Research Reports

Paclobutrazol and Uniconazole Solutions Maintain Efficacy after Multiple Lily Bulb Dip Events

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Additional index words. **Bonzi, height control, *Lilium*, Sumagic**

Summary. **One of the problems associated with preplant bulb dips into plant growth regulator (PGR) solutions is the lack of knowledge of solution efficacy as an increasing number of bulbs are treated. We evaluated the effectiveness ("longevity") of paclobutrazol (Bonzi) and uniconazole (Sumagic) solutions repeatedly used to dip hybrid lily (*Lilium* sp.) bulbs. Experiments were conducted over a 2-year period, using sequential 1-minute dips into paclobutrazol (100 or 200 mg·L^{-1}) or uniconazole (2.5 mg·L^{-1}). No difference in plant height occurred as the number of bulbs dipped into PGR solutions increased to at least 55 bulbs per liter. This was true whether bulbs were washed (with tap water to remove soil particles attached to the bulbs) or unwashed prior to the PGR dip. These findings have an important impact on cost effectiveness of bulb dips, as the more times the solution can be used, the lower the cost. Washed bulbs were taller than unwashed bulbs due to lower PGR liquid uptake in washed bulbs (about 1 mL less per bulb) compared to the unwashed bulbs. These results indicate that the hydration condition of bulbs prior to dipping can affect the amount of PGR liquid uptake and therefore final plant height.**

Each year many new hybrid lily cultivars are introduced to the market, with most being for cut flower use. Since long stem length is an obvious characteristic for cut flowers, when grown as pot plants, many lily cultivars require effective height control methods to keep the plant in aesthetic proportion to the container. Moreover, shorter plants are easier to handle and require less volume during transportation, which makes them more economical to deliver to the customer. While market conditions dominate, in general, the preferred height of a lily in a 6-inch-diameter pot is about 22 inches, including the pot (Miller, 1992).

Height control in lilies is primarily achieved with chemical PGRs. Foliar sprays, soil drenches, and preplant bulb dips are all common methods of PGR application and each have advantages and disadvantages. Foliar sprays have the advantage of being labor and material efficient, but they sometimes lack effectiveness on oriental hybrid cultivars, which tend to elongate significantly before a foliage canopy capable of intercepting the spray (and thereby directing it to the stem for absorption) is developed. Drenches can be highly effective, but not with cultivars that are slow-rooting since the plant cannot absorb the active ingredient if roots are not present. Growth regulator drench effectiveness can also depend on the substrate and adsorption to it, for example, pine bark (Bonaminio and Larson, 1978; Million et al., 1998, 1999; Tschabold et al., 1975).

Preplant bulb dips with paclobutrazol (Bonzi; Syngenta, Greensboro, N.C.) or uniconazole (Sumagic; Valent USA, Marysville, Ohio) are an alternative to spray and drench applications and are effective for controlling hybrid lily height (Miller et al., 2003; Ranwala et al., 2002). The advantages of preplant bulb dips over other methods of PGR application are early plant height control, correct dosage, and the potential for cost, time, and labor savings. Disadvantages are lack of knowledge of the strength of the dip solution over time (i.e., after repeated dips), response variation throughout the year (Larson et al., 1987), and need for careful disposal of the dip solution. Response variation of bulb dips may be due to characteristics of the bulb itself, such as size (Ranwala et al., 2002) "tight" vs. "loose" scales, or scale moisture content. The latter two may be related to the length of frozen storage before planting (unpublished observations of the authors).

It is also possible that cultural practices, such as washing the bulbs prior to dipping (to rehydrate them

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Use of trade names does not imply endorsement of the products named or criticism of similar ones not named. We are grateful to the Royal Dutch Wholesalers' Association for Flowerbulbs and Nursery Stock, the Fred C. Gloeckner Foundation, and the Kenneth Post/Herman Schenkel Foundation for financial and material assistance with this research, and to the staff of the Kenneth Post greenhouses of Cornell University for plant care.

