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Paclobutrazol Effects on Bedding Plants During Production, Shipping, and the Retail Environment When Applied in Production[1]

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Abstract

Foliar sprays of 10, 15, or 20 ppm paclobutrazol followed by a second application of 50 ppm were applied to 'Bravo Lavender' and 'Celebrity Blue' petunias and 'Salvador Red' and 'Vista Red' salvia during production to determine their effects on plant growth, flowering and market quality during production, simulated shipping, and while in a simulated retail environment. Paclobutrazol effectively suppressed shoot growth and enhanced market quality of all cultivars during production, while minimally or not affecting time to first flower. Growth suppression and enhanced market quality continued through simulated shipping and the period plants were in the retail environment. While in the simulated retail environment, plants were exposed to six or seven wilt/hydration cycles. The % wilted plants of all four cultivars previously treated with paclobutrazol during production was much less than that of the controls: 'Bravo Lavender' petunia, 21 vs. 67%; 'Celebrity Blue' petunia, 10 vs. 88%; 'Salvador Red' salvia, 15 vs. 69%; and 'Vista Red' salvia; 13 vs. 74%.

Index words: plant growth retardant, shelf life, garden center, postharvest, marketing, floriculture crops.

Species used in this study: *Petunia ×hybrida* 'Bravo Lavender' and 'Celebrity Blue' (petunia), *Salvia splendens* 'Salvador Red' and 'Vista Red' (scarlet sage, salvia).

Chemicals used in this study: paclobutrazol [(±)-(R*,R*)-β-(4-chlorophenyl)methyl-α-(1,1,-dimethylethyl)-1*H*-1,2,4,-triazole-1-ethanol]; Bonzi.

Significance to the Nursery Industry

Paclobutrazol (Bonzi) is widely used in the production of high-quality bedding plants, however it is a very active growth retardant and it's effects can extend well beyond application during production. Paclobutrazol application to four cultivars of bedding plants during production promoted compactness and enhanced market quality at the ends of production and simulated shipping with minimal or no delay in flowering. While exposed to drought-stress cycles in a simulated retail environment, plants previously treated with paclobutrazol wilted in much lower percentages and maintained consistently higher quality than did control plants. Results of this study suggest that application of paclobutrazol during production, a standard practice in growing many bedding plants, has a positive impact on postproduction shelf life and may benefit sales in retail outlets where plants are often subjected to frequent drought stress.

Introduction

The use of chemical growth retardants (PGRs) is an integral part of producing uniform, compact bedding plants. Paclobutrazol (Bonzi), a triazole PGR labeled for use on ornamental plants grown in containers in greenhouses, nurseries, shadehouses, and interiorscapes, is highly effective in controlling height of most bedding plants grown in plug flats or larger containers when applied as a foliar spray (2, 4, 6, 11). However, the effects of paclobutrazol and other triazole PGRs on growth and flowering can extend beyond production to affect bedding plant performance in the landscape (11, 12, 13, 14).

In addition to growth suppression, triazole PGRs can increase a plant's tolerance to several types of stress including saline conditions (3), gaseous sulfur dioxide, low and high temperature extremes (1, 5, 15), desiccation (19), and water stress (7). Paclobutrazol-induced drought tolerance has been associated with a decrease in transpiration, plant height, biomass and leaf area, and an increase in stomatal resistance (1). Recently, Fernandez et al. (7) showed that paclobutrazol applied during nursery production induced morphological adaptations including increased root-to-shoot ratio and stomata density that allowed plants to tolerate drought after transplanting.

