Nutrition and Plant Growth Regulator Rates for High Quality Growth of Containerized Spiderwort (*Tradescantia virginiana* L.)

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ABSTRACT

Spiderwort (*Tradescantia virginiana*) is a flowering herbaceous perennial. Little information is available about its production requirements. This project's purpose was to determine fertilizer and PGR rates for high quality growth of Spiderwort in a greenhouse production setting. The first experiment screened three plant growth regulators (PGRs) at ascending rates on three *T. virginiana* cultivars. The most effective rates for height suppression were paclobutrazol at 120 $mg \cdot L^{-1}$, uniconazole at 45 $mg \cdot L^{-1}$, and flurprimidol at 45 $mg \cdot L^{-1}$.

The second experiment was divided into two parts. The first screened three *T. virginiana* cultivars for their growth response to several nitrogen (N) rates. The second experiment used results from the first experiment and examined two cultivars response to a basic fertilizer. For experiment 1, N rates between 100 and 200 $mg \cdot L^{-1}$ resulted in quality plant growth. The second experiment showed little difference between height, width and flowering of both cultivars with these N rates. Plant quality was similar for plants fertilized with 100 and 200 $mg \cdot L^{-1}$ N at the end of both experiments.

The third study examined how fertilization rate affects the persistence of PGR growth control. PGR rates identified as effective in experiment 1 were used. Plants fertilized with 200 $mg \cdot L^{-1}$ N were taller than those fertilized with 100 $mg \cdot L^{-1}$ N, regardless of PGR treatment. PGRs did not suppress plant growth; plant quality was similar regardless of treatment. The results of these studies indicate that PGR effectiveness in suppressing plant height may be dependent upon season, with PGR application necessary only during the spring growing season.

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CHAPTER 1: LITERATURE REVIEW

Tradescantia species

Tradescantia is a genus containing 50 to 60 species, most of which are found growing in Mexico or Central America (MacRoberts, 1980). The Anderson and Woodson (1935) study recognized 22 species with widespread geographical distribution in the United States. There is considerable dissension among scientists/taxonomists about the true number of *Tradescantia* species because of widespread hybridization among species. The Commelinaceae family is notorious for its many ill-defined taxonomic boundaries for genus, including *Tradescantia* (MacRoberts, 1980). The *Tradescantia* genus was named after John Tradescant in 1753 by Linnaeus (Grossman, 1979). The Commelinaceae family is included in the monocot order.

Tradescantia's ability to grow easily from seed and for transplants to withstand all sorts of mistreatment makes it excellent for experimentation and observation. The genus is popular for cyto-genetic studies due to large chromosomes, tetraploid and diploid species which occur in nature, and long flowering periods, which make artificial pollination easier (Anderson and Woodson, 1935; MacRoberts, 1980). Grossman (1979) utilized a *Tradescantia* clone as a radiation monitor. Genetic research has been done utilizing the stamen hair cells of the flower; and flowers can also be used as pollution indicators (MacKenzie, 1997).

Tradescantia species are all sub-succulent perennial herbs. An upright growth habit is typical of most species, except *T. micrantha* which is distinguished by its trailing growth habit. The nodes of all species are slightly swollen; some species are more likely

than others to root at these nodes. The inflorescences of species native to the United States are tight umbels that are bilaterally symmetrical (Anderson and Woodson, 1935; MacRoberts, 1980).

Speciation is very important in determining the taxonomic background of *T.* species. *T. virginiana* is self-sterile; its pollen can fertilize other species, but will not fertilize any plants within its own species. Many species are interspecies-fertile. Many of the American species related to *T. virginiana* can be intercrossed readily. This characteristic leads to many hybrids that are partially fertile.

Table 1: Species of *Tradescantia* indigenous to the United States (Anderson and Woodson, 1935; MacRoberts, 1980).

