which

are the majority of commercially available pineapple lily cultivars. Unlike cut flowers, very tall stems are not desirable in potted ornamentals (Lee et al., 2015). Although high light intensity during production can modestly reduce leaf and inflorescence length in pineapple lily (Carlson, 2010; Luria et al., 2011), this is impractical in many climates and is unlikely to result in sufficient height control overall.

Anti-gibberellin PGRs are used to restrict stem elongation in a wide variety of floriculture crops. Flurprimidol and paclobutrazol reduce stem and scape elongation in tulip (*Tulipa gesneriana*), hyacinth (*Hyacinthus orientalis*), caladium (*Caladium bicolor*), narcissus (*Narcissus pseudonarcissus*), and calla lily (*Zantedeschia aethiopica*) when applied as substrate drenches (Beckman and Lukens, 1997; Miller, 2016; Tjia, 1987; Whipker et al., 2011). Carlson et al. (2015) found that early postemergence substrate drenches of flurprimidol or paclobutrazol caused a 40% reduction in scape length in the dwarf ‘Leia’ pineapple lily at application rates of 1- and 2-mg a.i. per pot, respectively. Filios and Miller (2013) reported similar reductions in scape length in ‘Innocence’ pineapple lily (tall pineapple lily parentage) treated with substrate drenches (per pot) of 2-mg flurprimidol or 8-mg paclobutrazol. Because of the variability in size among commercially available pineapple lily cultivars, different degrees of height control are likely to be desired by growers. As in other ornamental bulbs, pineapple lily responsiveness to commercial PGR active ingredients is likely to vary with application timing and cultivar. The objective of this experiment was to examine the effects of flurprimidol or paclobutrazol drench concentrations on growth of several pineapple lily cultivars originally developed for the cut flower market, when grown as potted plants.

Materials and methods

YEAR 1. Bulbs (>18 cm circumference) of pineapple lily cultivars

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
29.5735	fl oz	mL	0.0338
2.54	inch(es)	cm	0.3937
28,350	oz	mg	3.5274×10^{-5}
1	ppm	mg·L ⁻¹	1
$(^{\circ}\text{F} - 32) \div 1.8$	$^{\circ}\text{F}$	$^{\circ}\text{C}$	$(^{\circ}\text{C} \times 1.8) + 32$

Fig. 1. 'Reuben' pineapple lily plant at the visible inflorescence stage, when plant growth regulators were applied in year 1. Some leaves were removed to expose inflorescence.

Fig. 2. 'Reuben' pineapple lily plant at the leaf whorl stage of emergence, when plant growth regulators were applied in year 2; 1 inch = 2.54 cm.

Reuben, Tugela Jade, and Tugela Gem were received from De Goede Bulb Farm (Mossyrock, WA) on 20 Mar. These cultivars were bred in New Zealand and are of tall pineapple lily parentage. Bulbs had been harvested from fields in late November and stored at $\approx 10^{\circ}\text{C}$ before shipment. On arrival, bulbs were held at 9°C before planting. On 14 Apr., bulbs were removed from storage and planted in 6-inch "azalea" pots containing a commercial peat-based substrate (LM-111; Lambert Peat Moss Co., Riviere-Ouelle, QC, Canada) and moved to a glass greenhouse heated to 17°C . Measured temperatures (Hobo dataloggers; Onset Computer Corp., Bourne, MA) during the growing season were $21 \pm 5^{\circ}\text{C}$ day maxima and $17 \pm 2^{\circ}\text{C}$ night minima. Plants were randomized (using a completely randomized design) within each of the three cultivars and pots spaced on 25-cm centers. After shoot emergence, 20N-2.2P-16.6K fertilizer (JR Peters, Allentown, PA) was applied via fertigation at a rate of $150\text{ mg}\cdot\text{L}^{-1}$ 5 d per week. Growth regulator treatments were applied to each cultivar when about 35% of plants exhibited inflorescence emergence at the center of the rosette (Fig. 1). Flurprimidol (Topflor; SePRO Corp., Carmel, IN) and paclobutrazol (Piccolo;

Fine Americas, Walnut Creek, CA) were applied on 19 June at 2, 4, or 6 mg/pot, with a nontreated control, with 10 replications (individual plants) per treatment. Growth regulators were applied as 120-mL substrate drenches to pots that had been irrigated earlier in the day. The date, scape length (pot rim to the top of inflorescence), and leaf length were measured for each plant at the onset of anthesis. Linear and quadratic regression was performed with JMP software (SAS Institute, Cary, NC) for the parameters of interest.

