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Watsonias as container plants: using paclobutrazol for flowering and height control

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South African watsonias were evaluated for their potential as flowering pot plants, following chemical dwarfing. Corms were treated with paclobutrazol as a 5mg, 10mg or 20mg active ingredient (a.i.) per pot post-emergent soil drench, or vacuum-infiltrated pre-planting with 0.5mg, 1mg or 2mg a.i. per corm. Both treatments significantly reduced perpendicular leaf height, although infiltration of all but the most under-developed corms caused inflorescence abortion. Flowering plants shorter than 36cm were considered to be attractive, commercially viable pot plants — provided that flowering percentage, flower number and the onset of flowering were not adversely affected by treatment and that flowers were displayed clear of the foliage. The highest concentration of paclobutrazol applied as a drench resulted in obscured inflorescences, indicating an enhanced dwarfing effect on the inflorescence rather than leaf heights. Marketable dwarfs were obtained following a single drench treatment of 10mg a.i. per pot or after a single infiltration episode with 1mg a.i. per corm, allowing the successful adaptation of watsonias to container cultivation.

Abbreviations: a.i. = active ingredient, paclobutrazol = (±)-(R*,R*)-β-[(4-chlorophenyl)methyl]-α-(1,1-dimethyl)-1H-1,2,4-triazole-1-ethanol

Introduction

A disproportionately small percentage of South African Iridaceae is known to Northern Hemisphere horticulturalists as cut flowers and garden ornamentals, and even less as flowering potted plants. Popular irids in cultivation include members of the genera *Babiana*, *Freesia*, *Gladiolus* and *Ixia*, and to a lesser degree, *Dierama*. As a measure of recognition, South African-derived *Freesia* and *Gladiolus* hybrids have been in the top 10 sellers at European cut flower markets in recent years (Wulster and Gianfagna 1991, Fennell and Van Staden 2003). Conventional line breeding is historically and widely used in introducing horticultural diversity (and thereby sustaining consumer interest; Jansen van Vuuren *et al*. 1993, Jansen van Vuuren 1995, Million *et al*. 1999, 2002, Niederwieser *et al*. 2002), although modifying traits through mutation breeding and *in vitro* techniques (somaclonal variation, embryo rescue, ploidy manipulation, genetic transformation — which can produce novelty in a relatively short period) is increasingly useful. Homozygosity has been achieved in *Gladiolus* and *Freesia* through chromosome doubling (Kim and De Hertogh 1997, Ziv 1997), and reports exist on the *Agrobacterium*-mediated transformation and biolistics of *Gladiolus* (Ziv 1997, Badu and Chawla 2000, De Villiers *et al*. 2000, Kamo *et al*. 2000). Market-rewarding novelty in the Irida-ceae is maintained primarily through continued breeding to create new hybrids, and more rarely through direct commercialisation of wild species.

Many South African iridaceous species are limited in horticulture (for example, excluded from container or garden planting), due to relaxed leaves and long flowering spikes which necessitate staking or wire-framed supports to maintain an attractive growth habit and prevent lodging (Larson 1985, Gianfagna and Wulster 1986a, 1986b, Million *et al*. 2002). Consequently, the ability to curb growth and satisfy consumer demand for smaller horticultural products (Beattie 1982, Cohen and Barzilay 1991, Barzilay *et al*. 1992) is very useful in extending the assortment of plants suitable for container cultivation (Henting 1985). For example, triazole applications — which block gibberellin biosynthesis by inhibiting the oxidative reactions that lead from *ent*-kaurene to kaurenoic acid (Larson 1985) — are widely used in restricting the heights of popular container plants across a broad range of species and varieties (Hanks and Menhenett 1979, Menhenett and Hanks 1982/83, Menhenett 1984, Goulston and Shearing 1985, Wilkinson and Richards 1987, Cox and Keever 1988, Sanderson *et al*. 1988, Barrett and

