Influence of fertility, plant growth retardants, and substrates on plant growth and postharvest quality of potted sunflowers

by

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Influence of fertility, plant growth retardants, and substrates on plant growth and postharvest quality of potted sunflowers

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Plant growth retardant (PGR) foliar sprays (mg·L^{-1}) of daminozide at concentrations from 1,000 to 16,000; paclobutrazol from 5 to 80; and uniconazole from 2 to 32 were applied to 'Pacino' pot sunflowers (*Helianthus annuus* L.) to compare their effectiveness at chemical height control. Total plant height, plant diameter, inflorescence diameter, and days until flowering were significant for the PGR treatment interaction. Marketable-sized plants grown in the 1.2-L pots were produced with uniconazole concentrations between 16 and 32 mg·L^{-1} or with daminozide concentrations between 4000 and 8000 mg·L^{-1}. Paclobutrazol foliar sprays up to 80 mg·L^{-1} had little effect. Drenches of PGR paclobutrozol were applied at 2, 4, 8, 16, or 32 mg active ingredient (a.i.)/pot, plus an untreated control to potted sunflowers to determine its effect on growth. Number of days from seeding until anthesis, total plant height, inflorescence diameter, and days until anthesis were significant for the PGR treatment and seasonal interaction. Plant growth was greater during summer than spring. Marketable sized plants grown in 15- to 16.5-cm-diameter pots were produced with paclobutrazol drench concentrations of 2 and 4 mg in both seasons, and 8 mg was also effective during the summer. Paclobutrazol drench applications of 0, 2, and 4 mg a.i./pot were applied to 'Pacino' potted sunflowers and 'Red Pigmy' tuberous rooted dahlias grown in substrates containing 50, 60, 70, or 80% (by vol.) *Sphagnum* peat or coir, with the remainder being perlite, to study the efficacy of paclobutrazol. Potted sunflower plant height significantly differed for peat and coir-based substrates, plant diameter was significantly influenced by the percentage of peat or coir in the substrates and paclobutrazol concentration, and inflorescence diameter was also

significantly influenced by paclobutrazol concentration. Though there was a difference in sunflower plant height between the peat and coir-based substrates, with greater plant growth being observed in coir-based substrates, the percent height control from the untreated plants caused by paclobutrazol was similar for both peat and coir-based substrates. This suggests a similar degree of paclobutrazol activity in both coir and peat-based substrates. Quality plants with longer postharvest life were produced with N at 100 $mg{\cdot}L^{-1}$ and by terminating fertilization 55 days after potting.

GENERAL INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the few crop species that originated in North America (most originated in the fertile crescent of Asia or in South and Central America). It was probably a "camp follower" of several of the western native American tribes who domesticated the crop (possibly 1000 B.C.) and then carried it eastward and southward in North America (Putnam et al., 1990). Sunflower has become one of the most important commercial crops in the world due to its high value as an oil and forage plant (Carter, 1978). Sunflower accounts for about 14% of the world production of seed oils (6.9 million metric tons of sunflower seed in 1985-86) and about 7% of the oilcake and meal produced from oilseeds (Putnam et al., 1990). Sunflower was probably first introduced to Europe through Spain, and spread through Europe as a curiosity until it reached Russia, where it was readily adapted (Putnam et al., 1990).

In recent years sunflower has also became a popular cut flower. Some growers even sell them as flowering pot plants or bedding plants (Healy, 1997). The highly developed, attractive inflorescence and foliage make it an a ideal potted floricultural crop. Potted sunflower has been popular in Europe for a number of years (Whipker and Dasoju, 1997). Potted sunflower is a relatively new floricultural crop in the North America and its popularity is still increasing. Noordegraaf (1987) describes a 'new floricultural crop' as one which has been grown for a long time but suddenly has received more attention and demand, stimulated by the saturation of the market by the main, traditional crops. Besides market saturation, the need to buy something else new stimulates the demand for other 'new' crops. Noordegraaf (1987) also states the three most important steps in development of a new crop as: introduction; breeding and selection; and cultural practices during production of the crop.

Potted sunflowers are a quick crop to produce and offer an opportunity for growers to capitalize on current demand for the plant if appropriate pot culture production practices are followed.

Objectives

The objectives of this research was,

A. To compare the effectiveness of foliar sprays of daminozide, paclobutrazol, and uniconazole as a chemical height control for potted sunflowers.

B. To determine the effectiveness of drench doses of paclobutrazol as a chemical height control for potted sunflowers.

C. To determine the activity of paclobutrazol drenches in coir and peat-based media and their influence on plant growth of potted sunflowers.

D. To identify the influence of N concentration, in combination with time of termination of fertilization, on plant growth and postharvest keeping quality of potted sunflowers.

Thesis Organization

This thesis consists of a review of relevant literature and four research manuscripts prepared in partial fulfillment of the requirements for the degree, Master of Science. Following the introduction is a review of relevant literature related to chemical growth retardants, media substrates, plant nutrition and postharvest longevity. The first three manuscripts have been submitted to *HortTechnology*. The fourth manuscript will be submitted to *Journal of Plant Nutrition*. Following the manuscripts are general conclusions and acknowledgments. The first manuscript for which I am the secondary author is primarily authored by Dr. Brian Whipker who is my major professor. My contribution towards this manuscript include: carrying out the experiment; collecting data and finally writing up a part of the manuscript, all of which form a major contribution to the project justifying the inclusion of this manuscript in my thesis.

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LITERATURE REVIEW

Foliar application of Plant growth retardants (PGR's)

Ornamental crops are frequently restricted in plant growth by the use of plant growth retarding chemicals for enhancement of appearance, conservation of production space, efficiency of operation, and prevention of overgrowth during marketing or during their final use as indoor or outdoor decorative plants (Shanks, 1980). A problem with many plant growth retardants (PGR's) has been finding an efficient application method that produces consistent results (Barrett et al., 1994). Sachs et al. (1976) recommended that optimal plant height should be 1.5 to 2 times the container height. These recommendations for plant height of potted plants varies with the species grown. PGR's are thought to indirectly influence flowering of several floricultural crops by retarding vegetative growth, or by promoting flower bud initiation in some crops and flower bud development in others (Larson, 1985).

Tjia and Sheehan (1986) did not find a delay in flowering with ancymidol or daminozide foliar sprays of 2500, 5000, or 7500 $mg{\cdot}L^{-1}$ when applied on lisianthus (*Eustoma grandiflorum* Shinn.). Halevy and Kofranek (1984) found that ancymidol at 0.5-mg a.i./pot advanced flowering by 10 days and daminozide foliar sprays of 2500, 5000, or 7500 $mg{\cdot}L^{-1}$ delayed flowering of lisianthus when grown at 13C, but not at 18C. In another study with lisianthus, daminozide at 2500, 5000, or 7500 $mg{\cdot}L^{-1}$ and ancymidol both delayed flowering by 10 to 14 days (Wobbe and Campbell, 1986). These diverse responses may possibly be due to variation in growing conditions in diverse geographical areas and of cultivar specificity; therefore thorough testing of growth retardants is essential in developing reliable recommendations for growers. Daminozide has been the most widely used growth retardant because it is easy to use and plant response is predictable (Crater, 1980). Ancymidol is also effective and may be applied as a foliar spray or substrate drench, whereas daminozide is effective only as a foliar spray (Nelson, 1985).

Foliar sprays of paclobutrazol and uniconazole effectively reduce stem elongation on various herbaceous crops (Davis et al., 1988). Generally, uniconazole has been more active than paclobutrazol in trials with lilies (*Lilium longifolium* Thumb.) (Wilfret, 1987), chrysanthemum (*Dendranthema grandiflorum* (Ramat.) Kitamura) (Barrett and Nell, 1989, 1990), foliage plants (Wang and Blessington, 1990), and other herbaceous species (Barrett and Nell, 1989; Davis et al., 1987). Barrett and Nell (1992) found that foliar application of uniconazole on four bedding plant species (*Impatiens* L. *Wallerana* Hook, *Salvia splendens* Sello ex Nees, *Tagetes erecta* L., and *Petunia hybrida* Vilm) reached a saturation level at concentrations of 80 $mg{\cdot}L^{-1}$, and there was little change in effect with incremental increase in concentration above 160 $mg{\cdot}L^{-1}$. At these concentrations, paclobutrazol had not reached its saturation level and was still in the linear portion of the response curve.

Foliar sprays (66 and 132 $mg{\cdot}L^{-1}$) of ancymidol decreased plant height, node number, fresh and dry weights, and leaf area of four sunflower cultivars grown in pots under greenhouse conditions (Starman et al., 1989). In the above study, field grown sunflower cultivars were grown in pots under greenhouse conditions. The only recommendation available for pot sunflower suggests applying foliar sprays of an unspecified concentration of daminozide three weeks after sowing for height control of potted sunflowers (Benary Seed, 1996).

Drench application of PGR's

PGR's are commonly applied to containerized crops when plants are likely to become disproportionately large relative to container size (Barrett et al., 1994; Tayama et al., 1992). Paclobutrazol provides good height control of several floricultural crops such as caladium, impatiens, salvia, and marigold (Barrett and Nell, 1989; Shanks, 1980). It is active when applied to the growing medium, but has little efficacy when applied to leaves because it is not translocated out of leaves (Barrett and Bartuska, 1982; Davis et al., 1988). Drench application of PGR's is often the preferred method of application, since they are more precise, their effectiveness is influenced less by environmental factors than foliar sprays, and there is no risk from spray drift. Paclobutrazol drenches produce good height control on various container-grown floricultural crops (Barrett and Nell, 1989). Paclobutrazol and ancymidol, applied as soil drenches, retarded easter lilly height more effectively than foliar sprays (Gianfagna and Wulster, 1986). Wilfret (1981) found that soil applications at 0.0625 to 2 mg active ingredient (a.i.) per plant were effective on poinsettia (*Euphorbia pulcherrima* Willd.), but foliar applications up to 1 mg per plant had little effect. Barrett and Bartuska (1982) compared the application of paclobutrazol as a liquid spray to the whole shoot, painted on plant stems, or painted on fully developed leaves of 'Bright Golden Anne' chrysanthemums. They found that spray applications of paclobutrazol to the stem were more effective at reducing stem elongation than leaf applications. Thus, the reduced effectiveness of paclobutrazol applied to mature leaves suggests that it was poorly translocated through the phloem compared to the xylem. Work with other growth retardants indicates that ancymidol is readily translocated from mature leaves to the stem of chrysanthemum (Robson et al., 1981) and that chlormequat moves in both xylem and phloem of monocots and dicots (Moore, 1968). Paclobutrazol applied as a spray may be absorbed by both the leaves and stems, but only the chemical is absorbed by the stem is effectively translocated to its site of action in the shoot apex, probably via the xylem (Barett, 1994). Other problems associated with paclobutrazol sprays are possible delay in flowering or reduction of flower size, which are notable problems with poinsettias and impatiens. Drenches have much less effect on flower development in all crops compared to spray treatments (Barrett, 1994).

Wample and Culver (1983) applied paclobutrazol drenches of 11.6, 58, and 116 mg of active ingredient (a.i.) per liter to sunflowers and found that water use decreased as paclobutrazol concentration increased. This was attributed to a reduction in both leaf expansion and internodal elongation, which resulted in reducing plant height measured at the end of the 8-

14 day experimental period. In that study, field grown sunflower cultivars were grown in pots under greenhouse conditions. No standard drench recommendations for paclobutrazol are available for potted sunflowers.

Root substrates and paclobutrazol drenches

Peat moss (peat) is one of the most extensively used substrates in the production of containerized greenhouse and nursery crops. Environmental concerns (Barkham, 1993; Buckland, 1993; Cresswell, 1992; Robertson, 1993) and increasing prices have generated significant interest in the development of alternatives to peat. Many waste materials, such as rice hulls, nut husks, and sewage sludge, have been used in container production. When these waste materials were used in correct proportions, acceptable plant material was produced (Nash and Hegwood, 1978). Most research into development of peat substitutes has focused on use of pine bark and coir dust (CD). Talukdar and Barooah (1987) reported that coconut fiber moss resulted in 'superior flowering' in *Dendrobium densiflorum* Wallich x Lindl. Evans and Stamps (1996) reported higher root fresh mass for geranium (*Pelargonium x hortorum* L.H.Bail.) and higher shoot fresh mass for marigold (*Tagetes patula* L.) and petunia (*Petunia x hybrida* Vilm - Ands.) when plants were grown in coir-based substrates than in peat-based substrates.