High-quality bedding plants are produced under optimal environmental conditions using sound cultural practices. Postproduction conditions are much less controlled but greatly impact the postproduction shelf life and garden performance of bedding plants. During shipping and marketing of floriculture crops in the retail environment plants are often exposed to extended periods of darkness, high temperatures, and ethylene leading to losses as great as 30% (10). Bedding plants in mass markets and retail outlets are frequently exposed to repeated drought stress cycles resulting in reduced quality. A reduced frequency of watering in postproduction reduced plant grade and bloom counts of two bedding plants (9). Water stress also reduced the opening, retention, and production of flowers on *Magnolia ×soulangiana* 'Jane' (8). Our objectives were to determine how paclobutrazol applied during the production of four bedding plant cultivars affected growth and market quality during production, simulated shipping, and a simulated retail environment, and to determine treatment effects on drought-stress resistance while plants were in a simulated retail environment.

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Materials and Methods

Production. Seeds of 'Bravo Lavender' petunia and 'Salvador Red' salvia were sown in 288-cell plug flats containing Fafard Germination Mix (Conrad Fafard, Inc., Agawam, MA) and placed in an environmentally-controlled room in Auburn, AL, at 25.6C (78F) under a 24-hour photoperiod from 40-watt, cool-white fluorescent lamps on March 27, 2006. On April 3 and April 7, when seedlings were about 1-cm (0.4 in) tall, salvia and petunia, respectively, were transferred to a polycarbonate greenhouse [heat/ventilation set points of 18.3/25.6C (65/78F)] and placed under natural photoperiod and 50% shade cloth to acclimate seedlings. Shade cloth was removed after five days. Seedlings received 150 ppm N from 20N–4.3P–16.6K (Pro Sol 20–10–20, Frit Industries, Inc., Ozark, AL) on Mondays, Wednesdays, and Fridays and water on other days as needed.

On April 18, 2006, 288-cell plug flats of 'Celebrity Blue' petunia and 'Vista Red' salvia were obtained from a commercial grower (Young's Plant Farm, Auburn, AL) and placed in the same polycarbonate greenhouse. Seedlings were similar in age and size to those already in the greenhouse, had not been treated with any PGR, and were watered and fertilized similarly.

Seedlings of 'Salvador Red' salvia received a foliar spray of 0, 15, 20, or 30 ppm paclobutrazol (Bonzi, Syngenta Crop Protection, Greensboro, NC) applied at 153 ml/m^2 (equivalent to 1.5 qt/100 ft^2) on April 25 [32.2C (90F) and 65% relative humidity (RH) when applied]. Seedlings of 'Vista Red' salvia and the two petunia cultivars received the same spray treatments on May 1, 2007 [32.8C (91F) and 62% RH]. At that time, seedlings were well rooted and had one to two true leaves. One week after initial treatment (WAT), seedlings were transplanted into 606 market flats containing Fafard 3B mix. Plants that had previously been sprayed with Bonzi received a second application of 50 ppm Bonzi at 204 ml/m^2 (equivalent to 2.0 qt/100 ft^2) on May 22 [33.3C (92F) and 60% RH].

Postproduction. On May 30, five WAT of 'Salvador Red' salvia and 4 WAT of other cultivars, plants were watered thoroughly and transferred to an unlit postproduction room maintained at 26.7C (80F) where they were kept for three days without watering to simulate shipping conditions. On June 2, plants were removed from the postproduction room and placed on tables outdoors underneath a building canopy open on the north and south sides where they received only indirect light. Plants were maintained in this simulated retail environment for 12 days. During the 12-day simulated retail environment, plants were monitored daily for wilting. When at least 30% of the plants of a cultivar in any one treatment were visibly wilted (loss of leaf turgidity), the percentage of wilted plants in all treatments was determined and all of the plants of that cultivar were thoroughly watered. Temperature was recorded every 12 minutes at plant height during simulated shipping and the simulated retail environment using two Hobo data loggers (Onset Computer Corp., Bourne, MA).