Nell 1989, McDaniel 1990, Wang and Gregg 1991, Bennell and Williams 1992, Ecker *et al*. 1992, Rebers *et al*. 1994, Wang and Hsu 1994, Million *et al*. 1998, 1999, 2002). Indeed, the overwhelming majority of cultivars and species in contemporary circulation as container plants would not meet the prescribed height requirements without plant growth regulator applications to curtail their growth (Hamada *et al*. 1990, Gilbertz 1992, Barrett *et al*. 1994). Through their ability to reduce plant (internode and leaf length) and inflorescence (floral scape length) height without compromising flower number or time to flowering, triazoles have found limited employ in developing several commercially acceptable dwarf *Freesia* (Gianfanga and Wulster 1986b, Berghoef and Zevenbergen 1990, Wulster and Gianfagna 1991), *Ixia* (Wulster and Ombrello 2000) and *Gladiolus* (Rounkova 1989, Barzilay *et al*. 1992) suitable for pot cultivation.

Members of the iridaceous genus *Watsonia* — 52 spp. restricted to southern Africa — exhibit many of the criteria of ideal horticultural subjects. They are perennial, primarily seasonal geophytes with cormous rootstocks and spicate inflorescences of brightly coloured, long-lived flowers. Colour is typically pink-purple or red-orange, and individual inflorescences last several weeks. Apart from a handful of species and hybrids of undocumented parentage which are grown in the larger South African gardens, and the development of natural dwarf species as container subjects (Duncan 2002), there has been scant horticultural development in this genus — attributable, at least in part, to unmanageable plant height. Furthermore, the exacting cultural requirements of many *Watsonia* species renders them unsuitable for garden cultivation, making container cultivation the only practical manner in which they can be grown *ex situ*. The aim of this study was therefore to evaluate the suitability of watsonia as a container crop using the triazole chemical growth retardant paclobutrazol (Cultar®).

Materials and Methods

Experimental

The results of four experiments dealing with the efficacy of paclobutrazol (all concentrations in a.i.) as a dwarfing agent for watsonia pot cultivation are reported. We used commercially-sourced, non-dormant corms of watsonia ‘Shrimp pink’ (a spring-flowering hybrid of unknown parentage) and *Watsonia tabularis* (a spring-flowering species). For all experiments a single corm (circumference >8cm) was planted per 18cm rim-diameter (3-litre) pot, in a medium-grained river sand:fine compost (1:1, v/v) growth medium. Corms were buried at an approximate depth equivalent to the height of the rootstock. Pots were housed under 30% shade and watering frequency was determined by environmental conditions and natural precipitation. It was preferable for the growing medium to be slightly dry. Typically, pots were watered once or twice weekly during the period of active growth and flowering. Temperature (monthly averages: 21–28°C day; 5–14°C night) and irradiance (maximum intensity at plant level at noon was 800–2 000µmol m^{-2} s^{-1}) were not controlled. Each pot was an experimental unit, with a minimum of 10 replicates for each treatment and for the controls, arranged in randomised complete blocks.

Infiltration and concentration

Watsonia ‘Shrimp pink’ corms were submerged in a vacuum chamber containing 200ml paclobutrazol solution, the concentration of which was made up to deliver 0.5mg, 1mg or 2mg a.i. per corm during the treatment period (20min under vacuum, follow by 5min infiltration). By weighing corms before and after treatment, it was determined that corms absorbed c. 0.04ml of solution. Corms were treated at the recommended or ready-for-planting stage (cataphylls 2–3cm in height). After treatment, corms were triple-rinsed in dH_2O and planted immediately. Controls were either untreated, or infiltrated with dH_2O.

Infiltration and maturity

Watsonia ‘Shrimp pink’ corms were vacuum-infiltrated with 1mg paclobutrazol and planted as above. The treatment was applied when the cataphylls were (1) <1.5cm in height (2) 2–3cm in height or (3) >4cm in height (first true leaf emergent). Controls were either untreated, or infiltrated with dH_2O, and displayed a range of cataphyll lengths (1.5–4cm) at planting. *Watsonia tabularis* corms (first two leaves trimmed for transport) were vacuum-infiltrated with 1mg paclobutrazol and planted, or soaked without vacuum for 24h before planting. Passive soaking allowed corms to absorb a maximum of 0.03ml of solution (≈0.75mg a.i.) after 24h. Controls were untreated.