Substrate drenches of PGR's are often the preferred method of application, since they are more precise and their effectiveness is less influenced by environmental factors than foliar sprays. Paclobutrazol drenches effectively control plant height of various container grown floricultural crops such as ageratum, antirrhinum, begonia, celosia, and chrysanthemum (Shanks, 1980). The base organic composition and particle size of the media influences paclobutrazol activity (Barrett, 1982, Quarrels and Newman, 1994). Quarrels and Newman (1994) found significant reduction in efficacy of paclobutrazol drenches (0.25 or 0.50 mg a.i./pot) applied to poinsettias grown in pine-bark based media, when compared to those grown in peat-based media. Similar results of paclobutrazol activity inhibition at 0.25 mg a.i./pot were reported by Barrett (1982) for chrysanthemum (*Dendranthema grandiflora* Tzuelev.) grown in pine-bark based media, with plants being 20% taller in pine bark-based substrates, compared to those grown in peat based substrates, for the same concentration of paclobutrazol applied. To compensate this reduction in activity of paclobutrazol the application rate needs to be increased for media having pine bark as a component. This increase will be 25 to 100 percent depending on the amount of pine bark and how decomposed it is (Barrett, 1994).

It is uncertain if CD alters the efficacy of paclobutrazol drenches. Paclobutrazol activity in CD needs to be thoroughly investigated before recommendations for drench application can be developed.

Nutrition, plant growth, and post harvest keeping quality of potted sunflowers

The use of blooming plants in interior landscapes can be limited by their relatively short postharvest life (Harlass, 1992; Newman, 1992). Therefore, plant choice is restricted to those that remain attractive for the longest time possible to reduce replacement costs. Longevity and interior performance of flowering potted plants has become a primary area of concerns for commercial producers, floral buyers and consumers (Nell and Hoyer, 1995).

Production and cultural practices influence postharvest quality of many potted plants. Long-term influence of cultural practices such as fertilization on postharvest qualities have been investigated on a number of crops. Surpluses or deficiencies of nutrients can create plant stress, which accelerates senescence (Roberts et al., 1984). Research on chrysanthemums (*Dendranthema grandiflora* Tzuelev.) has shown that postharvest keeping quality is effected by preharvest and postharvest practices (Halvey et al., 1978; Waters, 1965, 1967; Woltz and Waters, 1967). Higher levels of nitrogen (N) at 300 $mg{\cdot}L^{-1}$ have been found to reduce the keeping quality of chrysanthemum (Joiner and Smith, 1962; Woltz and Waters, 1967), whereas reduction in N fertilization from 15 lb/A/week during the later part of growing season increased chrysanthemum keeping quality (Waters, 1967). Conover et al. (1993) found that production plant grades and postharvest quality of begonias (*Begonia x semperflorens - cultorum* Hort.) were greatest at lower fertility rates of 1gm/10-cm pot of 14N-6.2P-11.6K Osmocote [Fast release (FR)], than at 1.5, 2.0 or 2.5 gm/10 cm-pot. Poinsettia (*Euphorbia pulcherrima* Willd.) plant quality and postharvest life were also extended by terminating fertilization two weeks before sale (Staby and Kofranek, 1997). Investigation with *Ficus benjamin* L. showed that high concentrations of fertilizer during growth increased leaf drop when the plants were transferred to an interior environment (Conover and Poole, 1977a; Milks et al., 1979). In another study, Conover and Poole (1977b) found that *Aphelandra squarrosa* Nees. plants receiving 0.9 kg N, 0.4 kg P, and 0.8 kg K/100 m^2 per month had better plant grades than those receiving fertilizer levels which were two or three times greater. In all the above studies postharvest life of potted plants decreased as fertilizer concentration increased. The more fertilizer given during the production of potted plants, the higher the level of salt accumulation, which means poorer post-harvest quality in the consumer's home (Conover and Poole, 1977a, b; Milks et al., 1979).

Production conditions must be evaluated on each crop, on multiple cultivars, and under varying cultural practices to fully establish criteria for extending the longevity of flowering potted plants. There has been no previous work on potted sunflowers to establish correlation between N levels during cultivation and their postharvest keeping quality.

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POT SUNFLOWER GROWTH AND FLOWERING RESPONSES TO FOLIAR APPLICATIONS OF DAMINOZIDE, PACLOBUTRAZOL, AND UNICONAZOLE

A paper submitted to HortTechnology

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Abstract

Plant growth retardant (PGR) foliar sprays (mg·L^{-1}) of daminozide at concentrations from 1,000 to 16,000; paclobutrazol from 5 to 80; and uniconazole from 2 to 32 were applied to 'Pacino' pot sunflowers (*Helianthus annuus* L.) to compare their effectiveness at chemical height control. Plants were grown in 650 mL or 1.2-L pots. When the first inflorescence opened, number of days from seeding until anthesis, total plant height measured from the pot rim to the top of the inflorescence, inflorescence diameter, and plant diameter were recorded. There was no significant difference in plant height between 'Pacino' plants grown in 650 mL or 1.2-L pots. Total plant height, plant diameter, inflorescence diameter, and days until flowering were significant for the PGR treatment interaction. Marketable-sized plants grown in the 1.2-L pots were produced with uniconazole concentrations between 16 and 32 mg·L^{-1} or with daminozide concentrations between 4000 and 8000 mg·L^{-1}. Paclobutrazol foliar sprays up to 80 mg·L^{-1} had little effect, and higher foliar spray concentrations or medium drench treatments should be considered.

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INTRODUCTION

Annual sunflower is native to North America, and cultivars grown for seed or oil are tall with a prominent inflorescence. Pot sunflower plants can become disproportionately large relative to their container size when grown in a greenhouse, making them less attractive to consumers. Plant growth retardants (PGRs) are commonly applied to containerized crops when plants are likely to become disproportionately large relative to the container (Barrett et al., 1994; Tayama et al., 1992). Foliar sprays (66 and 132 mg·L^{-1}) of ancymidol (α-cyclopropyl-α-(4-methoxyphenyl)-5-pyrimidinemethanol) decreased plant height, node number, fresh and dry weights, and leaf area of four sunflower cultivars grown in pots under greenhouse conditions (Starman et al., 1989). Wample and Culver (1983) applied paclobutrazol ((+)-(R*,R*)-ß([4-chlorophenyl]methyl)-α-(1,1-dimethylethyl)-1*H*-1,2,4-triazole-1-ethanol) drenches of 11.6, 58, and 116 mg of active ingredient (a.i.) per liter to sunflowers and found water use decreased as paclobutrazol concentration increased. This was attributed to a reduction in both leaf expansion and internodal elongation, which resulted in reduced plant height measured at the end of the 8-14 day experimental period. In both of the above studies, field grown sunflower cultivars were grown in pots under greenhouse conditions. The only recommendation available for pot sunflowers suggests applying foliar sprays of an unspecified concentration of daminozide three weeks after sowing for height control of pot sunflowers (Benary Seed, 1996). This study was conducted to compare the effectiveness of daminozide, paclobutrazol, and uniconazole ((E)-1-(p-chlorphenyl)-4,4-dimethyl-2-(1,2,4-triazol-1-yl-1-penten-3-ol)) as a chemical height control for 'Pacino' pot sunflowers grown in 650 mL and 1.2-L containers.

MATERIALS AND METHODS

Expt. 1 'Pacino' pot sunflower seeds were sown into cell packs (8 x 4 x 5.5 cm cells) on 25 Jan. 1996. On 15 Feb. the seedlings were transplanted into 650 mL (11 cm diameter) or 1.2-L (15-cm-diameter) round plastic pots. The root medium contained 2 soil : 5 sphagnum peat : 3 perlite (by volume) and was amended with ground dolomitic limestone to pH 5.1. Plants were fertilized at each watering ($mg{\cdot}L^{-1}$) with 155 N, 21 P, and 127 K. Greenhouse day/night set points were 24/18 °C. The plants were grown under natural day length. Fifteen PGR foliar spray treatments ($mg{\cdot}L^{-1}$) were applied 18 days after potting by using a volume of 204 $ml{\cdot}m^{-2}$: daminozide at 1,000, 2,000, 4,000, 8,000, or 16,000; paclobutrazol at 5, 10, 20, 40, or 80; uniconazole at 2, 4, 8, 16, or 32; and an untreated control. A completely randomized design of 10 single-plant replications of the 32 treatment combinations (2 pot sizes x 16 PGR treatments including the control) was used. When the first inflorescence opened, the number of days from seeding until anthesis, total plant height measured from the pot rim to the top of the inflorescence, inflorescence diameter (measured at the widest dimension and turned 90^{o}, and averaged), and plant diameter (measured at the widest dimension and turned 90^{o}, and averaged) were recorded. Data were tested by analysis of variance by general linear model procedures (SAS Institute, Cary, NC). Means were separated by least significant differences (LSD) at P 0.05.

Expt. 2 The same procedures used in expt. 1 were repeated, except as noted. 'Pacino' pot sunflower seeds were sown into cell packs on 18 Dec. 1996 and seedlings were transplanted into 1.2-L (15-cm-diameter) round plastic pots on 5 Jan. 1997. The PGR foliar spray treatments of daminozide and uniconazole were applied 15 days after potting at the same concentration as expt. 1. The paclobutrazol treatments were not applied. A completely randomized design of 8 single-plant replications of the 11 treatment combinations (1 pot size x 11 PGR treatments including the control) was used.

RESULTS AND DISCUSSION

Results of the foliar PGR applications were similar for both experiments and only expt. 1 results are reported. Pot size x PGR treatment interaction was not significant. Total plant height, plant diameter, inflorescence diameter, and days until anthesis were significant for the PGR main effect.

Total Height: 'Pacino' pot sunflowers were not responsive to paclobutrazol concentrations 20 mg·L^{-1} or uniconazole concentrations 4 mg·L^{-1} when compared to the untreated control (Fig. 1). Plants treated with 40 and 80 mg·L^{-1} of paclobutrazol were 6% shorter than the untreated control. Total plant height was 5% shorter than the untreated control with uniconazole at 8 and 16 mg·L^{-1}, and 17% shorter at 32 mg·L^{-1}. Daminozide at all concentrations resulted in shorter plant height by ≥17% with concentrations ≥4000 mg·L^{-1}, with effectiveness increasing as the concentration increased. Plants treated with the highest concentrations of all three PGRs exhibited crinkled upper leaves, indicating excessive concentrations. In addition, plants treated with 16,000 mg·L^{-1} daminozide developed flower heads oriented upwards (perpendicular to the stem at a 45° angle) instead of parallel to the stem.

Plant Diameter: Plant diameter was not affected by daminozide (Fig. 1). Paclobutrazol at 80 mg·L^{-1} produced plants 6% smaller in diameter, and uniconazole concentrations ≥8 mg·L^{-1} resulted in plants 4% smaller in diameter, when compared to the control.

Inflorescence Diameter: Uniconazole at 32 mg·L^{-1} and daminozide at 4000 mg·L^{-1} resulted in an inflorescence diameter 5% smaller when compared to the untreated control (Table 1). Inflorescence diameter was not affected by paclobutrazol.

Days to Anthesis: The number of days from seeding to anthesis were significant for the PGR main effect. A statistical significant delay in flowering occurred only with the highest concentration of paclobutrazol (80 mg·L^{-1}) and uniconazole (32 mg·L^{-1}), and with daminozide concentrations 8,000 mg·L^{-1} (Table 1). Flowering was 2 to 3 days later than the untreated control. Although the delay was statistically significant, it would not be a detrimental delay to commercial growers. The two to three day delay of flowering is shorter than the 10 to 18 day delay reported when three foliar applications of daminozide at 1,500 mg·L^{-1} were used in Germany (Benary Seed Co., personal communication).

CONCLUSIONS

Sachs et al. (1976) recommended that optimal plant height should be 1.5 to 2 times the container height. In this study, marketable sized plants grown in the 1.2-L pots were produced with uniconazole concentrations between 16 and 32 mg·L^{-1} or with daminozide concentrations between 4000 and 8000 mg·L^{-1}, even though they were two to three times taller than the pot height of 12.5 cm. Inflorescence diameter was reduced with the 32 mg·L^{-1} uniconazole and both the 4000 and 8000 mg·L^{-1} daminozide sprays. While flowering was delayed with the 32 mg·L^{-1} uniconazole and 8000 mg·L^{-1} daminozide sprays. The choice of PGRs to control the growth of pot sunflowers should be based on the response of the plant and the cost of the PGR (Table 1). The desired control of growth was obtained for the lowest cost by using daminozide at the cost of \$0.36 to \$0.71 per 100 1.2-L pots, which was between 45 to 72% less expensive than uniconazole.