Data collection, experimental design, and statistics. Plant height and widest width were measured when plants were first treated with Bonzi and weekly for the remainder of the study. These data were taken on individual plants through 4 WAT (5 WAT for 'Salvador Red' salvia); thereafter, data were taken on 606-cell packs to avoid damaging plants during measurement. A growth index (GI) was calculated as a mean of plant height and width. Because height, width, and GI data paralleled each other, only widths of petunia and heights of salvia, the dominant directions of growth, are reported. Days to first flower, when petals on the first petunia bloom and first salvia floret were fully reflexed, were recorded during production. Plant quality was rated (QR: 1 = unmarketable: leggy, excessively tall, minimal branching, off-color foliage, and few or no flowers; 2 = intermediate between 1 and 3; 3 = marginally marketable: some stretching of shoots, medium green foliage, flowers or flower buds present; 4 = intermediate between 3 and 5; 5 = highly marketable: compact, well-branched, dark-green foliage, flowering) at the end of production (4 WAT, except 5 WAT for 'Salvador Red' salvia), immediately following simulated shipping, and 5 and 6 WAT (6 and 7 WAT for 'Salvador Red' salvia). Treatments were arranged in a completely randomized design within cultivar using six replications (market packs) of six plants each. Quantitative responses were analyzed using PROC MIXED in PC-SAS (SAS Institute, Cary, NC). The six plants per market flat were analyzed as repeated measurements. Response to paclobutrazol rate was determined using linear and quadratic orthogonal polynomials ($P = 0.05$). Quality ratings were analyzed as ordinal responses (18). Mean separation of quality ratings was determined using t-tests, $P = 0.05$, from PROC GLIMMIX (17).

Results and Discussion

'Bravo Lavender' petunia. Plant width was not affected by treatments until 3 WAT at which time there was a linear decrease of up to 14% with increasing paclobutrazol rate (Table 1). By the end of plant production, 4 WAT, plant width changed quadratically in response to increasing rate with the greatest reduction in width, 11%, occurring in plants treated with 20 ppm paclobutrazol. A similar trend was evident at 5 and 6 WAT when plants were in the simulated retail environment. Paclobutrazol-induced growth suppression of petunia during production agrees with previous research with paclobutrazol (2, 4, 11, 12, 13, 14). That the growth suppression continued through the simulated retail period is not surprising considering the persistent effects of paclobutrazol on bedding plants following transplanting into the landscape (11, 12, 13, 14). Time to first flower was minimally affected by treatments, 27 days for controls and plants receiving 15 ppm paclobutrazol and 28 days for plants receiving higher rates (data not shown), agreeing with earlier research (11). There was no paclobutrazol-related injury to 'Bravo Lavender' petunia or any other cultivar in the study. Compared to that of control plants, QR taken at the end of production, 4 WAT, was 52% higher for plants treated with 30 ppm paclobutrazol and 44 or 46% higher for plants receiving 15 or 20 ppm paclobutrazol, respectively (Table 2). Paclobutrazol-treated plants were more compact than controls with darker green foliage.

Mean temperature over the three days of simulated shipping was 25.2C ± 0.23 (standard deviation) (77.4F ± 0.36) with a maximum and minimum of 25.6 and 24.8C (78.1 and 76.6F), respectively. Following simulated shipping during which no visible wilting occurred in any cultivar, QR of 'Bravo Lavender' petunia treated with 15 or 30 ppm paclobutrazol was 53% higher than that of controls and 33% higher in plants treated with 20 ppm paclobutrazol (Table 2).

During the 12 days plants were in the simulated retail environment mean temperature was 23.2C ± 3.7 (73.8F ±

Table 1. Paclobutrazol effects on plant width (cm) of two petunia cultivars and plant height (cm) of two salvia cultivars treated during greenhouse production.[z]