Soil drench and concentration

Watsonia ‘Shrimp pink’ corms were planted untreated when the cataphylls were 2–3cm in height, and the retardant was applied in a single post-emergent dose when the second leaf reached 15cm in length (about 10 weeks after planting). Pots were drenched with 5mg, 10mg or 20mg paclobutrazol, delivered in 100ml dH_2O. Watering was withheld for five days following application. Controls were untreated.

Data collection and statistical analyses

Container plants should be no taller than twice the diameter of their pot to maintain a pleasing aesthetic ratio (Beattie 1982, Deneke and Keever 1992), thus prescribing the maximum acceptable plant height for this study — including the inflorescence — as 36cm. Perpendicular leaf and inflorescence heights (soil level to apex) were recorded coincident with first-flower anthesis (the commercial marketing stage). In cases of multiple shooting, only the morphometrics of the flowering shoot were recorded. Morphometric data were subjected to regression analysis where appropriate, with control plants included at 0mg a.i. per experimental unit. Assumptions of normality and variance homogeneity were tested with Kolmogorov-Smirnov and Levene’s tests, respectively. Perpendicular leaf and inflorescence height data within experiments were independently compared using ANOVA. Means were separated by a Scheffé test (fixed factor was treatment) at $P < 0.01$ for significant F. All analyses were performed using Statistica (StatSoft Inc. 1998). For figures and tables, values with the same letter(s) are not significantly different from each other (P > 0.05). Percentage flowering, modal flower number, time to flowering, number of leaves and multiple shooting data were not analysed statistically.

Results and Discussion

Vacuum-infiltration of ready-for-planting watsonia corms with 0.5mg, 1mg or 2mg a.i. per corm significantly reduced perpendicular leaf height to a maximum of 23% of control plants (Figure 1 and Table 1), which is well below the maximum acceptable height required for commercial purposes (based on container dimensions). A significant quadratic equation (r^2 = 0.7335, Figure 1) defined the relationship between leaf height and retardant concentration, allowing for a fairly accurate prediction of dwarfing under vacuum-infiltration conditions for watsonia 'Shrimp pink'. Unfortunately, none of these dwarf plants matured their inflorescences (Figure 2a). Barzilay *et al*. (1992) reported a correlation between reduced flowering percentages and reduced leaf length in chemically-induced gladiolus dwarfs, but as a consequence of individual flower abortion (bud-blasting) rather than from failed inflorescence maturation. Dwarf watsonias only produced a modal number of four or five leaves, which was critical, as control and vacuum-control plants required a minimum of six leaves for successful spike emergence.

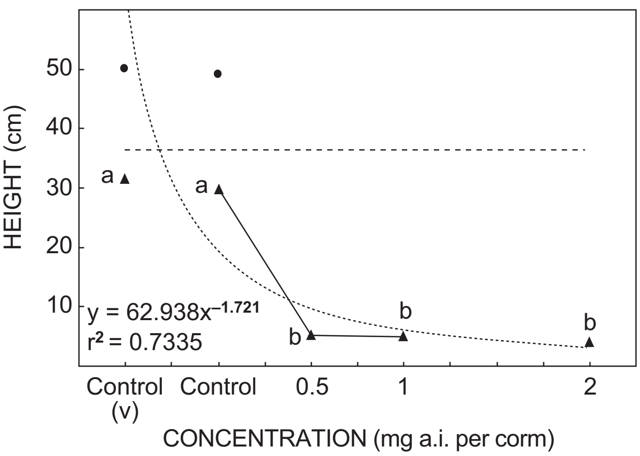

Figure 1: Effect of paclobutrazol concentration on perpendicular leaf (▲) and inflorescence (●) heights for vacuum-infiltrated corms of *Watsonia* 'Shrimp pink'. Corms were treated at the ready-for-planting stage (cataphylls extended by 2–3cm). Controls were untreated or infiltrated with dH_2O [control (v)]. The maximum acceptable height for flowering subjects is indicated at 36cm. Mean separation by Scheffé test for significant F. $F_{4,45}$ = 371.94, P < 0.01