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
3.7854	gal	L	0.2642
2.5400	inch(es)	cm	0.3937
1	ppm	mg·L^{-1}	1
(°F – 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

and presumably improve uniformity), could alter the amount of PGR absorbed. Washed bulbs may be more turgid and not absorb as much PGR as unwashed bulbs. On the other hand, peat or soil particles on unwashed bulbs may adsorb some PGR active ingredient otherwise absorbed by the bulbs, and, with many bulbs dipped, reduce the active ingredient available for bulb uptake.

Finally, it is important to know whether the effectiveness of the PGR solution changes as an increasing number of bulbs are dipped into it. This is because the concentration of dip solutions tends to be greater than those used for spray or drench applications. Therefore, the cost per bulb is directly related to the number of bulbs that can be effectively treated in a given volume of growth regulator solution. Additionally, the more times a dip solution can be used, the less material is left that must be discarded. Therefore, the objectives of the present study were to determine whether bulb moisture content (hydration) before dipping into PGR solutions reduces the amount of PGR liquid absorbed with resulting growth changes, and whether the effectiveness of PGR dip solutions changes as more bulbs are sequentially treated.

Materials and methods

Experiments were conducted from Apr. to June 2002 and repeated in 2003. Precooled bulbs (14- to 16-cm circumference) of the LA-hybrid lily 'Fangio' were obtained from a commercial source (Royal Van Zanten, Hillegom, The Netherlands) and held in the original packaging with peat moss at –1 °C until treatment. After thawing, bulbs were either used directly from the case (as unwashed bulbs, but with the removal of much of the adhering peat moss) or were liberally rinsed (1 min) with tap water to remove all of the adhering peat moss ("washed" bulbs).

In 2002, 15 sets of six washed or unwashed bulbs (total of 90 bulbs each) were dipped, one set at a time, for 1 min into 2 L of paclobutrazol (200 mg·L^{-1}) or uniconazole (2.5 mg·L^{-1}). Washed or unwashed bulbs dipped in water for 1 min served as the respective PGR controls. All bulbs were weighed before and 30 min after dipping to determine the amount of liquid absorbed during the PGR treatment (bulbs were allowed to drip-dry). Two to three hours after dipping, bulbs were planted in 6-inch-diameter standard pots using Metro Mix 360 (Scotts, Marysville, Ohio). Plants were grown in Cornell University glass greenhouses according to standard cultural practices, with a constant temperature setpoint of 17 °C. As the first flower on each plant opened, data were recorded on date and height at flowering, the number of flower buds, aborted buds, and yellow leaves (>50% of the leaf chlorotic, Ranwala and Miller, 1998).

In the 2003 experiment, we increased the number of bulbs dipped into the PGR solution in order to determine further effectiveness of dip solution over time. Twenty-four sets of six washed or unwashed bulbs (144 bulbs each) were sequentially dipped in 2.5 L of 100 mg·L^{-1} paclobutrazol or 2.5 mg·L^{-1} uniconazole. Since height control in 2002 was slightly excessive, in 2003 we reduced the concentration of paclobutrazole to provide a more rigorous test of the hypothesis (a less concentrated solution presumably would show greater loss of effectiveness). After dipping, plants were handled and grown as above.

Data for each PGR treatment were analyzed using analysis of variance with treatments arranged in a factorial design [two bulb treatments (washed or unwashed) and 15 or 24 dip order treatments] with six replicates (plants) per treatment. "Dip order" refers to the sequence of dipping (e.g., dip order 4 was the fourth set of six bulbs to be dipped into the solution). Mean comparisons were done using orthogonal contrasts or least squares means.

Results and discussion

We hypothesized that washing would increase bulb water content (either internal or superficial) and thereby reduce the amount of liquid absorbed during the subsequent PGR dip. While bulb moisture content *per se* was not determined, through pre-dip and post-dip weighing experiments we determined that bulb washing reduced the amount of solution absorbed by about 1 mL, or approximately 30% to 40% less per bulb, for both paclobutrazol or uniconazole treatments (data not shown). Consistent with these results, PGR-dipped plants grown from washed bulbs were significantly taller than plants from unwashed bulbs (Table 1). Overall, plant height of washed bulbs treated with paclobutrazol or uniconazole was 5 to 7 cm, or 6 to 11 cm taller, respectively, than unwashed bulbs. All plants flowered 68 to 70 d after planting, with five to six flower buds and no aborted buds per plant. The date of flowering time or number of flower buds per plant was not significantly affected by the bulb treatment or PGR used.