Bonzi (ppm)	WAT[y] 0[x]	1	2	3	4	5	Significance[w]	WAT 5	6	7
'Bravo Lavender' petunia plant width (cm)										
0	3.5	3.4	10.2	18.3	23.1		L***	38.2	40.9	
15	3.2	4.4	10.7	16.9	21.1		L***	32.4	36.0	
20	3.8	4.4	9.6	15.7	20.5		L***	33.2	35.8	
30	3.8	4.8	9.8	16.7	23.1		L***	36.4	41.1	
Significance	NS	NS	NS	L**	Q**			Q***	Q***	
'Celebrity Blue' petunia plant width (cm)										
0	2.7	3.8	9.9	18.0	23.9		L***	42.3	45.2	
15	2.4	3.6	8.5	14.3	17.9		L***	34.1	38.4	
20	2.6	3.7	7.8	14.5	19.3		L***	36.3	40.8	
30	2.6	3.6	7.7	14.2	19.9		L***	35.3	40.0	
Significance	NS	NS	L***	Q**	Q***			L***	NS	
'Salvador Red' salvia plant height (cm)										
0	2.3	3.4	7.3	13.1	16.8	20.3	L***		24.2	23.7
15	2.1	2.7	5.9	11.3	14.7	17.6	L***		19.7	20.5
20	2.2	2.7	6.0	11.7	16.1	18.2	L***		20.3	20.8
30	2.0	2.6	5.3	10.5	15.1	17.7	L***		20.2	20.7
Significance	NS	L***	L***	L***	Q**	Q**			Q***	Q**
'Vista Red' salvia plant height (cm)										
0	1.5	2.8	5.1	9.2	15.7		L***	18.2	18.5	
15	1.6	2.7	4.7	9.1	13.6		L***	17.2	17.3	
20	1.4	2.6	4.9	9.5	13.8		L***	16.3	17.0	
30	1.4	2.3	4.1	8.0	11.8		L***	14.8	15.2	
Significance	NS	L***	L***	Q**	L***			L***	L***	

[z]Interactions between date and rate significant for all cultivars, $P = 0.05$.

[y]WAT = weeks after initial treatment.

[x]Data taken on individual plants at 0–4 WAT and on 606 flats at 5 and 6 WAT.

[w]Non-significant (NS) or significant linear (L) or quadratic (Q) trend at $P = 0.01$ (**) or 0.001 (***).

6.7) with a maximum and minimum of 30.7 and 15.2C (87.3 and 59.4F), respectively (Fig. 1). 'Bravo Lavender' petunia experienced seven wilt/hydration cycles during the 12 days plants were in the simulated retail environment, however there was no interaction between wilting date and paclobutrazol rate for percent wilt (Table 3). Across all wilting dates, an average of 67% of controls wilted, while only 19–22% of paclobutrazol-treated plants wilted. Numerous studies have demonstrated increased stress tolerance, including to drought, of paclobutrazol-treated plants (1, 7, 8, 15, 19). This increased stress tolerance has been attributed to smaller stomatal apertures, increased epicuticular waxes, shortened stems and thickened roots, increased chlorophyll concentration (19), and increased root-to-shoot ratio and stomata density (7). Whether due to a direct effect of treatments on plant size or appearance or indirectly to a greater resistance to desiccation, a higher QR of paclobutrazol-treated plants continued throughout the period plants were maintained in the simulated retail environment (5 and 6 WAT, Table 2).

'Celebrity Blue' petunia. Results with 'Celebrity Blue' petunia were similar to those with 'Bravo Lavender' petunia. Plant width at 2, 3, or 4 WAT decreased as much as 21 to 25% with increasing paclobutrazol rates (Table 1). A similar trend in plant width was evident at 5 WAT in the simulated retail environment, however by 6 WAT paclobutrazol's effect on plant width had dissipated. First flowering occurred 29 or 30 days after first application of paclobutrazol but was not affected by treatments (data not shown). QR of paclobutrazol-treated plants was up to 67% higher than that of the controls at the end of production (Table 2), 4 WAT; treated plants were more compact with more flowers and darker green foliage. A similarly higher QR for paclobutrazol-treated plants also was present following simulated shipping (Table 2).