Infiltration of 1mg paclobutrazol into more mature corms (leaves emergent) of both watsonia 'Shrimp pink' and *Watsonia tabularis* saw reductions in eventual leaf height (reduced to a maximum of 31% of controls) and number which were similar to those observed for the ready-for-planting corms (Tables 1 and 2). These data also suggest some degree of uniformity in response to paclobutrazol treatment among members of the same genus. It was also not necessary to vacuum-infiltrate corms to induce dwarfing — a long-term soak or passive infusion (24h, Table 2) produced a similar reduction in plant stature to vacuum-treatment in *Watsonia tabularis*, representing a more widely employable, cost-effective treatment. However, plants originating from the more developed corms which were retardant-treated were also unable to mature their inflorescences, irrespective of the method of infiltration.

Alternatively, 70% of corms treated when the developing shoot was less than 1.5cm high (comparatively under-developed corms), produced inflorescences which flowered. Leaf and inflorescence heights for these plants were significantly shorter than for controls, being reduced to 46% and 57% of control heights, respectively (Table 1). Modal leaf number for flowering dwarfs was six. Importantly, these flowering subjects of watsonia 'Shrimp pink' were below the 36cm size prescription, making them suitable for container cultivation. Subjects also presented a desirable leaf-to-inflorescence height ratio of 51:49, and the leaves were unblemished. To be commercially acceptable, no overly apparent phytotoxic effect of the treatment required for necessary growth control should be manifest (Bennell and Williams 1992). The inflorescences also emerged vertically — imparting a high degree of marketability. Paclobutrazol infiltration extended the time to first-flower anthesis by approximately three weeks (184 days after planting), and reduced the modal number of flowers borne per inflorescence from 10 to nine. Both are common carry-over effects of triazole treatment in the Iridaceae and elsewhere, being species-, cultivar- or variety-dependent (Gianfagna and Wulster 1986a, 1986b, Barzilay *et al*. 1992, Wulster and Ombrello 2000). Neither aspect impacted severely on the market value of the dwarf watsonia plants produced.

Table 1: Effect of 1mg paclobutrazol on perpendicular leaf and inflorescence heights (cm) and percentage flowering for vacuum-infiltrated corms of *Watsonia* 'Shrimp pink'. Cataphyll length at application correlates with emergent shoot maturity

	Control	Vacuum-infiltration		
	Cataphyll length (cm)			
	1.5–4	<1.5	2–3	>4[x]
Leaf height	29.9 a[y]	13.8 b (46)[z]	6.8 c (23)	7.6 c (25)
Inflorescence height	49.6 a	28.3 b (57)		
Flowering (%)	100	70	0	0

[x] First true leaf visible externally to sheath
[y] Mean separation within rows by Scheffé test for significant F
Leaf height: $F_{4,45}$ = 142.79, P < 0.01. Inflorescence height: $F_{3,19}$ = 19.36, P < 0.01
[z] Percent of control, in parentheses

The drastic reductions observed in plant stature irrespective of paclobutrazol concentration (Figure 2a), together with lost flowering capacity and reduced numbers of leaves in all but the most under-developed corms, suggest a physiological sensitivity of the shoot apex — specifically of the leaf and flower primordia — to the retardant at the time of application. The physical stresses of vacuum treatment cannot be responsible for failed flowering, since forced infiltration with dH_2O alone did not affect leaf or inflorescence height, or percentage flowering, relative to control plants (Figure 1). Congruently, passive infiltration with paclobutrazol caused inflorescence abortion (Table 2). Parallel work on the effect of environmental cues (temperature and photoperiod) on watsonia flowering revealed a five-leaf juvenile period (Mtshali *et al*. 2005). Thus, it seems likely that infiltration of paclobutrazol into more mature corms, which delivers the retardant directly to the shoot apex, adversely affects the ability of the plant to later transition from juvenile to the reproductive life-stage. Infiltration with paclobutrazol is therefore an unsuitable method for producing flowering dwarfs of watsonia 'Shrimp pink' and *Watsonia tabularis*, unless the chemical dwarfing treatment is applied at some undetermined time before extension of the cataphylls beyond 1.5cm — presumably before the formation of the terminal leaf and flower initials. In contrast, Barzilay *et al*. (1992) reported that vacuum-infiltration (in combination with other application treatments) was necessary to produce marketable-sized gladiolus dwarfs with retained percentage flowering. However, they gave no indication of the developmental stage of the corms at the time of infiltration.