YEAR 2. Bulbs (>18 cm circumference) of 'Reuben', 'Tugela Jade', and 'Tugela Gem' pineapple lily were received from De Goede Bulb Farm on 2 Apr. Bulbs had been harvested from fields and were handled as described previously. By contrast to year 1, PGR substrate drench treatments were applied when about 50% of bulbs of an individual cultivar had produced aboveground growth of ≈ 7 cm and had reached the leaf whorl stage (defined as the point when true leaves begin to unfold from the shoot apex, Fig. 2). Dates of application were 22 Apr. for 'Tugela Jade' and 27 Apr. for 'Reuben' and 'Tugela Gem'. The date, scape length, and leaf length were recorded for each plant at the onset

Table 1. Effect of flurprimidol (Flur) and paclobutrazol (Paclo) drenches on production time, scape length, and leaf length in pineapple lily cultivars Reuben, Tugela Jade, and Tugela Gem in year 1. Plant growth regulator (PGR) drench treatments were applied to each cultivar when about 35% of bulbs had reached inflorescence emergence stage.

PGR rate (mg/pot)*	Time to anthesis (d)		Scape length (cm) ^y		Leaf length (cm) ^y	
	Flur	Paclo	Flur	Paclo	Flur	Paclo
'Reuben'						
0	98	98	52.2	52.2	41.3	41.3
2	98	98	50.1	48.3	38.8	39.3
4	98	100	44.7	45.2	37.8	40.3
6	98	97	41.7	45.6	31.2	38.7
Significance ^x	NS	NS	NS	NS	NS	NS
'Tugela Jade'						
0	97	97	47.7	47.7	39.4	39.4
2	97	98	40.1	39.0	39.0	36.1
4	98	99	41.2	37.4	34.7	36.0
6	101	97	36.4	41.0	34.0	38.7
Significance	NS	NS	L*Q*	L**Q NS	NS	NS
'Tugela Gem'						
0	98	98	43.0	43.0	37.2	37.2
2	98	99	33.9	31.0	38.0	37.6
4	99	98	34.5	29.4	37.1	36.8
6	98	98	31.0	34.6	32.3	37.6
Significance	NS	NS	L**Q*	L**Q NS	NS	NS

*1 mg = 3.5274×10^{-5} oz.

^yScape length and leaf length were recorded at the onset of anthesis, when the first florets opened; 1 cm = 0.3937 inch.

^xSignificance of linear (L) or quadratic (Q) regression: NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

of anthesis. Inflorescence length (measured from the lowest pedicel to the terminus of the scape) and stem length (measured from the rim of the pot to the lowest pedicel) were measured at the onset of anthesis in 'Reuben' and 'Tugela Gem'. Statistical analysis was performed as described previously.

Results

YEAR 1. With 'Reuben', as the application rate of either PGR increased, scape length and leaf length tended to decrease, but there was no significant difference among the treatments and there was no significant difference in time to anthesis (Table 1).

With 'Tugela Jade' and 'Tugela Gem', as the PGR application rate increased, scape length was reduced by both chemicals. There was, however,

no significant difference in time to anthesis or leaf length (Table 1).

YEAR 2. With 'Reuben', a highly significant linear decrease in scape length was observed as flurprimidol application rate increased (Table 2). Although scape length generally decreased as paclobutrazol rate increased, no significant linear or quadratic trend was observed (Table 2). For both PGRs, most of the PGR-induced scape height control resulted from a reduction in stem length (below the inflorescence) as inflorescence length was unaffected by treatments. Highly significant linear and quadratic decreases in leaf length were observed as flurprimidol application rate increased, and paclobutrazol linearly decreased leaf length as application rate increased. Flurprimidol had no significant effect on days to anthesis, but

increasing paclobutrazol rates delayed flowering. Across both PGRs, the delay in flowering was ≈ 1 week for the highest rates (Table 2; Fig. 3).

With 'Tugela Jade', a highly significant linear and a significant quadratic decrease in scape length were observed as flurprimidol application rate increased (Table 2). Although scape length decreased as paclobutrazol rate increased, the effect was not statistically significant (Table 2). For both chemicals, there was no significant effect on leaf length or days to anthesis (Table 2).

With 'Tugela Gem', both chemicals significantly reduced scape length, leaf length, stem length, and inflorescence length. Both flurprimidol and paclobutrazol significantly increased time to anthesis by 9–13 d, respectively (Table 2).

Table 2. Effect of flurprimidol or paclobutrazol drenches on morphological characteristics of pineapple lily cultivars Reuben, Tugela Jade, and Tugela Gem in year 2. Drenches were applied when $\approx 50\%$ of the plants (per cultivar) reached the leaf whorl stage (≈ 7 cm tall).