Species	Height (dm)	Distribution
bracteata	0.5-4.4	Prairies to thickets and roadsides. Minnesota to central Missouri west to Montana and central Kansas. Central plain states, southern Oklahoma to central Texas
caniculata	1.7-6.5	Meadows and thickets, less frequently woods, common spreading to roadsides. Southern New England to Florida, west to Minnesota and Texas
edwarsiana	2.5-7.0	Rich woods along moist alluvial terraces and ravines. South central Texas
ernestiana	2.0-4.0	Rocky, wooded hillsides and ledges, extreme southwestern Missouri and adjacent to Arkansas and Oklahoma
gigantea	3.0-7.0	Eastern Texas and western Louisiana
hirsuticaulis	1.5-4.0	Rocky, sandy woods, thickets and ledges. Southern Appalachian mountains, Alabama, Georgia, and Arkansas
hirsutiflora	0.7-6.0	Sandy soil. Central Texas to Florida, north to Oklahoma and central Arkansas and northern boundary of Mississippi, Alabama, and Georgia. Complete range unknown due to confusion with *T. virginiana* in the east and *T. bracteata* to the west.
humilis	0.5-4.5	Sandy and rocky soil. East-central and southern Texas
longipes	0.2-1.0	Hillsides, southeast central Missouri
micrantha	0.3-3.0	Moist soil, southeastern coastal Texas

occidentalis var. *occidentalis*	0.5-7.0	Prairies and plains North Dakota to Texas, west of Mississippi river and east of Rockies
occidentalis var. *melanthera*	1.0-9.0	East Texas, eastern Oklahoma, southern Arkansas and Louisiana
ohiensis var. *ohiensis*	4.0-18	Throughout U.S. east of 100th meridian
ohiensis var. *foliosa*	1.5-8.0	Southern U.S. Florida, Alabama, Arkansas, Oklahoma, Louisiana, and Texas
ohiensis var. *paludosa*	1.5-6.0	Alluvial bottoms and forests. Lower Mississippi river in Louisiana and Alabama, less common southern Mississippi, scattered southern Arkansas
ozarkana	1.5-5.0	Rocky, wooded hillsides and ravines, southwestern Missouri, northwestern Arkansas, and extreme eastern Oklahoma
pinetorum	0.8-3.9	Moist canyons and stream banks, southwestern New Mexico and Arizona
reverchonii	1.0-10.5	Deep sand hills and dunes in eastern Texas and western Louisiana
roseolens	1.9-4.2	Deep sand. Florida, south-central South Carolina and Southern Georgia
subacaulis	1.0-3.0	Sandy soil, south-central Texas
subaspera	5.0-10.0	Woods and thickets, rarely into fields and roadsides. Central states, from Ohio to Missouri, south to Gulf coast and west to Louisiana
tharpii	0.2-0.7	Rocky prairies, extreme southwestern Missouri to southern Arkansas, northeastern Texas and eastern Oklahoma
virginiana	0.5-3.5	Woods and thickets, spreading to meadows, fields, and roadsides. Connecticut to northern Georgia, westward to eastern and central Missouri
wrightii	0.8-1.8	Moist canyon stream banks, Guadalupe mountains, extreme western Texas

Impact of Gibberellins on Plant Height

Most plant growth regulators (PGRs) inhibit some step in gibberellin (GA) biosynthesis. In order to understand how PGRs work, a basic understanding of the function of GA in plants is necessary. Gibberellin was discovered in Japan from studies with diseased rice (*Oryza sativa*) plants that grew excessively tall. These rice plants, infected by a fungus, were spindly, pale and prone to lodging (Raven et al., 1999). In the 1930s, the active compound in the fungus was isolated and named gibberellin (Salisbury

and Ross, 1992). Gibberellins have now been isolated from many plant species and been found to be present in varying concentrations in all plant parts. Over 84 GAs have been isolated and identified through chemical analysis (Raven et al., 1999). All gibberellins are named GA (for gibberellic acid) with a different numerical subscript for differentiation and are acidic (Salisbury and Ross, 1992).

Gibberellins stimulate cell division and elongation, and stem, leaf, flower stalk, and fruit growth; they can also inhibit the development of lateral buds (Salisbury and Ross, 1992; Kappers et al., 1997). Gibberellins are produced mainly in shoot tips and small leaves. Gibberellin application causes plants to grow taller because internodes become longer. For many plant species, flowering is stimulated by the application of GAs, thus reducing the amount of time needed for crop production (Barrett, 2001). Effective delay of leaf senescence in a number of plant species has been noted when gibberellins are applied (Kappers et al., 1997).