Soil-drench applications of 5mg, 10mg and 20mg a.i. per pot all significantly decreased perpendicular leaf height relative to untreated plants in accordance with a logarithmic regression (r^2 = 0.996, Figure 3). Leaf heights were reduced to 75%, 63% and 49% of controls, respectively. Unlike vacuum-infiltration treatments, leaf number was unaffected by the dwarfing agent and all plants in all treatments retained the capacity to flower and ultimately matured their inflorescences (Figure 2b). Inflorescence heights were significantly reduced in a linear manner following treatment (r^2 = 0.998, Figure 3). Applications of 5mg, 10mg and 20mg paclobutrazol curtailed inflorescences to 83%, 62% and 28% of control heights respectively, with the two higher concentrations producing flowering subjects of marketable size. Unfortunately, increased concentration of the growth retardant produced an exaggerated distortion of the leaf-to-spike ratio, with the leaf contribution eventually dominating over an obscured inflorescence (Figure 2b). Although suitably reduced in stature, these dwarfs therefore fell considerably short of being ideal horticultural potted plant products. The increased dwarfing effect of drench applications of paclobutrazol on inflorescence height relative to leaf height was reported previously by Barzilay *et al*. (1992), but in response to a minimum dose of 10mg a.i. per pot. Collapse or lodging of less compact inflorescences was also observed at the higher concentrations, interpreted

Table 2: Effect of 1mg paclobutrazol on perpendicular leaf and inflorescence heights (cm) and percentage flowering for infiltrated corms of *Watsonia tabularis*. Corms were treated after elongation of the second true leaf

	Control	Vacuum-infiltration	Passive-infiltration
Leaf height	48.54 a[y]	13.17 b (27)[z]	15.17 b (31)
Inflorescence height	69.33		
Flowering (%)	100	0	0

[y] Mean separation within rows by Scheffé test for significant F $F_{3,45}$ = 70.57, P < 0.01
[z] Percent of control, in parentheses