At the concentrations used, paclobutrazol had little effect on plant height and medium drench treatments or higher spray concentrations -although delay in flowering should be expected- should be considered. There was no significant difference in plant height between ‘Pacino’ plants grown in 650 mL or 1.2-L pots. For ‘Pacino’ to be suitable when grown in 650 mL pots, a smaller sized plant will have to be produced. This may be possible by applying PGRs earlier in the production cycle or by using medium drench treatments.

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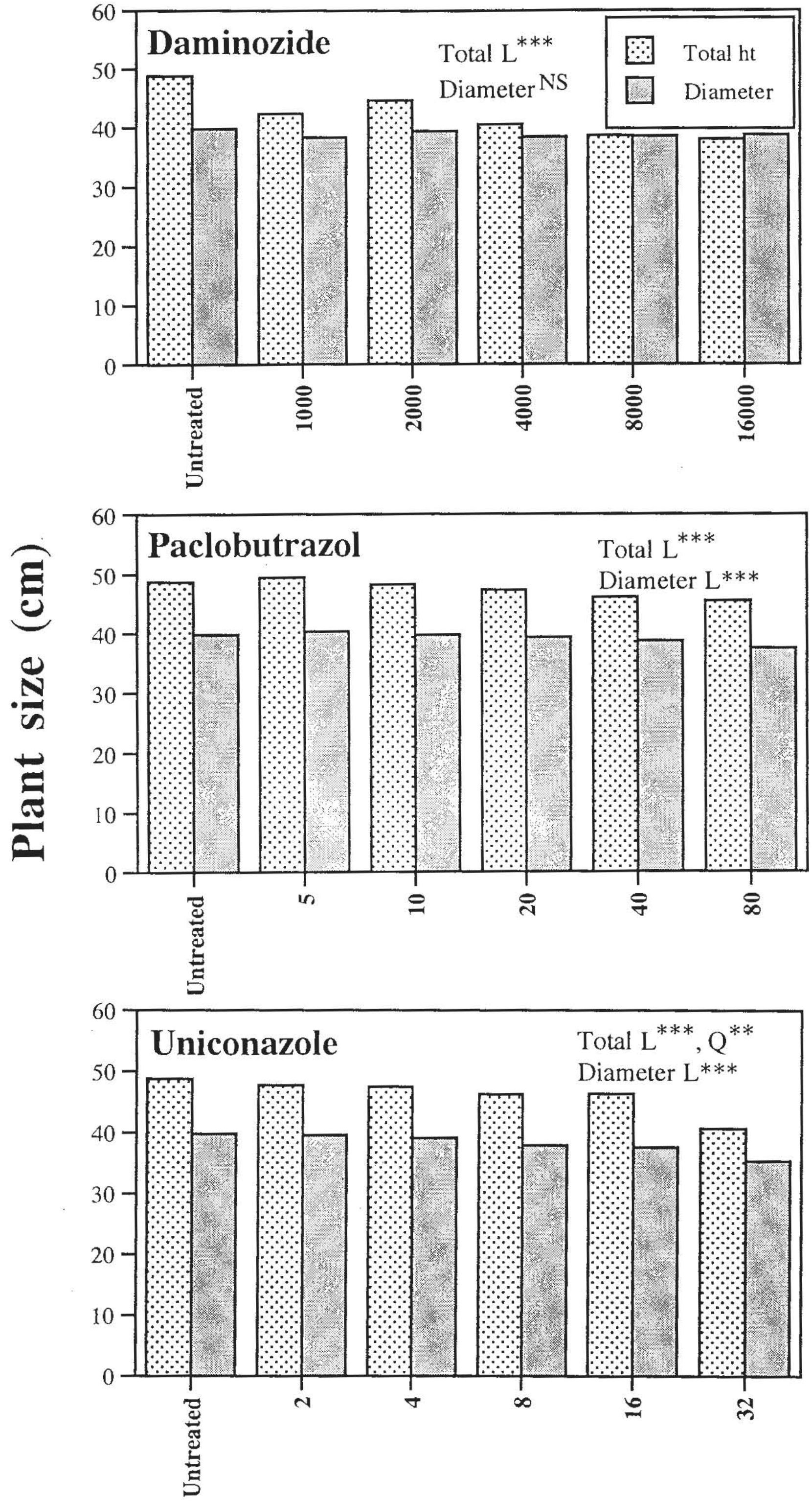
Figure 1. Effect of foliar applications of daminozide, paclobutrazol, and uniconazole ($mg \cdot L^{-1}$) on total plant height and plant diameter of 'Pacino' pot sunflowers. Total height and plant diameter were both significant at P 0.001 for the plant growth retardant (PGR) treatments. LSD (α 0.05) for total plant height and plant diameter were 2.2 and 1.6, respectively, for the PGR treatments. $^{NS, **, ***}$ Nonsignificant or significant by single-degree-of-freedom test for each treatment grouping at P 0.01 or 0.001, respectively; respectively L=linear, Q=quadratic.



Plant size (cm)
Daminozide
Total L***
Diameter NS
Total ht
Diameter
Untreated
1000
2000
4000
8000
16000
Paclobutrazol
Total L***
Diameter L***
Untreated
5
10
20
40
80
Uniconazole
Total L***, Q**
Diameter L***
Untreated
2
4
8
16
32

Table 1. Effectiveness of foliar applications of daminozide, paclobutrazol, and uniconazole on inflorescence diameter, days from sowing until anthesis, and costs of the plant growth retardant (PGR) treatments for 'Pacino' pot sunflowers.

PGR treatment	Concn ($mg \cdot L^{-1}$)	Inflorescence diam (cm) [z]	Days to anthesis[z]	PGR cost per 100 pots ($)[y]
Untreated control	---	14.0	75.8	--
Paclobutrazol	5	14.0	76.7	0.07
	10	14.1	75.7	0.13
	20	13.9	75.7	0.26
	40	13.7	75.7	0.56
	80	13.8	77.2	1.05
Significance		NS	Q**	
Uniconazole	2	14.0	75.7	0.16
	4	13.7	76.2	0.32
	8	13.7	76.2	0.64
	16	13.8	76.7	1.28
	32	13.0	78.9	2.56
Significance		L***	L***, Q*	
Daminozide	1000	13.3	77.0	0.09
	2000	13.8	76.3	0.18
	4000	13.4	77.1	0.36
	8000	13.2	77.4	0.71
	16000	12.7	78.9	1.43
Significance		L**, Q**	L**, Q*	

[z] *** Significant at (*P* 0.001) for the PGR treatments. LSD (α 0.05) was 0.5 cm and 1.4 days, respectively, for inflorescence diameter and days to anthesis for the PGR treatments. Mean for both pot sizes and n=20.

[y] Cost (rounded) as of 1 Jan., 1997 based on the use of foliar applications of PGRs on 1.2-L pots spaced pot to pot at 42 pots/m^2. Corresponding to the cost of $102/quart for paclobutrazol, $78/quart for uniconazole, and $71/pound for daminozide.

[NS, *, **, ***] Nonsignificant or significant by single-degree-of-freedom test for each treatment grouping at *P* 0.05, 0.01, or 0.001, respectively; respectively L=linear, Q=quadratic.

PACLOBUTROZOL DRENCHES CONTROL GROWTH OF POTTED SUNFLOWERS

A paper submitted to HortTechnology

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Abstract

Drenches of plant growth retardant (PGR) paclobutrozol were applied at 2, 4, 8, 16, or 32 mg active ingredient (a.i.)/pot, plus an untreated control to potted sunflowers (*Helianthus annuus* L. 'Pacino') to determine its effect on growth. When the first inflorescence opened, number of days from seeding until anthesis, total plant height, inflorescence diameter, and days until anthesis were significant for the PGR treatment and experiment interaction. Plant growth was greater during summer than spring. Marketable sized plants grown in 15- to 16.5-cm-diameter pots were produced with paclobutrozol drench concentrations of 2 and 4 mg in both seasons, and 8 mg was also effective during the summer.

INTRODUCTION

Sunflower has become one of the most important commercial crops in the world due to its high value as an oil and forage plant (Carter, 1978). The attractive inflorescence and foliage makes it an a ideal potted floricultural crop, however its tall-growing nature can be problematic. Plant growth retardants (PGR's) are commonly applied to container-grown crops when plants are disproportionately large relative to the container (Barrett et al., 1994; Tayama et al., 1992).

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Whipker and Dasoju (unpublished data) found significant reduction in plant height of 'Pacino' potted sunflower plants treated with foliar sprays of daminozide (2,2-dimethylhydrazide) at 4000 to 8000 mg·L^{-1} or uniconazole ((E)-1-(p-chlorophenyl)-4-,4-dimethyl-2-(1,2,4-triazol-1-yl-1-pentan-3-ol)) at 16 to 32 mg·L^{-1}, but paclobutrazol ((2R, 3R+ 2S, 3S)-1-(4-chlorophenyl)-4,4-dimethyl-2-(1,2,4-triazol-1-yl) pentan-3-ol)) concentrations from 5 to 80 mg·L^{-1} produced no significant reduction in plant height. Paclobutrazol is active when applied to the growing medium, but may have little efficacy as a chemical growth retardant when applied as a foliar spray because it is not translocated out from treated leaves (Barrett and Bartuska, 1982; Davis et al., 1988). Wample and Culver (1983) applied paclobutrazol drenches of 11.6, 58 and 116 mg of active ingredient (a.i.) per liter to field-type sunflowers and found as paclobutrazol concentration increased, there was a significant reduction in water use. The reduced water use was attributed to a reduction in both leaf expansion and internodal elongation, which resulted in reduced plant height measured at the end of the eight- to14-day experimental period. This study was conducted to determine the effectiveness of drench doses of paclobutrazol as a chemical height control for 'Pacino' potted sunflowers.

MATERIALS AND METHODS

Expt. 1 'Pacino' pot sunflower seeds were sown into cell packs (8 x 4 x 5.5 cm cells) on 18 May 1996. On 8 June, the seedlings were transplanted into 1.2-L (16.5-cm-diameter) round plastic containers. The root medium contained 2 soil : 5 *Sphagnum* peat : 3 perlite (by volume) and was amended with ground dolomitic limestone to pH 5.1. Plants were fertilized at each watering (mg·L^{-1}) with 155 N, 21 P, and 127 K. Greenhouse day/night set points were 24/18 ^{o}C, and the plants were grown under natural day length. Five PGR substrate drench treatments (mg a.i./pot) were applied 12 days after potting using 133 ml per pot: paclobutrazol at 2, 4, 8, 16 or 32; and an untreated control. The experimental design was a completely randomized design of 12 single-plant replications of the six treatment combinations.

When the first inflorescence opened, the number of days from seeding until anthesis, total plant height measured from the pot rim to the top of the inflorescence, and inflorescence and plant diameter (measured at the widest dimension and turned 90^{o}, and averaged) were recorded. Data were tested by analysis of variance by general linear model procedures (SAS Institute, Cary, NC). Means were separated by least significant differences (LSD) at P 0.05.

Expt. 2 The same procedures used in expt. 1 were repeated, except as noted. ‘Pacino’ seeds were sown into cell packs on 18 Dec. 1996, and seedlings were transplanted into 1.0-L (15-cm-diameter) round plastic pots on 5 Jan. 1997. The PGR substrate drench treatments of paclobutrazol were applied 15 days after potting at the same concentration as during expt. 1. A completely randomized design of eight single-plant replications of the six treatments was used.

RESULTS AND DISCUSSION

The PGR drench treatment *x* experiment interaction was significant for total plant height, plant diameter, inflorescence diameter, and number of days until anthesis.