'Celebrity Blue' petunia experienced six wilt/hydration cycles while in the simulated retail environment, and there was an interaction between wilting date and paclobutrazol rate for percent wilt (Table 3). However, at all wilt dates, except the sixth, percent wilt changed quadratically with increasing paclobutrazol rate. At the first two wilting dates 33 and 100% of controls had wilted, while none of the paclobutrazol-treated plants were wilted. Similar large differences in percent wilt of the controls and paclobutrazol-treated plants continued throughout the period plants were

Table 2. Paclobutrazol effects on quality rating[z] of petunia and salvia cultivars.[y]

	'Bravo Lavender' petunia				'Celebrity Blue' petunia			
	WAT[x]				WAT			
Bonzi (ppm)	4	4.5	5	6	4	4.5	5	6
0	3.3c[w]	3.0c	4.0b	3.5b	3.0c	2.0b	4.0b	3.8b
15	4.7b	4.6a	5.0a	4.8a	5.0a	5.0a	5.0a	5.0a
20	4.8ab	4.0b	5.0a	4.8a	4.5b	5.0a	5.0a	5.0a
30	5.0a	4.6a	5.0a	5.0a	5.0a	5.0a	5.0a	5.0a
	'Salvador Red' salvia				'Vista Red' salvia			
Bonzi (ppm)	5	5.5	6	7	4	4.5	5	6
0	4.2c	4.0b	4.0b	4.0b	3.0c	4.0b	4.0b	4.0b
15	4.8a	5.0a	5.0a	5.0a	4.3b	5.0a	5.0a	5.0a
20	4.5b	5.0a	5.0a	5.0a	5.0a	5.0a	5.0a	5.0a
30	5.0a	5.0a	5.0a	5.0a	5.0a	5.0a	5.0a	5.0a

[z]Quality rating: 1 = unmarketable: leggy, excessively tall, minimal branching, off-color foliage, and few or no flowers; 2 = intermediate between 1 and 3; 3 = marginally marketable: some stretching of shoots, medium green foliage, flowers or flower buds present; 4 = intermediate between 3 and 5; 5 = highly marketable: compact, well-branched, dark-green foliage, flowering.

[y]Interactions between date and rate significant for all cultivars, $P = 0.05$.

[x]WAT = weeks after initial treatment; the first rating was taken at the end of production, the second rating was taken after simulated shipping, and the last two ratings were taken while plants were in the simulated retail environment.

[w]Mean separation in columns using t-tests, $P = 0.05$, from PROC GLIMMIX.

in the simulated retail environment. Wilting percentages increased at increasingly later dates reflecting plant maturity and a concomitant higher demand for water. QR of plants in all paclobutrazol treatments was excellent throughout the simulated retail environment period, averaging 25 and 32% higher than that of controls at 5 and 6 WAT (Table 2).

'Salvador Red' salvia. Treatment effects on plant height were recorded as early as one WAT and continued throughout the study. Paclobutrazol-treated plants were up to 24, 27, 20, 13, and 13% shorter than control plants at 1, 2, 3, 4, and 5 WAT, respectively, and 19 and 14% shorter while in the simulated retail environment, 6 and 7 WAT (Table 1). Paclobutrazol-treated plants were visibly more compact with darker green foliage than controls during production, however paclobutrazol delayed first flowering by three to five days (data not shown). This delay in flowering is consistent with previous research in which paclobutrazol was applied to annuals (16). QR of plants receiving 15 or 30 ppm paclobutrazol was the highest at the end of production, followed by that of plants treated with 20 ppm paclobutrazol, and lowest for control plants (Table 2). QR of all paclobutrazol-treated plants was similarly higher than that of control plants following simulated shipping and continued at 6 and 7 WAT while plants were in the simulated retail environment. As with the two petunia cultivars, paclobutrazol greatly reduced the percentage of 'Salvador Red' salvia that wilted between watering while in the simulated retail environment, 69% for the controls vs. as low as 10% for paclobutrazol-treated plants (Table 3).