Gianfagna and Merritt (2000) found that $GA_{4/7}$ increased flower number and plant height of *Aquilegia* x *hybrida* while decreasing time to flower. GA_3 promoted flower bud opening in *Azalea* (Systema and Ruesink, 1996) and division and elongation of pith and epidermal tissues in *Phaseolus vulgaris* (Knoche et al., 1998). GA application on cabbage (*Brassica oleracea capitata*) and other rosette-type plants caused elongation of internodes, creating a 2 m tall flowering plant, whereas the nontreated plant was short and vegetative (Salisbury and Ross, 1992). Raven et al. (1999) reported that when gibberellins were applied to many dwarf mutants of *Phaseolus vulgaris*, they become indistinguishable from the normal, non-dwarf mutants. GA appears to be the main plant

hormone impacting the height of plants, mainly by influencing the degree to which the cells in stems, petioles, and leaves elongate.

Description of Plant Growth Regulators

Many growth retardants exert their influence by inhibiting cell division in the sub-apical zones of the shoot apex and subsequent cell enlargement, resulting in reduced stem elongation. Certain classes of growth retardants such as the triazoles, pyrimidines, and quaternary ammonium compound derivatives interfere with the biosynthesis of sterols and GAs, thus inhibiting stem elongation (Sauerbrey et al., 1987). Most of the plant growth regulators (PGRs) currently used in greenhouse and nursery production are used to control the shoot growth or habit of containerized herbaceous and ornamental crops (Banko and Stefani, 1995; Pobudkiewicz, 2000a). These growth retardants, often called anti-gibberellins, control shoot growth by inhibiting the production of gibberellins, which are responsible for the cell elongation of shoots and leaves (Barrett, 2001). Further benefits of PGR use in plant production include improvement of appearance by maintenance of plant size and shape in relation to pot size (Whipker and McCall, 2000). PGRs also enhance stress tolerance of plants by increasing the xylem pressure potential of treated plants and thereby enhancing plant moisture status during times when water is limited, i.e. during transport and retail marketing (Olsen and Andersen, 1995a). Plants treated with PGRs often exhibit reduced internode length and the leaves appear smaller and darker green. These darker green leaves may be due to increased accumulation of chlorophyll, reduced cell size and smaller intercellular spaces in leaves (Cathey, 1975). Gaussoin et al. (1997) noted that PGRs inhibitory to GA biosynthesis often have a moderate restraining effect on carbon dioxide exchange rate, thus possibly reducing the

photosynthetic rate. However, these same authors found an increase in chlorophyll levels present in plants after treatment with PGRs.

Flurprimidol (TopFlor, SePRO Corp., Carmel, IN) ((α-1-methylethyl)-α4-(trifuloromethoxy) phenyl-5-pyrimidinemethanol).

Flurprimidol is an effective GA biosynthesis inhibitor; it is a substituted pyrimidine compound and related in mode of action and structure to ancymidol. Flurprimidol is commonly used on floricultural crops in Europe and has a soil half-life of 4 to 5 months (Archbold, 1986; McDaniel, 1986). Sterrett and Tworkoski (1987) confirmed flurprimidol's role as a GA biosynthesis inhibitor, when they found that GA_3 reversed the inhibitory effect of flurprimidol on *Ligustrum ovalifolium*. They also found that flurprimidol is stable and not highly mobile in plants, indicating that it is active in small amounts. Flurprimidol, both foliar and root active, reduces internode elongation and leaf expansion of *Photinia* x *fraseri* and *Ilex crenata* 'Compacta' (Laiche, 1988), as well as *Capsicum frutescens* and *Helianthus* sp. (Premachandra et al., 1996). Flurprimidol also appears to be more readily transported via the xylem than the phloem (Sterrett and Tworkoski, 1987). Pobudkiewicz and Nowak (1994) reported no effect on flower diameter or shoot number after application of flurprimidol to *Dianthus caryophyllus*. Foliage of plants after treatment with flurprimidol has a darker green appearance (Pobudkiewicz, 2000b; Pobudkiewicz and Nowak, 1994, 1997; Sterrett and Tworkoski, 1987). Typical application rates for flurprimidol on perennials range between 7.5 to 50 $mg \cdot L^{-1}$ (Abdullah et al., 1998; Archbold, 1986; Burnett et al., 2000; McDaniel, 1986; Pobudkiewicz, 2000b; Pobudkiewicz and Nowak, 1992,1997; and Thomas et al., 1992).