Total Height: All concentrations of paclobutrazol significantly reduced plant height of potted sunflowers. There was a significant quadratic relationship between paclobutrazol concentration and total height in expt. 1 and 2. Plant height was shorter as paclobutrazol concentration increased up to 16 mg, however, additional increases in concentration had little effect on height (Fig. 1). Plants treated with 2 mg paclobutrazol were 27% shorter than the untreated control in both experiments, and those treated with 4 mg were 36% and 26% shorter than the untreated control in expt. 1 and 2, respectively. Severe height retardation of ‘Pacino’ plants was evident at 16 and 32 mg. Untreated control plants were 30% taller in expt. 1 than in expt. 2. Paclobutrazol inhibits cell elongation and reduces internodal length (Wample and Culver, 1983). This difference in plant height between expt. 1 and 2 at the 4 mg concentration can be attributed to seasonal variations of sunlight and temperature. Increases in temperature and light has been demonstrated to accelerate growth during all developmental stages, especially prior to flowering, of sunflower (Schuster, 1985).

Plant Diameter: Plant diameter exhibited a quadratic concentration effect in both experiments (Fig. 2). Plant diameter was smaller as paclobutrazol concentration increased up to 16 mg, with additional increases in concentration having little effect on plant diameter. Plants treated with 2 mg of paclobutrazol were 17% and 25% shorter than untreated control in expt. 1 and 2, respectively. Paclobutrazol at 4, 8, 16, and 32 mg reduced plant diameter by 24, 31, 38, and 51%, respectively, when compared to untreated control in expt. 1. The same concentrations of paclobutrazol applied in expt. 2, the reduction in plant diameter was 35, 36, 45, and 55%, respectively, when compared to untreated control. Plants treated with 16 and 32 mg of paclobutrazol exhibited phytotoxicity symptoms including crinkled leaves and stunted growth. Plants also exhibited smaller and greener leaves. Wood (1984) explained the intensification of folige color on plants treated with paclobutrazol results from an increase in total chlorophyll content per unit leaf area. Finally, a downward cupping of the leaf margin suggests a greater growth of the adaxial than the abaxial tissues was noted and contributed to a decrease in plant diameter.

Inflorescence Diameter: Inflorescence diameter exhibited a linear concentration effect in both experiments (Fig. 3), with increasing concentrations of paclobutrazol resulting in additional control of inflorescence diameter. Whipker and Dasoju (unpublished data) found no difference in inflorescence diameter of 'Pacino' potted sunflower treated with foliar sprays of paclobutrazol at 5 to 80 $mg{\cdot}L^{-1}$. Drench application of paclobutrazol at 4, 8, 16, and 32 mg reduced inflorescence diameter by 12, 15, 13, and 30% when compared to untreated control in expt. 1, but only the highest rate of paclobutrazol (32 mg) significantly reduced inflorescence diameter by 14% when compared to untreated control for expt. 2. Plants treated with 16 and 32 mg of paclobutrazol developed flowers that were oriented upwards (perpendicular to the stem at an 45° angle) instead of parallel to the stem. Whipker and Dasoju (unpublished data) reported similar upward oriented sunflower heads for plants treated with foliar sprays of daminozide at 16000 $mg{\cdot}L^{-1}$.

Days to Anthesis: The effect of paclobutrazol on number of days from seeding to anthesis was significant for paclobutrazol in both the experiments (Table 1). In expt. 1, plants treated with 32 mg of paclobutrazol bloomed 3 days later, compared to untreated control. Flowering was delayed by 4 to 6 days with paclobutrazol drench treatments of 2 to 32 mg, when compared to untreated control in expt. 2, however, delay in flowering was more pronounced as the concentration of paclobutrazol applied increased. The number of days from seedling to anthesis was longer in expt. 2 (early spring) than in expt. 1 (summer). Differences can be attributed to how photoperiod and temperature influences the number of days to anthesis of sunflower (Schuster, 1985).

CONCLUSIONS

The new shorter cultivars of sunflowers can be adopted to pot culture by controlling the plant growth with the application of PGR's. Paclobutrazol drenches were effective in controlling total height, plant diameter, and inflorescence diameter of potted sunflowers, although seasonal differences were evident. Sunflower plant growth was greater in the summer (expt. 1) than in spring (expt. 2). Seasonal differences in growth and flowering date should be considered when determining the appropriate paclobutrazol drench concentration. In the summer, higher concentrations of paclobutrazol will be required than in spring for growth control. Sachs et al. (1976) recommend optimal plant height for potted plants should be 1.5 to 2 times the container height. In this study, marketable sized plants grown in 15-to 16.5-cm-diameter pots were produced with drenches of paclobutrazol at 2 and 4 mg in both seasons, even though the plants were two to three times taller than the pot height. Paclobutrazol at 8 mg can also be used in summer for growth control.

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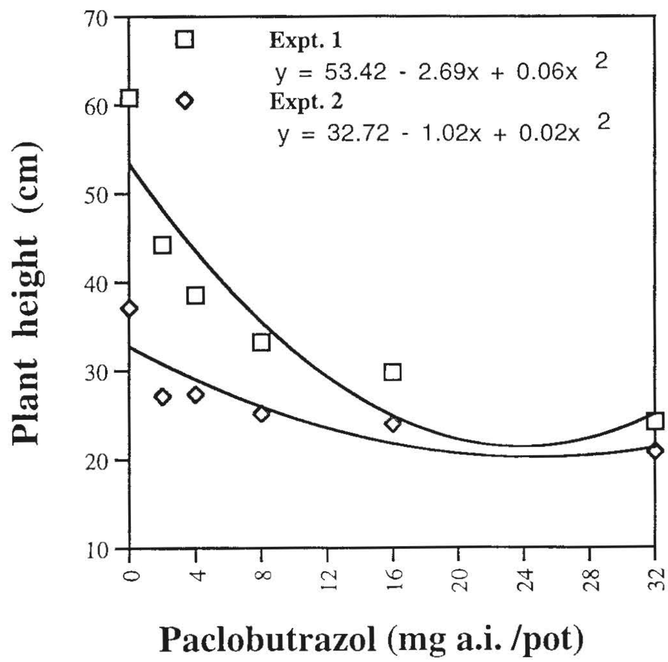

Figure 1. Plant height of potted sunflowers treated with paclobutrazol drenches. Regression lines were generated from means of the treatments, and points are means for each treatment (n = 12 and eight, respectively, for expt. 1 and 2). The adjusted r^2 for expt. 1 and 2 are 0.80 and 0.58, respectively.

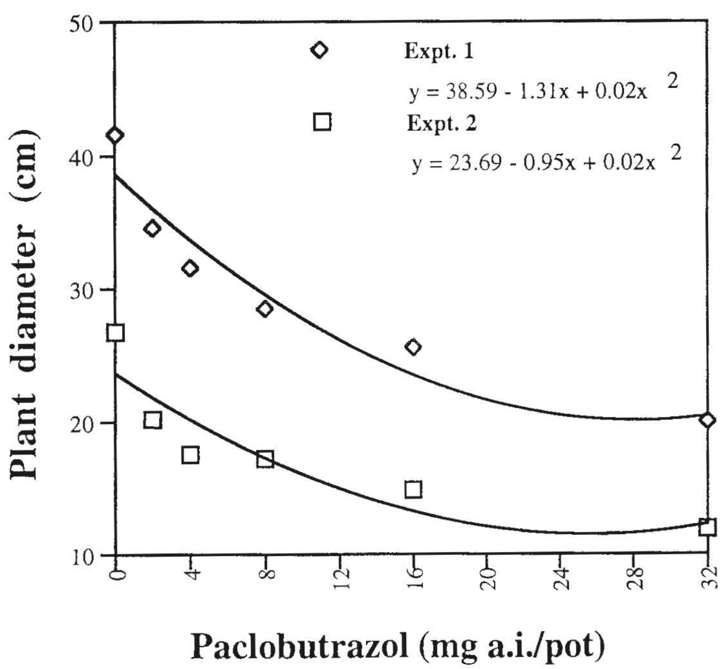

Figure 2. Plant diameter of potted sunflowers treated with paclobutrazol drenches. Regression lines were generated from means of the treatments, and points are means for each treatment (n = 12 and eight, respectively, for expt. 1 and 2). The adjusted r^2 for expt. 1 and 2 are 0.82 and 0.73, respectively.

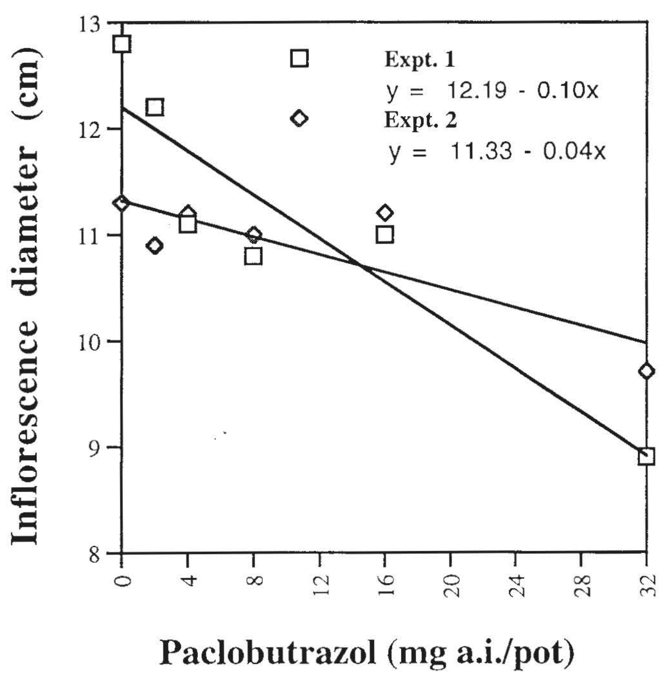

Figure 3. Inflorescence diameter of potted sunflowers treated with paclobutrazol drenches. Regression lines were generated from means of the treatments, and points are means for each treatment (n = 12 and eight, respectively, for expt. 1 and 2). The adjusted r^2 for expt. 1 and 2 are 0.44 and 0.29, respectively.

Table 1. Effect of paclobutrazol drenches on days to anthesis of 'Pacino' potted sunflower.

Paclobutrazol drench conc. (mg a.i./pot)	Days to anthesis	
	Experiment 1 Summer 1996	Experiment 2 Spring 1997
0	62.6	72.3
2	62.6	76.6
4	64.5	78.4
8	63.8	78.0
16	62.7	79.0
32	65.8	78.1
Significance	*	
LSD ($\alpha = 0.05$)	2.0	

* Significant at $P \leq 0.05$ for treatment × experiment interaction.

PACLOBUTRAZOL DRENCH ACTIVITY IN COIR AND PEAT-BASED ROOT SUBSTRATES

A paper to be submitted to HortTechnology

Shravan K. Dasoju[1], Michael R. Evans[2], and Brian E. Whipker[2]

Abstract

Paclobutrazol drench applications of 0, 2, and 4 mg a.i./pot were applied to 'Pacino' potted sunflowers and 'Red Pigmy' tuberous rooted dahlias grown in substrates containing 50, 60, 70, or 80% (by vol.) *Sphagnum* peat or coir, with the remainder being perlite, to study the efficacy of paclobutrazol (Bonzi). Potted sunflower plant height differed significantly for peat and coir-based substrates with greater plant height being observed in coir-based substrates. Plant diameter was significantly greater at higher percentages of peat or coir in the substrate at 2 and 4 mg of paclobutrazol. Inflorescence diameter also was significantly decreased with increase in paclobutrazol concentration. When the percent of height control from the untreated plants for potted sunflower was compared between coir and peat-based substrates, heights were similar for both peat and coir-based substrates at 2 mg of paclobutrazol and height control was greater at 4 mg of paclobutrazol in coir-based substrates. The differences in plant growth observed in peat and coir-based substrates can be attributed to differences in physical properties of these substrates.

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Dahlia plant height, diameter, and number of days until anthesis were not influenced by substrate type or percentage. However, dahlia growth was significantly reduced as paclobutrazol concentration increased. Coir-based substrates did not reduce the activity of paclobutrazol drenches when compared to peat-based substrates, although to compensate for the greater amount of plant growth in coir-based substrates, paclobutrazol concentrations may need to be increased slightly to achieve a similar plant height as with peat-based substrates.