Active ingredient	Rate (mg/pot) ^z	Time to anthesis (d)	Scape length (cm) ^y	Leaf length (cm) ^y	Stem length (cm)	Inflorescence length (cm)
'Reuben'						
Flurprimidol	0	98	42.9	36.0	23.6	18.1
	2	101	30.2	11.9	11.3	19.7
	4	104	24.5	19.3	6.8	17.9
	6	107	19.4	20.0	4.1	17.0
Significance ^x		NS	L***Q NS	L***Q***	L***Q*	NS
Paclobutrazol	2	101	37.7	25.6	17.3	19.4
	4	106	30.0	23.6	10.1	20.5
	6	104	28.3	22.1	8.9	9.1
		L***Q***	NS	L*Q NS	L**Q NS	NS
'Tugela Jade'						
Flurprimidol	0	97	42.4	34.6	—	—
	2	101	33.5	33.0	—	—
	4	101	31.8	25.6	—	—
	6	102	30.6	26.5	—	—
Significance		NS	L***Q*	NS		
Paclobutrazol	2	97	35.6	33.0	—	—
	4	99	34.5	20.5	—	—
	6	102	31.0	23.5	—	—
		NS	NS	NS		
'Tugela Gem'						
Flurprimidol	0	99	31.7	36.8	16.6	14.0
	2	103	22.0	19.2	5.5	16.9
	4	104	18.4	25.2	3.8	14.6
	6	112	17.2	24.3	2.4	14.7
Significance		L***Q*	L***Q NS	L***Q***	L***Q***	L**Q**
Paclobutrazol	2	102	24.8	25.7	9.1	16.7
	4	107	26.1	28.7	7.5	18.0
	6	108	19.2	25.7	4.1	15.9
		L*Q**	L***Q***	L**Q*	L***Q**	L*Q NS

^z1 mg = 3.5274×10^{-5} oz.

^yScape length and leaf length were recorded at the onset of anthesis, when the first florets opened; 1 cm = 0.3937 inch.

^xSignificance of linear (L) or quadratic (Q) regression: NS, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively, within an active ingredient and including the control.

Fig. 3. 'Reuben' pineapple lily plant showing overall effects of growth regulator substrate drenches. Left to right: 0-, 2-, 4-, or 6-mg/pot paclobutrazol (top panel) or flurprimidol (bottom panel); 1 mg = 3.5274×10^{-5} oz.

Discussion

With different cultivars, Filios and Miller (2013) reported that 4- and 8-mg/pot paclobutrazol drenches and 2-mg/pot flurprimidol drenches applied at the inflorescence emergence stage (Fig. 1) resulted in notable scape length reduction in 'Innocence' and 'Tugela Ruby'. Based on this, in year 1, flurprimidol and paclobutrazol substrate drenches (2,

4, or 6 mg/pot) were applied at the inflorescence emergence stage. The treatments were somewhat less effective at controlling scape length at the equivalent rates tested by Filios and Miller (2013). For plants treated with flurprimidol, the greatest reduction in scape length was observed at the rate of 6 mg/pot, at which scape length in 'Reuben', 'Tugela Jade', and 'Tugela Gem' was reduced 20%, 24%, and

28%, respectively, vs. the untreated control. With paclobutrazol, the greatest reduction in scape length from the untreated control was observed at 4 mg/pot for 'Reuben' (13%) and 'Tugela Jade' (22%), and 'Tugela Gem' (32%). Although the PGR treatments evaluated in year 1 and by Filios and Miller (2013) controlled scape length sufficiently to eliminate most of the scape leaning and toppling observed in untreated plants, greater reductions in scape length and overall plant height were ultimately desired.

Working with the dwarf pineapple lily 'Leia', Carlson et al. (2015) reported optimal scape length reduction with flurprimidol and paclobutrazol drenches at rates of 0.5–1.0 and 0.5–2.0 mg/pot, respectively, substantially lower than those reported effective by Filios and Miller (2013). Furthermore, paclobutrazol drenches at 4 and 8 mg/pot, and flurprimidol drenches at 2 and 4 mg/pot resulted in excessive growth control. Although 'Leia' is a smaller cultivar and of a different species, Carlson et al. (2015) also applied their treatments at an earlier growth stage than we did in year 1. Therefore, in year 2 of the current experiments, drenches were applied at the earlier "leaf whorl" stage described by Carlson et al. (2015). In year 2, in all cultivars evaluated, control of scape length at all flurprimidol and paclobutrazol rates tested was substantially greater than that in year 1. Flurprimidol drenches applied at the earlier stage effectively controlled plant height in 'Reuben' and 'Tugela Jade' at rates of 2 mg/pot or greater. Paclobutrazol was effective for 'Reuben' at 6 mg/pot and for 'Tugela Gem' at 2 mg/pot or greater. 'Tugela Jade' was less responsive to both flurprimidol and paclobutrazol drenches. In all cultivars, compared with the controls, stem length (below the inflorescence) was sharply decreased as PGR rates increased, accounting for most of the overall scape length reduction.

Although we were unable to conduct a controlled comparison of the application stage, the results suggest that efficacy of flurprimidol and paclobutrazol substrate drenches is highly dependent on application timing and that early application is more efficacious. In year 2, 2-mg/pot applications of flurprimidol and

paclobutrazol applied at leaf whorl emergence achieved similar or greater control of scape height in 'Reuben', 'Tugela Jade', and 'Tugela Gem' than the 6-mg/pot applications applied later at the visible inflorescence stage in year 1.

Although flurprimidol and paclobutrazol substrate drenches successfully controlled scape length in the cultivars evaluated, particularly in year 2, considerable variation in scape length was observed in most of the PGR drench treatments, possibly attributable to variations in shoot emergence in the population.

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