Paclobutrazol (Bonzi, Syngenta Chem. Co., Greensboro, NC) [(±)-(R*,R*)-β-((4-chlorophenyl) methyl)-α-(1,1,-dimethylethyl)-1H-1,2,4,-triazole-1-ethanol)]

Paclobutrazol, a triazole, is an extremely active chemical and affects almost all plant species, whether applied as a spray or a soil drench (Barrett, 2001). Paclobutrazol inhibits GA biosynthesis by blocking the oxidation of *ent*-kaurene (Sponsel, 1995). It is applied to plants in the floricultural industry to control their size and quality (Million et al., 1999). Paclobutrazol is applied to perennials and other pot crops at rates of 1 to 90 $mg \cdot L^{-1}$ (Barrett, 2001; Dole and Wilkins, 1999). When applied as a foliar spray, paclobutrazol is absorbed by petioles and stems and is translocated through the xylem to the growing tip. When applied as a soil drench, it is taken up through the roots and then translocated through the xylem to the apical meristems (Syngenta, 2003). Soil drenches with paclobutrazol may be more effective than the foliar sprays due to increase activity and less probability of stunting and flowering delay, due to no direct contact with flowers or flower buds (Million et al., 1999). Depending on plant species, paclobutrazol can delay or promote flowering. Paclobutrazol half-life in the soil varies between 6 and 12 months depending upon the soil type and environmental conditions (Nørremark and Andersen, 1990).

Effectiveness of drenches is reduced if the crop is grown in a bark medium, because the chemical will adsorb to the bark and less will be available in the medium solution for the plant to absorb. Phytotoxicity symptoms are not common when applied to perennials, but care must be taken with those species that are known to be sensitive. Excessive stunting can result from application of higher rates or over application of

paclobutrazol (Dole and Wilkins, 1999). Excessively high concentrations can also result in excessive stunting and failure to flower (Abdullah et al., 1998).

Uniconazole-P (Sumagic, Valent USA, Marysville, Ohio) ((E)-1-(p-chlorphenyl)-4,4-dimethyl-2-(1,2,4-triazol-1-yl-1-penten-3-ol))

Uniconazole is also a triazole, and will have similar effects as paclobutrazol. Precautions taken with paclobutrazol also should be taken with uniconazole. Uniconazole is applied at rates of 1 to 50 $mg \cdot L^{-1}$ to different crops, some perennials may need higher rates applied to gain control over growth (Barrett, 2001). Pobudkiewicz and Nowak (1994) reported no effect on flower diameter or shoot number, when uniconazole was applied to *Dianthus caryophyllus*. Four to ten times less uniconazole is needed to achieve the same reduction in height as paclobutrazol gives (Barrett and Nell, 1995).

Previous Uses of Growth Retardants

Pobudkiewicz and Podwyszyńdska (1999) worked with *Globba winitii* and found that both drench (0.075 mg/pot) and foliar (15 $mg \cdot L^{-1}$) applications of flurprimidol effectively reduced plant height. They also found that flurprimidol treated *G. winitii* were darker green than untreated, but date of flowering was not affected. Foliar application of flurprimidol to *Cuphea ignea* at 5 to 10 $mg \cdot L^{-1}$ provided acceptable height suppression, foliage became darker green, and flower size was reduced (Pobudkiewicz, 2000a). *Osteospermum* plants treated with 45 $mg \cdot L^{-1}$ of flurprimidol had both optimal and maximal compactness as rated by Olsen and Andersen (1995a). Flurprimidol application reduced flower size by 0.1 cm, increased time to flower from 66 to 70 days, and decreased flower longevity from 5 to 4 days. Flurprimidol applied at 45 $mg \cdot L^{-1}$ to *Osteospermum ecklonis* 'Calypso' resulted in plants two to four times more compact than

those plants treated with 8 mg·L^{-1} uniconazole in both height and width; it took 2 to 3 more days for flurprimidol treated plants to flower than the control plants (Olsen and Andersen, 1995b).