INTRODUCTION

Plant growth retardants (PGR's) are commonly applied to containerized greenhouse crops when plants would normally be disproportionately large relative to the container (Barrett and Nell, 1994). PGR's may be applied as foliar sprays or substrate drenches. Drenches are preferred because they allow for a more precise application, their effectiveness is influenced less by environmental factors than foliar sprays, and there is no risk from spray drift (Quinlan, 1982). However, a major problem with substrate applied chemicals is that soil organic matter can markedly influence effectiveness of the treatment (Walker, 1983). Of all organic components used in substrates, bark has the greatest impact on PGR efficacy. Tschabold et al. (1975) compared the movement of ancymidol through columns of soil-sand or pine bark-sand mixtures and concluded that ancymidol binds to the bark, which decreased its activity as a PGR. Burchill et al. (1981) further demonstrated that binding of organic compounds such as PGR's by the substrate particles resulted from a hydrophobic attraction between the non-polar portions of the PGRs molecule and the bark.

Paclobutrazol ((2R, 3R+2S, 3S)-1-(4-Chlorophenyl)-4, 4-dimethyl-2-(1, 2, 4-triazol-1-yl)pentan-3-al)) (Uniroyal Chemical Company, Inc, Middlebury, CT) provides effective height control on many floricultural crops (Barrett and Nell, 1989). It is active when applied as a substrate drench and taken up by the plant through the roots (Barrett and

Bartuska, 1982; Davis et al., 1988), but efficacy has been shown to be influenced by substrate composition. Quarrels and Newman (1994) found a significant reduction in the efficacy of paclobutrazol drenches applied to poinsettia (*Euphorbia pulcherrima* Willd.) grown in a pine bark-based substrate when compared to its efficacy on plants grown in a peat-based substrate. Similar results of paclobutrazol activity inhibition were reported by Barrett (1982) for chrysanthemum (*Dendranthema grandiflora* Tzuelev.) grown in a pine bark-based substrate.

Coconut coir dust (coir) is an agricultural waste product produced from the mesocarp or husk of the coconut fruit and is being marketed as an alternative substrate component. In plant production trials, coir has been demonstrated to be a suitable substrate component for greenhouse crop production; promoting shoot and root growth in certain species (Evans and Stamps, 1996; Lokesha et al., 1988; Talukdar and Barooah, 1987). However, no information is available regarding the activity of paclobutrazol drenches in coir-based substrates. Therefore, the objective of this study was to determine if the efficacy of paclobutrazol substrate drenches differed when applied to peat and coir-based substrates.

MATERIALS AND METHODS

Substrates were formulated to contain 50, 60, 70, or 80% (by vol.) *Sphagnum* peat (peat) or coir, with the remainder being perlite. Prior to formulation of the substrates, dolomitic limestone was added (4.15 $kg{\cdot}m^{-3}$) to the peat and pasteurized at 60 °C for 30 min. The peat was allowed to incubate at 20 °C for 10 d before use at which time the pH was 5.1. Coir was also pasteurized and allowed to incubate for 10 d, after which time the pH was 5.2.

<u>Expt. 1:</u> On 22 Mar. 1996 dormant tubers of 'Red Pigmy' dahlias were potted into 1.5-L round plastic containers filled with the experimental substrates listed above. Plants were

fertilized at each watering with Excel 15-5-15 Cal-Mag (Scotts, Marysville, Ohio) to provide 155 N, 21 P, and 127 K ($mg \cdot L^{-1}$). Greenhouse day/night set points were 24/18 ^{o}C, and the plants were grown under naturally occuring day lengths. Twelve days after potting, 133 ml of solution containing 0, 2, or 4 mg (a.i.) paclobutrazol was applied per container. The experimental design was a completely randomized design of six single-plant replications of the eight substrates x three PGR treatment combinations. At the first sign of anthesis, the number of days from potting until anthesis, leaf canopy height measured from the pot rim to the top of the foliage, inflorescence height above the foliage, total plant height, and plant diameter (measured at the widest dimension, turned 90^{o}, and averaged) were recorded. Data were subjected to analysis of variance by the general linear model procedures and regression analysis (SAS Institute, Cary, NC). Means were separated by least significant differences (LSD) at *P* 0.05.

Expt. 2 Except where indicated, procedures for expt. 2 were as described for expt. 1. On 18 Dec. 1996 'Pacino' sunflowers seed were sown into cell packs (8 x 4 x 5.5 cm cells). On 6 Jan. 1997, the seedlings were transplanted into 1-L (15-cm-diameter) round plastic containers filled with the experimental substrates. Fifteen days after potting, paclobutrazol was applied. Inflorescence diameter (measured at the widest dimension, turned 90^{o}, and averaged) was also recorded at anthesis. A completely randomized design of eight single-plant replications of the eight substrates x three PGR treatments combinations was used.

RESULTS AND DISCUSSION

Plant Height: Sunflower height was not significantly influenced by substrate percentage for peat or coir-based substrates, and therefore plant height data was pooled across the peat and coir-based substrates respectively. There was a significant quadratic relationship between sunflower height and paclobutrazol concentration for both peat and coir-based substrates, with a shorter plant height being resulting as the concentration of paclobutrazol increased (Fig. 1). Plant height was reduced by 27% and 29% from the untreated control for the 2 and 4 mg concentration of paclobutrazol respectively, when applied to the peat-based substrates. Plant height was reduced by 28% and 33% from the untreated control for the 2 and 4 mg concentration of paclobutrazol respectively, when applied to the coir-based substrates (data not shown). There was no significant difference in percent plant height reduction at 2 mg concentration of paclobutrazol for peat and coir-based substrates. However the percent plant height reduction was significantly greater ($P \leq 0.01$) at 4 mg concentration of paclobutrazol in coir-based substrates than in peat-based substrates.

Dahlia height was not significantly affected by substrate type (peat/coir) or percentage (data not shown), and therefore plant height data at 0, 2, and 4 mg concentration of paclobutrazol was pooled across the peat and coir-based substrates respectively. Plant height for dahlias had a significant linear trend for paclobutrazol concentration, with shorter heights as the paclobutrazol concentration increased (Fig. 2). Plants treated with 2 and 4 mg paclobutrazol were 13 and 21% shorter, respectively, than the untreated control.

For all PGR concentrations, sunflower height was greater in coir-based substrates than in peat-based substrates. This difference in plant height of sunflower may be attributed to the differences in physical or chemical properties between coir and peat. Evans and Stamps (1996) compared the growth and development of bedding plants produced in *Sphagnum* peat and coir-based substrates and found a higher root fresh mass for geraniums (*Geranium aconitifolium* L.), a higher shoot fresh mass for marigolds (*Tagetes petula* L.) and petunias (*Petunia axillaris* Lam.) and an increase in overall height of petunias grown in coir-based substrates. Evans and Stamps speculated that the increased growth observed in coir-based substrates may have been a function of the higher water-holding capacity of coir. Evans et al. (1996) examined the physical properties of coir and found that the water-holding capacity of coir ranged from 750% to 1100% of dry weight, while peat held 400% to 800% of its dry weight in water. Cresswell (1992) compared the chemical and physical properties of coir and peat and found both to have similar electrical conductivities and hydrophobic properties. Therefore, increased height in sunflower in coir-based substrates may have been a function of the properties of coir and not an inactivation of the PGR. This conclusion is further supported by the fact that at 2 mg of paclobutrazol concentration the percent height reduction in coir was the same as for peat, and at 4 mg the percent height reduction was greater in coir than in peat. Thus efficacy of the PGR on sunflower was not reduced in coir-based substrates.

Increased efficacy of paclobutrazol at 4 mg may be an artifact as no such results were observed for dahlia. However, it is possible that coir's increased water-holding capacity may have allowed the substrate to retain more of the PGR solution for a longer period of time as compared to the peat. Although root growth was not measured in this study, coir has been shown to promote root growth in several species. If root growth is promoted, uptake of the PGR may be more efficient and thus the PGR being more effective. However, if these mechanisms were responsible for the increase in PGR efficacy, the results should have also been observed for the 2 mg treatment. Finally, although statistically significant, the difference in efficacy between the 2 and 4 mg treatment in sunflower would not be practically significant in a commercial production situation.

Plant Diameter: Sunflower plant diameter was not significantly influenced by substrate type, and therefore plant diameter data was pooled for percentage of peat or coir. There was a significant linear relationship for sunflower plant diameter between the percentage of peat or coir in the substrate, and the paclobutrazol concentration. Plant diameter was greater as the percentage of peat or coir increased for both the 2 and 4 mg concentrations of paclobutrazol (Fig. 3). The increase in percentage of peat or coir was accompanied by a decrease in percentage of perlite in the substrate. The observed increase in plant diameter as the percentage of perlite decreased from 50% to 20% suggests a decrease in paclobutrazol activity as the percentage of perlite decreased. These results were similar to those of Million et al. (1997), who found that paclobutrazol activity was enhanced in vermiculite and perlite when compared with peat.

Dahlia plant diameter was not affected by substrate type or percentage. Data for plant diameter pooled for substrate type and percentage showed a significant linear relationship between plant diameter and paclobutrazol concentration (Fig. 4). As the paclobutrazol concentration increased from 0 to 4 mg, plant diameter decreased by 6%.

Inflorescence Diameter: Data for inflorescence diameter was pooled from all the treatments since substrate type or percentage had no effect on sunflower inflorescence diameter. Inflorescence diameter for sunflower decreased linearly with increasing paclobutrazol drench concentration. Inflorescence diameter decreased by 8% as the paclobutrazol concentration increased from 0 to 4 mg (Fig. 5).

Days to Anthesis: There was no significant influence of PGR concentration, substrate type or substrate percentage on the number of days to anthesis for either sunflower or dahlias. The mean number of days to anthesis was 75 for 'Pacino' sunflowers and 57 for 'Red Pigmy' dahlias (data not shown) and results were similar to those reported earlier for the same crops (Dasoju and Whipker, 1997; Whipker and Hammer, 1997).

CONCLUSIONS

The activity of paclobutrazol drenches in coir and peat-based substrates was similar at 2 mg concentration in this study for potted sunflower. Greater percent of plant height reduction in coir-based substrate at 4 mg concentration of paclobutrazol for sunflower suggests an increase in paclobutrazol activity at higher concentrations in coir-based substrates. Increased sunflower plant growth in coir-based versus peat-based substrates may be attributed to greater water retention capacity of coir and not a decreased efficacy of paclobutrazol in coir-based substrates. This study suggests that similar drench concentrations of paclobutrazol as recommended for peat-based substrates can be used for coir-based substrates to control plant size of potted floricultural crops, although to compensate for the greater amount of plant growth in coir-based substrates, paclobutrazol concentrations may need to be increased slightly to achieve a similar plant height as with peat-based substrates. Growth responses to PGR's and substrates may vary for different crops, which has to be considered in deciding upon a working concentration of a PGR for different substrates. Our results were similar to those reported by Million et al. (1997) on the similar bioassay activity of paclobutrazol drenches observed in peat and coir-based substrates. This apparent property of coir-based substrates of not inhibiting the paclobutrazol activity is a positive factor in developing coir as potential potting substrate, in contrast to pine bark-based substrates, which decrease the activity of paclobutrazol drenches and require higher PGR concentrations.

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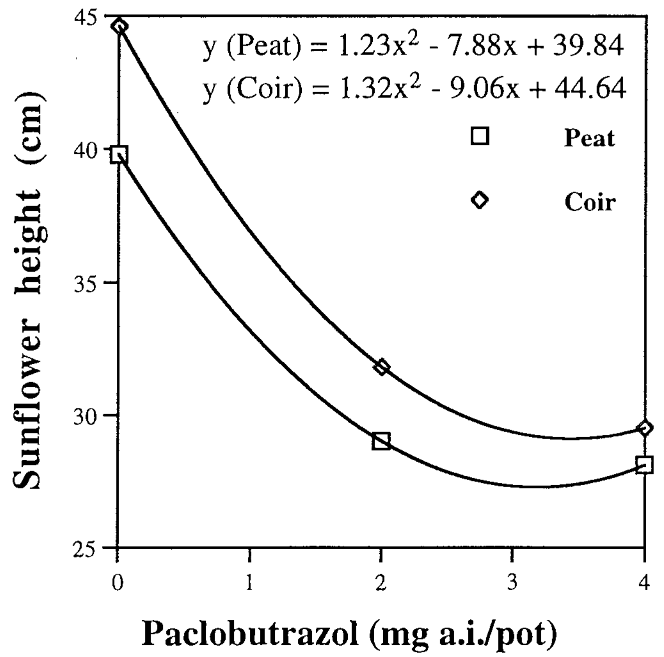

Figure 1. Plant height (cm) of potted sunflowers influenced by root substrate (peat/coir) and paclobutrazol (mg. a.i./pot) drenches, (n=eight). The adjusted r^2 for peat and coir based substrate were 0.713 and 0.864, respectively.