These results show that bulb hydration prior to a PGR dip affects the amount of PGR uptake by lily bulbs and, therefore, the final height control potential of the treatment.

Plant height at flowering was used as an indicator to determine the effectiveness of each PGR dip solution with repeated use. Plant height was not significantly different among the dip orders, and for both PGRs, the last-dipped bulbs were the same height as the first-dipped bulbs (Table 1). Thus, there was no change in height control effectiveness as the paclobutrazol or uniconazole solutions became increasingly "used," regardless of whether or not bulbs were previously washed. The PGR solutions at the end of the experiment were dramatically different: the solution used to dip washed bulbs was quite clean, while the solution used for dipping unwashed bulbs was very dirty (not quantified). These observations suggest that mineral soil or peat moss residue deposited in the dip solution may not have absorbed a significant amount of PGR since the effectiveness of the dip solution was unchanged even as the solution became quite dirty. These results are consistent with earlier research indicating that peat has a relatively low potential to adsorb paclobutrazol (Million et al., 1998).

These findings have an important impact on cost effectiveness of dips. Since dip solution concentrations are greater than those of sprays or drenches, the more times the solution can be used, the lower is the material cost. Using the specific case from 2003, where we used 2.5 L of 100 mg·L^{-1} paclobutrazol to treat 144 bulbs, and assuming a price of $140/L of Bonzi, the material cost is $0.06 per bulb. A similar calculation for uniconazole (assumptions: 2.5 mg·L^{-1} solution, $110/L for Sumagic) yields a per-bulb cost of $0.009. Obviously, the price competitiveness of a particular PGR depends on the concentration needed to obtain the desired response.

Table 1. Plant height at flowering for hybrid lily 'Fangio' bulbs (14- to16-cm circumference) that were washed (with tap water for 1 min) or unwashed, and dipped into paclobutrazol [200 mg·L^{-1} (ppm) in 2002, 100 mg·L^{-1} in 2003] or uniconazole (2.5 mg·L^{-1}).[z] Dip order refers to individual sets of six bulbs, each dipped sequentially into the indicated plant growth regulator (PGR). For clarity, only one-third of the dip order treatments are shown.

		Plant ht at flowering (cm)[y]			
	Dip	Paclobutrazol		Uniconazole	
Bulb treatment	order (D)	2002	2003	2002	2003
Unwashed	---	87[x]	114	87	114
	3	48	93	51	75
	6	44	91	54	74
	9	46	96	55	78
	12	51	89	61	74
	15	43	92	56	85
	18	---	94	---	76
	21	---	91	---	81
	24	---	87	---	82
Washed	---	92	114	92	114
	3	52	94	56	85
	6	50	98	67	91
	9	48	100	62	91
	12	52	96	59	86
	15	51	96	61	89
	18	---	104	---	91
	21	---	104	---	92
	24	---	97	---	90
Contrasts					
Control (0 dip) vs. any PGR		***	***	***	***
Unwashed vs. washed		**	***	***	***
D3 vs. D15 (2002)[w] (within each PGR treatment)		NS	NS	NS	NS
D3 vs. D24 (2003)[w] (within each PGR treatment)		NS	NS	NS	NS

[z]Fifteen (2002) or 24 (2003) sets of bulbs (six bulbs per set), one set at a time, were dipped into PGR solutions [2 L (2.1 qt) in 2002, or 2.5 L (2.64 qt) in 2003] for 1 min and allowed to drain before planting.
[y]1 cm = 0.3937 inch.
[x]Values are means of six replicates (plants).
[w]Within a PGR and year, there was no significant difference among any dip order combination; therefore, for clarity only the extreme contrasts are shown.
[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

On a commercial scale, growers may be advised that as many as 55, 14- to 16-cm bulbs may be dip-treated per liter of paclobutrazol or uniconazole without loss of solution efficacy.

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