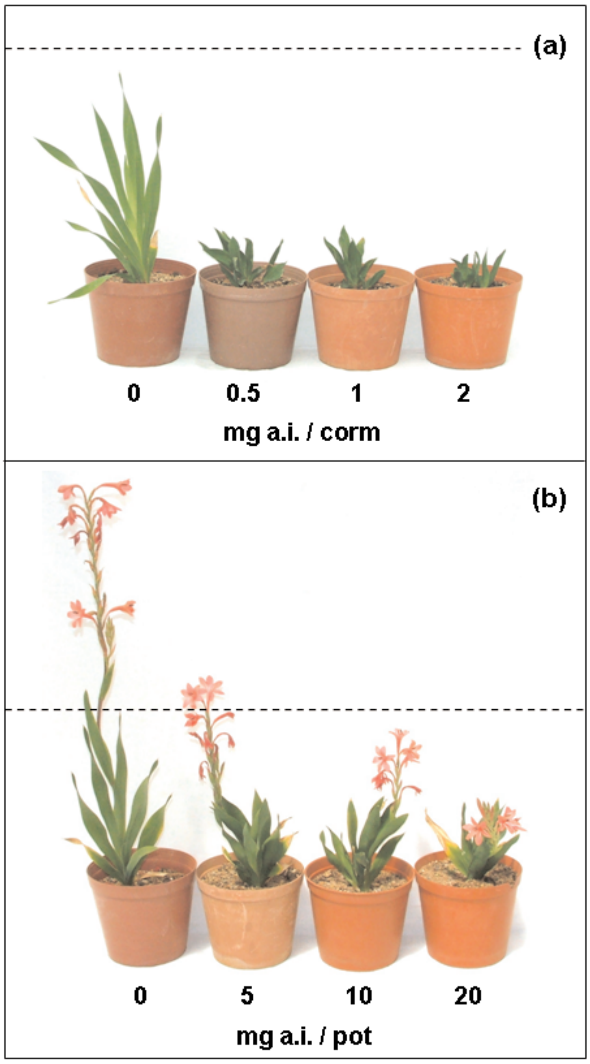

Figure 2: Effect of paclobutrazol on perpendicular leaf and inflorescence heights for *Watsonia* 'Shrimp pink' following: (a) vacuum-infiltration of ready-for-planting corms or (b) application as a post-emergent soil drench. Controls were untreated. Dwarfing was excessive and flowering was inhibited following infiltration, irrespective of concentration. The emergent inflorescence of the control plant is visible between the terminal leaves. Soil-drench application resulted in moderate reduction in plant stature, without compromising marketability at intermediate concentrations. The maximum acceptable height (36cm) for flowering subjects in 18cm rim-diameter pots is indicated (- - -)

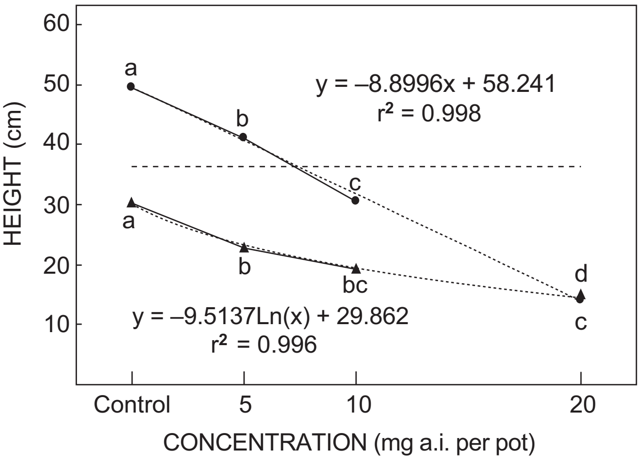

Figure 3: Effect of post-emergent soil-drench paclobutrazol concentration on perpendicular leaf (▲) and inflorescence (●) heights for *Watsonia* 'Shrimp pink'. Plants were treated when the second leaf reached 15cm in height. The maximum acceptable height for flowering subjects is indicated at 36cm. Mean separation by Scheffé test for significant F. Leaf height: $F_{3,33} = 33.77$, $P < 0.01$. Inflorescence height: $F_{3,27} = 39.69$, $P < 0.01$

after Sanderson *et al*. (1975) and Roh and Wilkins (1977) as reduced wall thickening of cortical sclerenchyma cells, and was observed previously in paclobutrazol drench-treated freesia (Gianfagna and Wulster 1986b). Increased concentration of paclobutrazol extended the time to first-flower anthesis by a maximum of 14 days following a dose of 20mg a.i. per pot (167 days from planting), and reduced the number of flowers borne per spike. The latter effect was only noteworthy (reduced from a modal number of 10 to seven flowers) following maximum paclobutrazol exposure.

In the current study, a single drench application of 10mg a.i. per pot shortened leaves and inflorescences to just over 60% of control heights, thus producing plants of marketable size (below the 36cm prescription) whilst retaining the natural leaf-to-inflorescence ratio (60:40). A drench application of 5mg paclobutrazol per pot produced plants with a more balanced (i.e. aesthetically favourable) leaf-to- spike ratio, but these unfortunately exceeded the size ceiling (Figure 2b and Figure 3). Regression analysis predicts that a dwarf watsonia of suitable stature for 18cm diameter container cultivation, but with retained marketability (minimised occurrence of inflorescence lodging and a balanced leaf-to-inflorescence ratio), could be achieved using a single drench application of approximately 7.5mg paclobutrazol per pot (Figure 3). Time to flowering and the number of flowers produced in such dwarfs would be similar to controls. Consequently, a medium drench treatment produces the most commercially-desirable plants.

Results for the chemical dwarfing of watsonia are therefore encouraging, with all indications being that these geophytes could successfully make the transition to pot cultivation. Both single application vacuum and drench treatments have the potential to produce dwarf plants with retained marketability, but we caution that the infiltration treatment requires far tighter control over the timing of application if the capacity for flowering is to be preserved. Paclobutrazol treatment provides immediate and, within limits, predictable reduction in watsonia stature, offering reprieve from conventional and costly long-term breeding programmes in order to introduce horticultural novelty.