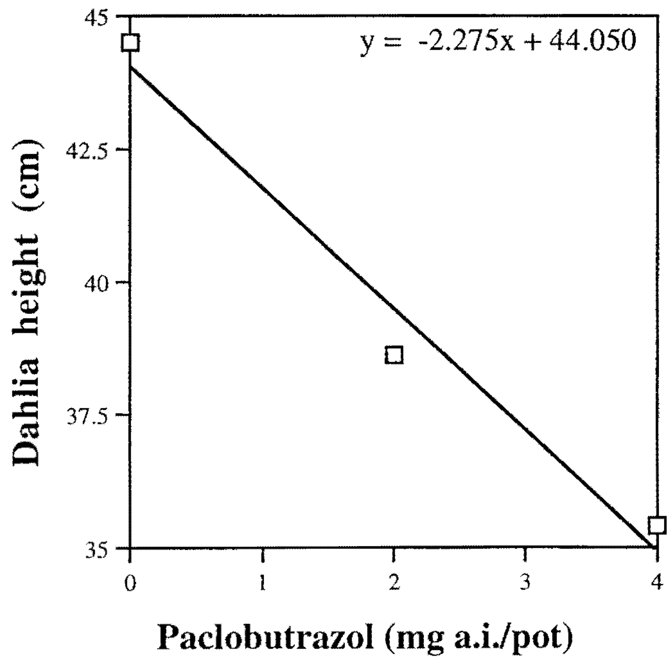

Figure 2. Plant height (cm) of potted dahlias influenced by paclobutrazol (mg. a.i./pot) drenches, (n=six). The adjusted r^2 for plant height was 0.2546.

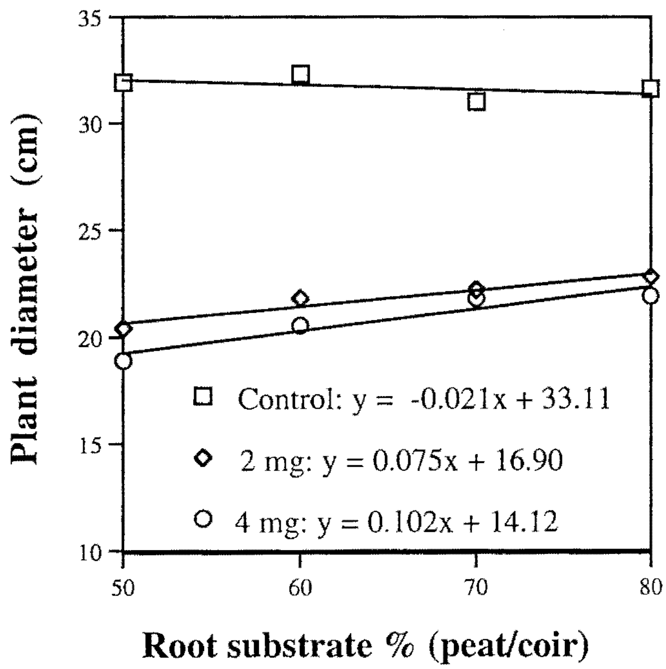

Figure 3. Plant diameter (cm) of potted sunflowers influenced by root substrate (peat/coir) percentage and paclobutrazol (mg. a.i./pot) drenches, (n=eight). The adjusted r^2 for plant diameter at 0, 2, and 4 mg a.i./pot of paclobutrazol were -0.0092, 0.1457 and 0.1584, respectively.

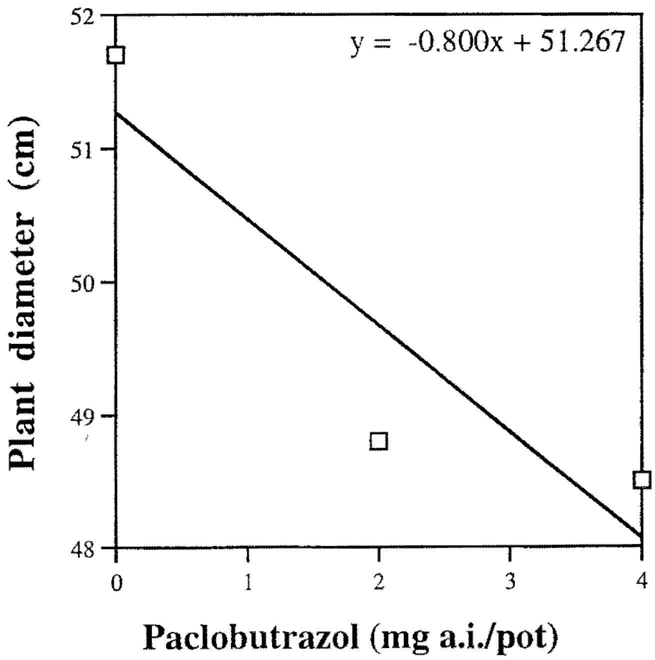

Figure 4. Plant diameter (cm) of potted dahlias influenced by paclobutrazol (mg. a.i./pot) drenches, (n=six). The adjusted r^2 for inflorescence diameter was 0.0405.

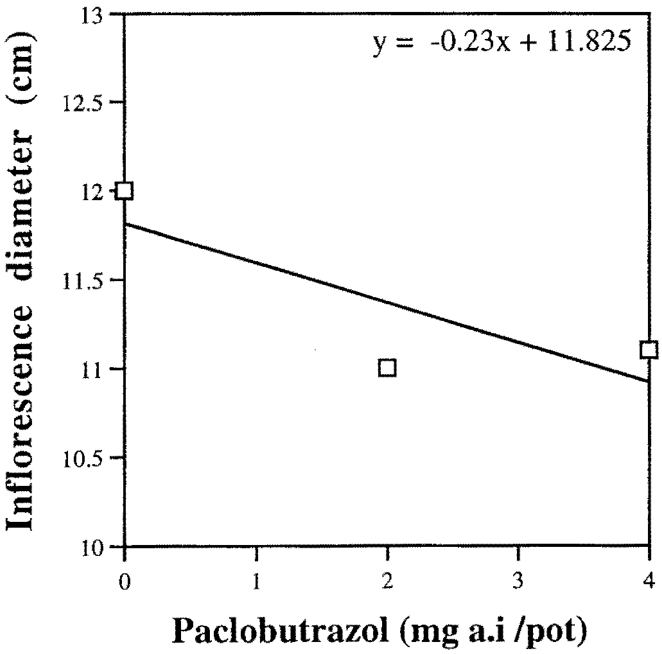

Figure 5. Inflorescence diameter (cm) of potted sunflowers influenced by paclobutrazol (mg. a.i./pot) drenches, (n=eight). The adjusted r^2 for inflorescence diameter was 0.1806.

NITROGEN FERTILIZATION INFLUENCES LONGEVITY AND PLANT GROWTH OF POTTED SUNFLOWERS

A paper to be submitted to Journal of Plant Nutrition

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Abstract

Surpluses or deficiences of nutrients can create plant stress which accelerates senescence, thus reducing postharvest quality. Potted sunflowers (*Helianthus annuus* L. 'Pacino') were fertigated on ebb and flow benches with 100 or 200 mg·L^{-1} of N to determine the influence of N level on plant growth and postharvest quality in controlled interior environment conditions. Fertilization rates of 100 or 200 mg·L^{-1} of N were held constant from potting until day 45, then the fertilization was continued, decreased, or terminated on day 45 and day 55 from the time of potting, giving a combination of nine treatments. Fertilizer treatments did not affect the number of days to flowering, plant height, or flower diameter. Plants fertigated with N at 100 mg·L^{-1} had a longer postharvest life. The highest quality plants with longer postharvest life were produced with N at 100 mg·L^{-1} and by terminating fertilization 55 days after potting.

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INTRODUCTION

The use of flowering plants in interior landscapes is limited by their relatively short postharvest life (Harlass, 1992; Newman, 1992). Therefore, plant choice is restricted to those that remain attractive for the longest time possible to reduce replacement costs. Production and cultural practices influence postharvest quality of many potted plants. Long-term influences of cultural practices such as fertilization on postharvest qualities have been investigated on a number of crops. Research on chrysanthemum (*Dendranthema grandiflora* Tzuelev.) showed that postharvest keeping quality is affected by preharvest and postharvest practices (Halvey et al., 1978; Waters, 1965, 1967; Woltz and Waters, 1967). Higher levels of N at 300 $mg \cdot L^{-1}$ have been found to reduce the keeping quality of chrysanthemum (Joiner and Smith, 1962; Woltz and Waters, 1967), whereas reduction in N fertilization from 30 lb/A/week to 15 lb/A/week during the latter part of the growing season increased chrysanthemum keeping quality (Waters, 1967). Roude et al. (1991) reported a decrease in postharvest longevity of 'Tip' chrysanthemum as N concentration increased from 1.3 to 2.6 kg N/m^3. Conover et al. (1993) found that production plant grades and postharvest quality of begonias (*Begonia* × *semperflorens-cultorum* Hort.) were optimal at 1g/10-cm pot of 14N-6.2P-11.6K Osmocote (FR), rather than at 1.5, 2.0 or 2.5gm/10-cm pot. Experiments with poinsettias (*Euphorbia pulcherrima* Willd.) showed that better quality plants with longer postharvest life were produced by terminating fertilization two weeks before sale (Staby and Kofranek, 1979). There has been no previous work on potted sunflowers to establish a correlation between N levels during cultivation and their postharvest keeping quality. Our study was conducted to identify the influence of N concentration in combination with time of termination of fertilization on plant growth and postharvest keeping quality of potted sunflowers.

MATERIALS AND METHODS

'Pacino' sunflower seeds were sown into cell pacs (8 × 4 × 5.5 cm cells) on 11 July 1996, and placed under mist irrigation for 3 days. Trays were misted for 15 seconds once every 15 min. After 3 days, cell packs were moved to benches in a greenhouse and hand watered every other day with clear tap water. When seedlings were 2 weeks old, they were transplanted into 1.2 - L (15-cm-diameter) round plastic pots. The rooting medium contained 2 soil: 5 sphagnum peat: 3 perlite (by vol.) amended with ground dolomitic limestone to a pH of 5.1. Plants were initially fertilized for a week by irrigating with 100 $mg \cdot L^{-1}$ PETERS® EXCEL® 15-5-15 Cal-Mg (Scott's, Marysville, Ohio) fertilizer. The following week the plants were moved into a temperature-controlled greenhouse and placed on ebb-and-flow benches, where the day/night temperatures were maintained at 20 °C. The plant growth regulator daminozide was applied as a foliar spray on 21 August 1996 at 4000 $mg \cdot L^{-1}$, by using a spray volume of 204 $ml \cdot m^{-2}$ to control plant height in relation to pot size.

Nutrient solutions of N at 100 $mg \cdot L^{-1}$ were prepared by mixing 75 $mg \cdot L^{-1}$ of KNO_3 and 600 $mg \cdot L^{-1}$ of PETERS® EXCEL® 15-5-15 Cal-Mg., which contained 81 $mg \cdot L^{-1}$ of NO_3-N, 19 $mg \cdot L^{-1}$ of NH_4-N, 13 $mg \cdot L^{-1}$ of P, 104 $mg \cdot L^{-1}$ of K, 30 $mg \cdot L^{-1}$ of Ca, and 12 $mg \cdot L^{-1}$ of Mg. The fertilizer concentrations were doubled for the 200 $mg \cdot L^{-1}$ rate. Plants were fertilized with 100 or 200 $mg \cdot L^{-1}$ of N, which were held constant from potting until day 45. Fertilization rates were then maintained, decreased, or terminated on day 45 or day 55, creating a combination of nine fertilization treatments (Table 1). The fertilizer solutions were replaced every 6-7 days. On day 45, five replicates from both N fertilization treatments were analyzed for nutrient concentration of the root medium. The root medium was analyzed for pH (epoxy Ag/AgCl electrode; Cole-Parmer, Vernon Hills, Ill.), electrical conductivity (E.C.) (Solu-bridge; Beckman Instruments, Cedar Grove, N. J.). NO_3-N (Smith and Scott, 1991) (QuickChem AE;Lachet, Milwaukee, Wis.), and P, K, Ca, Mg were determined using an inductively coupled Ar plasma emissions spectrophotometer (IRIS/AP Duo; Thermo Jarrel Ash, Franklin, Mass.). A completely randomized design of ten single plant replications per treatment was used.