Burnett et al. (2000) treated *Achillea* x 'Coronation Gold' and *Gaura lindheimeri* 'Corrie's Gold' with flurprimidol, and reported reductions in plant height of 21% and 46%, and 19% and 13%, respectively in 1998 and 1999 after 150 mg·L^{-1} application. Flurprimidol applied to *Swainsona formosa* at 0.5 and 1.0 mg a.i. per pot, effectively reduced plant height by 28% and 29%, respectively. No toxicity symptoms were noted, and treated plants were greener than untreated plants (Hamid and Williams, 1997). Application of 22.5 mg·L^{-1} of flurprimidol to *Alstroemeria* cultivars 'Rosalina' and 'Dorotea' adequately controlled height; 'Rosalina' florets were smaller than control florets, while 'Dorotea' florets were not affected (Pobudkiewicz et al., 2000). Following flurprimidol treatment floret longevity and number of flowering shoots of both cultivars were reduced and both cultivars were darker green than controls. Lekawatana and Criley (1989) reported excessive height reduction and prevention of flowering stalk development after application of flurprimidol at 0.5, 1.0, 2.0 mg a.i. per pot to *Heliconia stricta* 'Dwarf Jamaican.' Both foliar application at 25 mg·L^{-1} and soil drench at 0.03-0.06 mg a.i. per pot of flurprimidol effectively reduced plant height of three poinsettia (*Euphorbia pulcherrima*) cultivars (McDaniel, 1986).

'Prima' lilies (*Lilium asiaticum*) treated with 20 mg·L^{-1} of flurprimidol attained the desired height for growth in a 10-cm container, while 40 and 50 mg·L^{-1} resulted in excessive height reduction; no delay in flowering was noticed with the 20 mg·L^{-1} treatment, but approximately 8% of flower buds were aborted, and foliage was darker

green (Pobudkiewicz and Nowak, 1992). Application of flurprimidol to *Dendranthema grandiflora* 'Quest' as a capsule (0.5 mg a.i.), drench (0.5 mg a.i.), gel (0.5 mg a.i.), tablet (0.5 mg a.i.) or spray (50 mg·L^{-1}) effectively retarded plant growth (Sanderson et al., 1990a). The drench application caused 70% height reduction and reduced flower number, while the other treatments averaged around a 40% reduction in height and did not reduce flower number. Flurprimidol application to southern bleeding heart (*Dicentra spectabilis*) at 0.5 mg a.i. per pot in tablet form adequately reduced plant height, but the number of racemes per plant was reduced by 55% (Sanderson et al., 1990b). Excessive suppression of vegetative and flower stalk growth of *Canna* x *generalis* 'Florence Vaughn' was attained with application of flurprimidol (Bruner et al., 2000). Even at the lowest rate, 50 mg·L^{-1}, flurprimidol suppressed flower stalk growth resulting in flower stalks shorter than plant foliage, so floral display became less striking and plants less marketable. Keever et al. (1994) treated 'China Girl' holly (*Ilex* x *meserveae*) with 500, 1,500, or 2,500 mg·L^{-1} flurprimidol; they found that 500 mg·L^{-1} reduced first season growth 17%. When 1,500 and 2,500 mg·L^{-1} were applied a 40% reduction in growth occurred and lasted for two seasons. Foliage color of plants treated with flurprimidol was noticeably darker green, and the difference in color lasted for over two growing seasons at the higher rates. *Buddleia davidii* 'Royal Red' treated with flurprimidol at 62.5 mg·L^{-1} controlled shoot growth over a short time without any delay in flowering, whereas 125 or 250 mg·L^{-1} resulted in control over shoot height for a longer time period with no negative impact on time to flower (Keever and Gilliam, 1994).

Dianthus caryophyllus 'Snowmass' height was suppressed after treatment with 15 or 22.5 mg·L^{-1} flurprimidol with no adverse effects on flower size or number