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References

Badu P, Chawla HS (2000) *In vitro* regeneration and *Agrobacterium*-mediated transformation in gladiolus. *Journal of Horticultural Science and Biotechnology* **75**: 400–404

Barrett JE, Nell TA (1989) Comparison of paclobutrazol and uniconizole on floriculture crops. *Acta Horticulturae* **251**: 275–288

Barrett JE, Bartuska CA, Nell TA (1994) Comparison of paclobutrazol drench and spike applications for height control of potted floriculture crops. *HortScience* **29**: 180–182

Barzilay A, Ben-Jaacov J, Cohen A, Ion A, Halevy H (1992) Minigladiolus as a flowering pot plant. *Scientia Horticulturae* **49**: 117–124

Beattie DJ (1982) Minimum attention helps popularity of herbaceous perennial pot plants. *Florists' Review* **171**: 66, 71–72, 74

Bennell MR, Williams RR (1992) Cultivation of the pink mulla mulla, *Ptilotus exaltatus* Nees. 2. Nutrition and growth regulation. *Scientia Horticulturae* **51**: 107–110

Berghoef J, Zevenbergen AP (1990) The effects of precooling, environmental factors and growth-regulating substances on plant height of Freesia as potplant. *Acta Horticulturae* **266**: 251–257

Cohen A, Barzilay A (1991) Miniature *Gladiolus* cultivars bred for winter flowering. *HortScience* **26**: 216–218

Cox DA, Keever GJ (1988) Paclobutrazol inhibits growth of zinnia and geranium. *HortScience* **23**: 1029–1030

Deneke CF, Keever GJ (1992) Comparison of application methods of paclobutrazol for height control of potted tulips. *HortScience* **27**: 1329

De Villiers SM, Kamo K, Thomson JA, Bornman CH, Berger DK (2000) Biolistic transformation of chincherinchee (*Ornithogalum*) and regeneration of transgenic plants. *Physiologia Plantarum* **109**: 450–455

Duncan G (2002) Dwarf watsonias: ten of the best for containers and rock gardens. *Veld and Flora* **88**: 94–98

Ecker R, Barzilay A, Afgin L, Watad A-EA (1992) Growth and flowering responses of *Matthiola incana* L. R. BR. to paclobutrazol. *HortScience* **27**: 1330

Fennell C, Van Staden J (2003) Biotechnology of southern African bulbs. *South African Journal of Botany* **70**: 37–46

Gianfagna TJ, Wulster GJ (1986a) Comparative effects of ancymidol and paclobutrazol on Easter lily. *HortScience* **21**: 263–264

Gianfagna TJ, Wulster GJ (1986b) Growth retardants as an aid to adapting freesia to pot culture. *HortScience* **21**: 463–464

Gilbertz DA (1992) Chrysanthemum response to timing of paclobutrazol and uniconazole sprays. *HortScience* **27**: 322–323

Goulston GH, Shearing SJ (1985) Review of the effects of paclobutrazol on ornamental pot plants. *Acta Horticulturae* **167**: 339–348

Hamada M, Hosoki T, Maeda T (1990) Shoot length control of tree-peony (*Paeonia suffruticosa*) with uniconazole and paclobutrazol. *HortScience* **25**: 198–200

Hanks GR, Menhenett R (1979) Responses of potted tulips to new and established growth-retarding chemicals. *Scientia Horticulturae* **10**: 237–254

Henting VW-U (1985) Treatment of rarely cultivated pot-plants with growth regulators. *Acta Horticulturae* **167**: 309–326

Jansen van Vuuren PJ (1995) New ornamental crops in South Africa. *Acta Horticulturae* **397**: 71–84

Jansen van Vuuren PJ, Coetzee JH, Coertse A (1993) South African flowering plants with a potential as future floriculture crops. *Acta Horticulturae* **337**: 65–71

Kamo K, McElroy D, Chamberlain D (2000) Transforming embryogenic cell lines of *Gladiolus* with either a *bar-uidA* fusion gene or co-bombardment. *In Vitro Cellular and Developmental Biology — Plant* **36**: 182–187