A plant was considered to be flowering when the outer row of ray florets was perpendicular to the stem. When the plants started flowering, five replicates from each treatment were randomly sampled for plant tissue dry mass, and for determining root medium nutrient concentration. Plants were harvested and dried in a forced-air oven at 67 °C for 72 h before dry masses were measured.

Five replicates per treatment were also used for studying postharvest performance in a controlled interior-environment room. When the first inflorescence opened, plants were moved into a room maintained at 21 ± 2 °C where cool-white fluorescent lamps provided photosynthetically active radiation (PAR) at 30-36 $\mu mol \cdot s^{-1} \cdot m^{-2}$ for 24 hr/day and relative humidity (RH) was 50% ± 2%. Plants were watered every other day with tap water. Data was collected for the number of days from seeding until flowering, plant height (measured from pot rim to top of inflorescence), plant diameter and inflorescence diameter (measured at the widest dimension and turned 90° and averaged). Plants were also graded for quality on a scale of 1 = excellent; 2 = good; 3 = fair; 4 = poor; 5 = dead. Subsequent grading using the same scale was done after 5, 10, and 15 days. Flower longevity was determined by the length of time taken for outer row of ray florets to wilt and the plants were considered dead when there was petal wilting and curling. The experiment was completed when all flowers wilted. Data were tested by analysis of variance by using general linear model procedures (SAS Institute, Cary, NC). Means were separated by least significant differences (LSD) at *P* 0.05.

RESULTS AND DISCUSSION

Plant height, flower diameter, and days to anthesis: Plant height, flower diameter, and days to flower were not significantly influenced by fertilization rate (Table 2). The lack of a fertilizer rate effect on plant height can be attributed to the uniform height control caused by the foliar application of the plant growth retardant daminozide. The overall treatments means for plant height, flower diameter, and days to flower were 43.5 cm, 11.75 cm, and 59.4 days, respectively. Whipker and Dasoju (1997) (unpublished data) found plant height and flower diameter of 'Pacino' potted sunflowers treated with foliar sprays of daminozide at 4000 $mg\cdot L^{-1}$ to be similar. Plants required two more weeks of growth before flowering occured in the earlier study and differences can be attributed due to seasonal variation in sunlight and temperature.

Plant diameter: Plant diameter was significantly different among treatments (Table 2). Plants fertilized with 200 $mg\cdot L^{-1}$ N had a larger plant diameter than those fertilized with 100 $mg\cdot L^{-1}$, except for when fertilization was terminated at day 45 (200 ; 0 ; 0) or for the constant fertigation of 100 $mg\cdot L^{-1}$ (100 ; 100 ; 100). Termination of fertilization on day 45 for both fertilizer rates (200 ; 0 ; 0 and 100 ; 0 ; 0) or on day 55 for the 100 ; 100 ; 0 fertilization rate resulted in significantly smaller sized plant. Although treatments with low fertility rates resulted in smaller diameter plants, this can be an advantage for pot culture because a greater number of pots be produced per unit of bench area.

Plant shoot dry mass: Dry mass of the plant shoot tissue were different for the treatments (Table 2). Treatments receiving 200 $mg\cdot L^{-1}$ of N until anthesis (200 ; 200 ; 200) had the largest dry mass; plants in this treatment were 22% heavier than the other treatments, indicating that higher fertility levels may have caused more growth due to more N being applied. Decreasing the constant fertilization rate of 200 $mg \cdot L^{-1}$ on day 55 (200 ; 200 ; 100) and termination of fertilization of 100 $mg \cdot L^{-1}$ on day 45 (100 ; 0 ; 0) significantly reduced plant shoot mass. Potted sunflowers treated with 100 $mg \cdot L^{-1}$ of N from potting until day 55 (100 ; 100 ; 0) produced similar amount of plant shoot dry mass as treatments 200 ; 100 ; 0 or 200 ; 0 ; 0.

Postharvest keeping Quality: Plant grades were similar for all the treatments on days 5, 10, and 15 after moving into interior conditions (Table 4). Flower quality declined over time with an overall grade of 1 (excellent) on day 5, 4.45 on day 10, and 5 (dead) on day 15.

Fertility treatments significantly affected flower longevity (Table 4). The duration for the potted sunflowers to retain good plant quality ranged from 9.2 to11.6 days, with the 100 ; 100 ; 0 fertility treatments having the greatest longevity. Flower longevity was significantly different for the fertilizer treatments, but plant grades were similar. Grading for flower quality only was done on days 5, 10, and 15, whereas flower longevity was measured on a daily basis. We considered a plant dead and unsalable when there was petal wilting and curling for determining flower longevity. This explains why differences were observed between flower longevity and plant grades. Gast (1995) evaluated the postharvest life of 33 cultivars of fresh-cut sunflowers and reported that the vase life of flowers held in tap water ranged from 5.5 to 13.3 days. The 'Pacino' flower longevity of 9.2 to 11.6 days was within the range reported by Gast (1995) for fresh-cut sunflowers, but was shorter than the 3-4 weeks of longevity possible for rieger begonias (*Begonia x hiemalis*) or cyclamen (*Cyclamen persicum* Mill.). This shorter post-production life for pot sunflowers is a limiting factor in its suitability as a pot crop.

A limitation associated with the postharvest keeping quality of 'Pacino' potted sunflowers is excessive pollen production. Flowers start losing their quality as the pollen production proceeds from outer row of disc florets to the center.

Electrical Conductance (E.C.), pH, and nutrient levels of rooting medium

E.C., pH, NO_3-N, P, K, Ca, and Mg of the root medium significantly differed among the treatments (Table 3).

E.C.: The E.C. values ranged from 0.9 to 3.1 mS/cm (Table 4), with higher E.C. values observed among plants treated with higher levels of N (Table 4). Treatments with constant fertilization of 200 $mg \cdot L^{-1}$ (200 ; 200 ; 200) and 200 ; 200 ; 0 significantly increased the E.C. levels of the rooting medium. Because plant demand for nutrition decreases as flowering occurs, nutrients supplied in excess resulted in an increase in E.C. (Figure 2). Plants treated with 200 $mg \cdot L^{-1}$ of N until anthesis had E.C. values 29% higher than the other treatments. Termination of fertilization on day 45 (200 ; 0 ; 0 and 100 ; 0 ; 0) or reducing fertilization on day 55 (200 ; 100 ; 0 and 100 ; 100 ; 0) resulted in significantly lower E.C. values. For greenhouse crops in general, Warncke and Krauskopf (1983) recommended an E.C. of 0.75 to 1.25 $dS \cdot m^{-1}$. Loss of vigour may occur when E.C. exceeds 1.25 $dS \cdot m^{-1}$ for most established plants. Root medium of fertilizer treatments 200 ; 100 ; 0, 200 ; 0 ; 0, 100 ; 100 ; 0, and 100 ; 0 ; 0 had E.C. values which were within the recommended range of 0.75 to 1.25 $dS \cdot m^{-1}$. Studies done on potted foliage plants have shown that higher concentration of salt accumulated in the root medium, which causes a reduction in postharvest quality (Conover and Poole, 1977a, b; Milks et al., 1979).

pH : pH of the root medium was significantly different among treatments. pH values for the root medium of all the treatments were within the optimal range though they were acidic. pH of the treatments ranged between 5.6 to 6.2. These acidic values of pH for the rooting medium can be attributed to the acidic nature of the fertilizer used for supplying the nutrients.

NO_3-N: A significant difference among treatments was observed for NO_3-N concentration of the root media of potted sunflowers. Comparing NO_3-N concentration on day 45 and at flowering, a build up of NO_3-N occurred for plants fertilized with a constant level of 200 $mg{\cdot}L^{-1}$ N (Fig. 1). Treatments with constant fertilization of 200 $mg{\cdot}L^{-1}$ (200 ; 200 ; 200) and 200 ; 200 ; 100 had a significant increase in the NO_3-N concentration of the root medium. Fertilization treatments 200 ; 100 ; 0, 200 ; 0 ; 0, 100 ; 100 ; 0, and 100 ; 0 ; 0 had a lower NO_3-N concentration in the root medium. Termination of fertilization on day 45 (200 ; 0 ; 0 and 100 ; 0 ; 0) or day 55 (100 ; 100 ; 0) resulted in a depletion of NO_3-N in the root medium, with NO_3-N values of 26.8, 6.3, and 25.2 $mg{\cdot}L^{-1}$ N, respectively. The amount of NO_3-N supplied with the fertilizer solution was 81 or 162 $mg{\cdot}L^{-1}$ N, respectively, for the 100 or 200 $mg{\cdot}L^{-1}$ solutions. Root medium of treatments supplied with a constant fertilization of 200 $mg{\cdot}L^{-1}$ (200 ; 200 ; 200) or 200 ; 200 ; 100 contained 316.8 and 198.6 $mg{\cdot}L^{-1}$ of NO_3-N, respectively, which was in excess of the NO_3-N supplied. This indicates that the amount of N required by sunflowers is less and the excess accumulated in the root medium. N fertilization at 100 $mg{\cdot}L^{-1}$ from potting until day 55 (100 ; 100 ; 0) contained a similar amount of NO_3-N as the 200 ; 100 ; 0 treatment. Previous results have shown that longevity of chrysanthemum grown with 300 $mg{\cdot}L^{-1}$ of N liquid fertilizer program can be increased by 22% by terminating fertilizer application 3 weeks before flowering (Nell et al., 1989). Flower longevity of potted sunflowers was increased by 12% by terminating fertilization on day 55, at lower fertility levels of 100 $mg{\cdot}L^{-1}$ of N.

Phosphorous (P): There was a significant difference among the treatments for P (Table 4). Treatments 200 ; 100 ; 100, 200 ; 100 ; 0, 200 ; 200 ; 0, and 200 ; 0 ; 0 had a lower P concentration in the root medium. The amount of P supplied with the fertilizer solution was 13 or 26 $mg{\cdot}L^{-1}$ respectively for the 100 or 200 $mg{\cdot}L^{-1}$ solutions. Root medium of the treatments contained P in the range of 3.1 to 6.0 mg·L^{-1} before moving to interior environment. These low P values indicates that the amount of P supplied was lower than required by sunflower. Treatments with constant fertilization of 200 mg·L^{-1} (200 ; 200 ; 200) or 100 mg·L^{-1} (100 ; 100 ; 100) and 100 ; 100 ; 0 had a significant increase in the P concentration of the root medium.

Potassium (K): There was a significant difference among the treatments for K (Table 4). Treatments 200 ; 100 ; 0, 200 ; 0 ; 0, 100 ; 100 ; 0, and 100 ; 0 ; 0 resulted in significantly lower concentration of K in the rooting medium. The unusually low K concentration of the rooting medium indicates that sunflowers are heavy feeders of K. Root medium of treatments supplied with a constant fertilization of 200 mg·L^{-1} (200 ; 200 ; 200) resulted in significantly higher concentration of K than other treatments. The amount of K supplied with the fertilizer solution was 104 and 208 mg·L^{-1}, respectively for the 100 or 200 mg·L^{-1} solutions. Extremely low values of K in the root medium indicate that the amount of K supplied was lower than that required by sunflowers.

Calcium (Ca): The fertilizer treatments differed for Ca concentration (Table 4). Treatments with constant fertilization of 200 mg·L^{-1} (200 ; 200 ; 200) and 200 ; 200 ; 100 had a significant increase in the Ca concentration of the root medium. Fertilizer treatments 200 ; 100 ; 0, 200 ; 0 ; 0, 100 ; 100 ; 0, and 100 ; 0 ; 0 had a lower Ca concentration in the root medium. N fertilization at 100 mg·L^{-1} from potting untill day 55 (100 ; 100 ; 0) contained a similar amount of Ca as the 200 ; 100 ; 0 treatment.