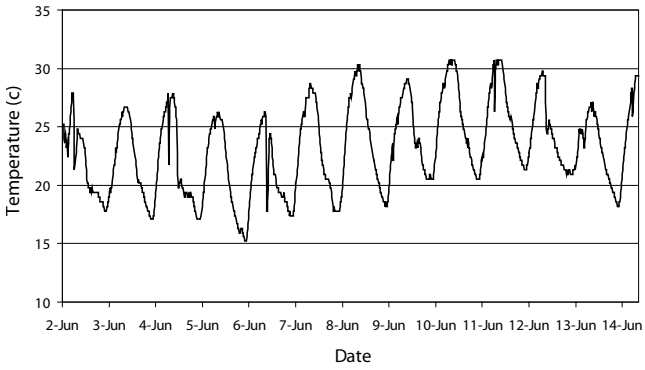

Fig. 1. Temperatures during the period four bedding plant cultivars were in a simulated retail environment, 2006.

'Vista Red' salvia. Similar to results with 'Salvador Red' salvia, paclobutrazol reduced the height of 'Vista Red' salvia as much as 13 to 25% during production and up to 19% while in the simulated retail environment (Table 1). Paclobutrazol-treated plants were visibly more compact with darker green foliage than controls during production, which contributed to a QR 43% (15 ppm) and 67% (20 and 30 ppm) higher than that of controls at the end of production (Table 2). Time to first flowering of the paclobutrazol-treated plants was delayed by only one or two days, as opposed to three to five days in 'Salvador Red' salvia (data not shown). As with 'Salvador Red' salvia, QR of all paclobutrazol-treated 'Vista Red' salvia was similarly higher than that of control plants following simulated shipping and continued at 5 and 6 WAT while plants were in the simulated retail environment (Table 2). As with 'Salvador Red' salvia, paclobutrazol greatly reduced the percentage of 'Vista Red' salvia that wilted between watering while in the simulated retail environment, 74% for the controls vs. a mean of 13% for paclobutrazol-treated plants (Table 3).

Paclobutrazol application to four cultivars of bedding plants during production promoted compactness and enhanced market quality at the ends of production and simulated shipping with minimal or no delay in flowering. With exposure to drought-stress cycles in a simulated retail environment, plants previously treated with paclobutrazol

Table 3. Paclobutrazol effects on percent wilt of petunia and salvia cultivars while in a simulated retail environment.

'Bravo Lavender' petunia[z]					
Wilt cycle	Wilt (%)		Bonzi (ppm)		Wilt (%)
1	8		0		67
2	45		15		19
3	25		20		21
4	13		30		22
5	38				
6	35				
7	64				
Significance	L***				Q***

'Celebrity Blue' petunia[y]					
	Bonzi (ppm)				
	0	15	20	30	
Wilt cycle	Wilt (%)				Significance[x]
1	33	0	0	0	Q*
2	100	0	0	0	Q***
3	100	6	3	0	Q***
4	100	14	0	8	Q***
5	97	17	0	31	Q***
6	100	33	36	28	L***
Significance	Q***	L***	Q**	L**	

	'Salvador Red' salvia[w]	'Vista Red' salvia[w]
Bonzi (ppm)	Wilt (%)	Wilt (%)
0	69	74
15	15	15
20	20	26
30	10	11
Significance	L***	L***

[z]Interaction between date and rate not significant, $P = 0.05$.

[y]Interaction between date and rate significant, $P = 0.05$.

[x]Non-significant (NS) or significant linear (L) or quadratic (Q) trend across rows at $P = 0.05$ (*), 0.01 (**), or 0.001 (***).

[w]Only rate significant, $P = 0.05$.

wilted in much lower percentages and maintained consistently higher market quality than did control plants. Results of this study suggest that application of paclobutrazol during production, a standard practice in growing many bedding plants, has a positive impact on postproduction shelf life and may benefit sales in retail outlets where plants are often subjected to frequent drought stress.

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