Kim K-W, De Hertogh AA (1997) Tissue culture of ornamental flowering bulbs (geophytes). Horticultural Reviews **18**: 87–169

Larson RA (1985) Growth regulators in floriculture. *Horticultural Reviews* **7**: 399–481

McDaniel GL (1990) Postharvest height suppression of potted tulips with paclobutrazol. *HortScience* **25**: 212–214

Menhenett R (1984) Comparison of a new triazole retardant, paclobutrazol (PP333), with ancymidol, chlorophoium chloride, daminozide and piproctanyl bromide, on stem extension and inflorescence development in *Chrysanthemum morifolium* Ramat. *Scientia Horticulturae* **24**: 349–358

Menhenett R, Hanks GR (1982/83) Comparisons of a new triazole retardant PP 333 with ancymidol and other compounds on pot-grown tulips. *Plant Growth Regulation* **1**: 173–181

Million JB, Barrett JE, Nell TA, Clark DG (1998) Influence of media components on efficacy of paclobutrazol in inhibiting growth of broccoli and petunia. *HortScience* **33**: 852–856

Million JB, Barrett JE, Nell TA, Clark DG (1999) Inhibiting growth of flowering crops with ancymidol and paclobutrazol in sub-irrigation water. *HortScience* **34**: 1103–1105

Million JB, Barrett JE, Nell TA, Clark DG (2002) One time vs continuous application of paclobutrazol in sub-irrigation water for the production of bedding plants. *HortScience* **37**: 345–347

Mtshali NP, Thompson DI, Erwin J, Van Staden J (2005) The influence of temperature, photoperiod and irradiance on flowering of *Watsonia* species. *South African Journal of Botany* **71**: 283

Niederwieser JG, Kleynhans R, Hancke FL (2002) Development of a new flower bulb crop in South Africa. *Acta Horticulturae* **570**: 67–73

Rebers M, Romeijn G, Knegt E, Van der Plas LHW (1994) Effects of exogenous gibberellins and paclobutrazol on floral stalk growth of tulip sprouts isolated from cooled and non-cooled tulip bulbs. *Physiologia Plantarum* **92**: 661–667

Roh SM, Wilkins HF (1977) The influence and interaction of ancymidol and photoperiod on growth of *Lilium longiflorum*. *Journal of the American Society for Horticultural Science* **102**: 255–257

Rounkova IV (1989) Effect of ethylene-producing substances and cultar on some ornamental plants. *Acta Horticulturae* **251**: 281–285

Sanderson KC, Martin WC Jr, Marcus KA, Goslin WE (1975) Effects of plant growth regulators on *Lilium longiflorum* Thunb. cv. Georgia. *HortScience* **10**: 611–612

Sanderson KC, Martin WC Jr, McGuire J (1988) Comparison of paclobutrazol tablets, drenches, gels, capsules, and sprays on chrysanthemum growth. *HortScience* **23**: 1008–1009

Statsoft Inc. (1998) *Statistica for Windows: Computer Program Manual*. Statsoft Inc., Tulsa

Wang Y-T, Gregg LL (1991) Modifications of hibiscus growth by treating unrooted cuttings and potted plants with uniconazole or paclobutrazol. *Journal of Plant Growth Regulation* **10**: 47–51

Wang Y-T, Hsu T-Y (1994) Flowering and growth of *Phalaenopsis* orchids following growth retardant applications. *HortScience* **29**: 285–288

Wilkinson RI, Richards O (1987) Effects of paclobutrazol on growth and flowering of *Bouvardia humboltii*. *HortScience* **22**: 444–445

Wulster GJ, Gianfagna TJ (1991) *Freesia hybrida* respond to ancymidol, cold storage of corms and greenhouse temperatures. *HortScience* **26**: 1276–1278

Wulster GJ, Ombrello TM (2000) Control of height and flowering of *Ixia* hybrids as container plants. *HortScience* **35**: 1087–1088

Ziv M (1997) The contribution of biotechnology to breeding, propagation and disease resistance in geophytes. *Acta Horticulturae* **430**: 247–258

Edited by CH Bornman