Magnesium (Mg): Mg concentration of the root medium was significantly different for the treatments (Table 4). Treatments with constant fertilization of 200 mg·L^{-1} (200 ; 200 ; 200) and 200 ; 200 ; 100 had a significant increase in the Mg concentrationof the root medium. Fertilizer treatments 200 ; 100 ; 0, 200 ; 0 ; 0, and 100 ; 0 ; 0 had a lower Mg concentration in the root medium. The amount of Mg supplied with the fertilization solution was 12 and 24 $mg \cdot L^{-1}$ respectively for the 100 or 200 $mg \cdot L^{-1}$ solutions. Root medium of all the treatments, except for fertilizer treatments 100 ; 0 ; 0 contained Mg in excess of that supplied. This indicates that the amount of Mg required by sunflower is less and the excess accumulated in the root medium.

CONCLUSION

Surpluses or deficiences of nutrients can create plant stress which accelerates senescence, thus reducing the postharvest quality. The application of fertilizer in excess of requirements can result in the potential leaching of nutrients into the ground water. Growers concern for possible environmental regulation that could restrict their current fertigation practices can be handled by reducing the application of excess fertilizer, which can be acheived by correlating fertilizer application with the nutrient requirement of plants over time. Fertilizer treatments did not affect the number of days to flower, plant height, or flower diameter. Our data suggest that potted sunflowers fertilized with N at 100 $mg \cdot L^{-1}$ from potting until day 55 (100 ; 100 ; 0) had a longer postharvest life and were of marketable quality, even though the plants were of lesser plant diameter and smaller dry mass.

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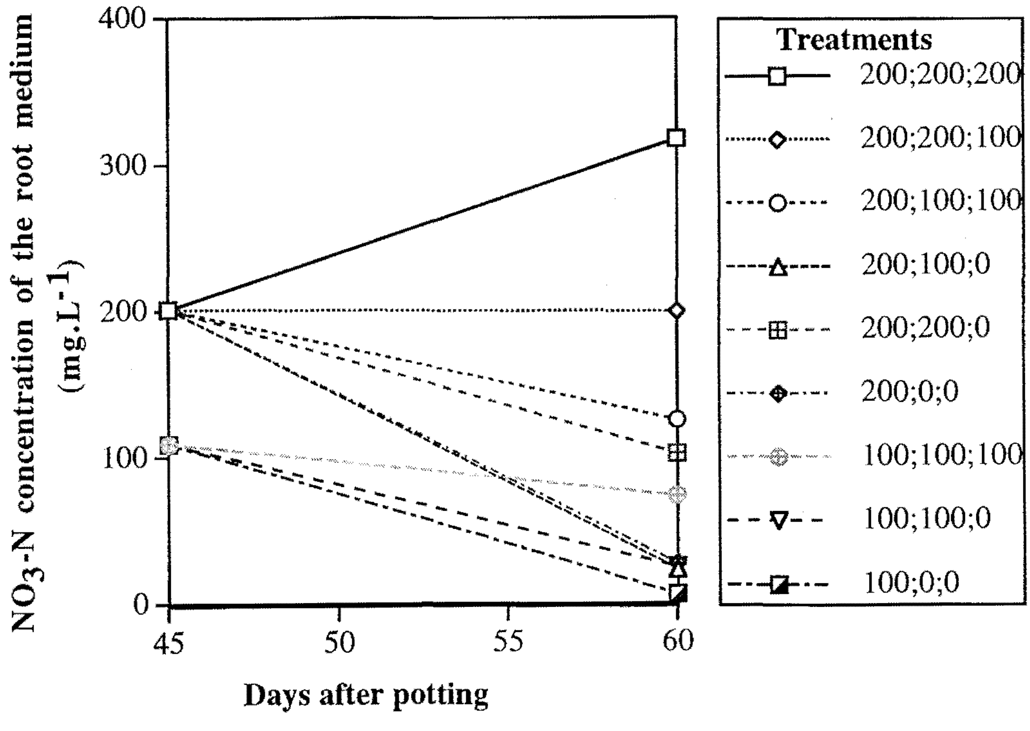

Figure 1. Changes in root medium NO_3-N concentration of 'Pacino' potted sunflowers fertilized initially with 100 or 200 mg·L^{-1} of N untill day 45, when fertilization rates were maintained, decreased, or terminated, and at anthesis (mean number of days to anthesis = 59.4 days).

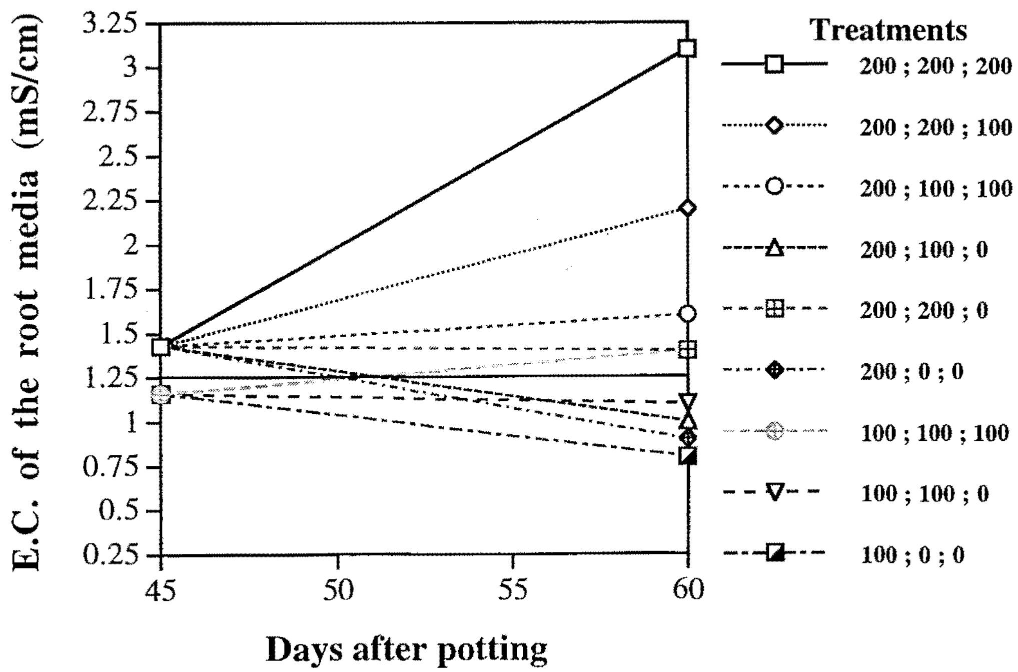

Figure 2. Changes in root medium EC concentration of 'Pacino' potted sunflowers fertilized initially with 100 or 200 mg·L^{-1} of N untill day 45, when fertilization rates were maintained, decreased, or terminated, and at anthesis (mean number of days to anthesis = 59.4 days). Solid line at 1.25 mS/cm represents upper limit of EC recommended by Warncke and Krauskopf (1983).

Table 1. Preharvest fertilization schedule ($mg{\cdot}L^{-1}$ of N) used for potted sunflowers.

Fertility subtreatments	Concentrations of N ($mg{\cdot}L^{-1}$)		
	Potting to day 45	Day 45 to 55	Day 55 to flowering [z]
1	200	200	200
2	200	200	100
3	200	100	100
4	200	100	0
5	200	200	0
6	200	0	0
7	100	100	100
8	100	100	0
9	100	0	0

[z] Mean number of days to flowering was 59.4. n = 45 plants (9 treatments x 5 reps).

Table 2. Effect of N (mg·L $^{-1}$) concentrations on growth characteristics of potted 'Pacino' sunflowers at anthesis.

Fertility treatments	N (mg·L $^{-1}$)	Plant ht (cm)	Plant dia (cm)	Flower dia (cm)	Days to flower	Dry mass (g)
1	200 ; 200 ; 200	43.1	45.5	11.8	59.4	19.1
2	200 ; 200 ; 100	44.3	45.4	11.6	59.4	12.0
3	200 ; 100 ; 100	44.2	44.9	12.4	58.8	12.8
4	200 ; 100 ; 0	43.2	44.0	12.8	59.0	14.3
5	200 ; 200 ; 0	43.3	42.9	11.8	59.4	13.2
6	200 ; 0 ; 0	42.1	41.9	11.4	59.4	14.2
7	100 ; 100 ; 100	44.4	43.6	11.0	59.8	13.0
8	100 ; 100 ; 0	45.7	41.9	12.3	60.2	14.9
9	100 ; 0 ; 0	41.2	37.6	11.4	59.0	11.9
$P > F^Z$		NS	***	NS	NS	***
LSD (∝ = 0.05)			1.98			1.67

^{Z}NS, *** Nonsignificant or significant at 0.001 level, respectively.

Table 3. Effect of N ($mg \cdot L^{-1}$) concentration on root medium levels of 'Pacino' potted sunflowers.

Fertility treatments	N ($mg \cdot L^{-1}$)	Root medium: Electrical conductance (mS/cm)	pH	NO_3-N	P ($mg \cdot L^{-1}$)	K	Ca	Mg
1	200 ; 200 ; 200	3.1	5.6	316.8	5.4	51.8	259.2	87.2
2	200 ; 200 ; 100	2.2	5.7	198.6	4.2	39.4	211.0	73.2
3	200 ; 100 ; 100	1.6	5.9	125.4	3.4	24.6	140.4	51.8
4	200 ; 100 ; 0	1.0	6.1	52.6	3.4	9.0	87.2	33.0
5	200 ; 200 ; 0	1.4	5.8	102.0	3.1	17.2	127.4	49.6
6	200 ; 0 ; 0	0.9	6.2	26.8	3.9	8.0	82.6	28.6
7	100 ; 100 ; 100	1.4	6.0	72.8	6.0	27.4	127.8	50.6
8	100 ; 100 ; 0	1.1	6.0	25.2	5.3	9.8	107.8	39.4
9	100 ; 0 ; 0	0.8	6.2	6.3	4.4	8.0	79.0	24.0
$P > F^z$		***	**	***	***	***	***	***
LSD ($\propto = 0.05$)		0.34	0.24	36.24	0.79	10.10	40.4	14.67

[z] Significant at 0.01 or 0.001 level respectively.

Table 4. Effect of N ($mg \cdot L^{-1}$) concentration on postharvest quality of 'Pacino' potted sunflowers.

Fertility treatments	N ($mg \cdot L^{-1}$)	Visual grade [Y]			Flower longevity
		Day 5	Day 10	Day 15	(Days)
1	200 ; 200 ; 200	1.0	4.6	5.0	9.2
2	200 ; 200 ; 100	1.0	4.8	5.0	9.4
3	200 ; 100 ; 100	1.0	4.2	5.0	9.4
4	200 ; 100 ; 0	1.0	5.0	5.0	10.2
5	200 ; 200 ; 0	1.0	5.0	5.0	9.2
6	200 ; 0 ; 0	1.0	4.8	5.0	9.6
7	100 ; 100 ; 100	1.0	4.2	5.0	9.2
8	100 ; 100 ; 0	1.0	3.0	5.0	11.6
9	100 ; 0 ; 0	1.0	4.8	5.0	9.4
$P > F^Z$		NS	NS	NS	*
LSD ($\alpha = 0.05$)					1.39

[Z] NS, * Nonsignificant or significant at 0.05 level.
[Y] Visual grade was evaluated on a scale of 1 = excellent, 2 = good, 3 = fair, 4 = poor, 5 = dead. Plants were evaluated on days 5, 10, and 15 after moving into a controlled interior environment room maintained at 21 ± 2 °C and 50 % ± 2 % RH with 30 - 36 $\mu mol \cdot s^{-1} \cdot m^{-2}$ of light for 24 h daily.

GENERAL CONCLUSION

Results of this study reported in the preceding four manuscripts suggest that sunflower can be suitably cultivated as a potted floricultural crop if appropriate pot culture techniques are used. The results of the first study suggest that growth control of sunflower can be favourably acheived by plant growth retardant uniconazole at concentrations between 16 and 32 $mg{\cdot}L^{-1}$ or with daminozide concentrations between 4000 and 8000, when applied as a foliar spray. The results of second experiment establishes the efficacy of paclobutrazol as a drench. Its effectively controls plant growth at concentrations of 2 and 4 mg a.i./pot. The third experiment suggests that paclobutrazol activity is not influenced by coir-based substrates, whereas pine bark-based substrates, which is commonly used as a media substrates inhibits the activity of paclobutrazol drenches (Barrett, 1982; Quarrels and Newman, 1994). Finally, the fourth study establishes the relationship between N fertilization, plant growth and postharvest quality of potted sunflowers. The results suggest that quality plants with longer postharvest life were produced with N at 100 $mg{\cdot}L^{-1}$ and by terminating fertilization 55 days after potting.

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