(Pobudkiewicz and Nowak, 1994). Flurprimidol applied at 50 mg·L^{-1} effectively reduced plant height and reduced production time for *Melastoma decemfidum* and *Tibouchina semidecandra* (Abdullah et al., 1998). An increase in the total number of flowers was also noticed as a result of flurprimidol application to *M. decemfidum.* *Tibouchina urvilleana* height was effectively controlled by flurprimidol at 0.15 mg·L^{-1} a.i. (Johansen et al., 1999). Response of seed propagated *Pelargonium* to flurprimidol application rate varied with cultivar (Pobudkiewicz, 2000b). The most vigorous geranium cultivars required higher flurprimidol rates to control height. Height of 'Ringo 2000 Violet' and 'Ringo 2000 Deep Rose' was controlled by flurprimidol at 15 mg·L^{-1}, while 22.5 mg·L^{-1} was needed to obtain similar results on 'Ringo 2000 Light Salmon' and 'Pinto Salmon.' Geranium florets were smaller and peduncle length shorter after flurprimidol application; deeper green coloration of foliage across all cultivars was noted after PGR application. *Dendranthema grandiflora* 'Altis' and 'Surf' both exhibited adequate reduction in plant growth after flurprimidol application at 7.5 or 22.5 mg·L^{-1} (Pobudkiewicz and Nowak, 1997). When applied at these rates, flurprimidol delayed flowering on *D. grandiflora* that were disbudded, but not on plants with developed flower buds.

Paclobutrazol, a triazole, brought into common use during the 1980's is a more active PGR than either daminozide or chlormequat, and thus is applied in much lower concentrations. Jiao et al. (1986) found the most effective method for height control of 'Nellie White' Easter lily (*Lilium longiflorum*) was granular soil incorporation and that paclobutrazol sprays were ineffective. Cox and Keever (1988) obtained acceptable height control for zinnia (*Zinnia elegans*) with paclobutrazol drench rates of 0.5 or 1.0 mg a.i./pot or spray rates of 250, 500, or 1,000 mg·L^{-1}. Drench treatments of

paclobutrazol at 0.0075 or 0.015 mg a.i./pot or spray treatments of 20 or 40 mg·L^{-1} caused acceptable height control of geraniums whereas higher rates produced unmarketable plants due to excessive stunting (Cox and Keever, 1988). Paclobutrazol did not affect days to flowering. Latimer (1991) gained good control over zinnia height in a greenhouse setting using 40 mg·L^{-1} paclobutrazol. Although this rate was lower than those typically applied to zinnias, plant height was reduced for 7 weeks in the field.

Paclobutrazol applied at rates of either 25 or 100 mg·L^{-1} to *Verbena rigida* adequately reduced plant height, had no impact on time to flower, and drastically reduced the incidence of plant lodging after transplant to the field (Davis and Andersen, 1989). Hamid and Williams (1997) found paclobutrazol to be the most effective PGR applied to *Swainsona formosa*. When applied as a drench at 10, 20, and 50 mg a.i. per pot, paclobutrazol reduced both main and lateral shoot growth, produced healthier fibrous roots, but significantly increased time to flowering by 4, 6, and 14 days respectively. McDaniel (1986) found paclobutrazol applied foliarly at 25 to 50 mg·L^{-1} or at 0.5 mg a.i./pot one week before short days began effectively controlled height of 'Eckespoint C-1 Red', 'Annette Hegg Dark Red' and 'Butbier V-14 Glory' poinsettia. Niu et al. (2002) obtained greatest reduction in height and bract area of poinsettia 'Freedom' with paclobutrazol drench application at 1 mg·L^{-1} in 118 mL volumes per pot immediately after initiation of short days, but the amount of height and bract area reduction decreased as the time of application drew closer to anthesis. Application of paclobutrazol to *Heliconia stricta* 'Dwarf Jamaican' at 0.5 mg a.i. per pot resulted in adequate height control without inhibiting formation of flowering stalk (Lekawatana and Criley, 1989).

Barrett et al. (1994) compared the effectiveness of drench versus spike treatments of paclobutrazol at rates ranging from 0.25 to 5.0 mg a.i./pot depending on species. Plant height did not differ between drench and spike treatments on four of the five species tested. *Caladium* grew too quickly for the spike to effectively control height. Further research on *Caladium* revealed that paclobutrazol drench treatments of 0.5 to 1.0 mg a.i./pot three weeks after planting resulted in adequate height control (Barrett et al., 1995). Application of paclobutrazol at 0.24, 0.47, 0.95, and 1.9 mg a.i./pot to tuberous-rooted dahlias (*Dahlia variabilis*) showed significant cultivar interactions; height was controlled on 'Golden Emblem,' but not on 'Red Pygmy' (Whipker et al., 1995a). Nørremark and Andersen (1990) worked with seed propagated *Pelargonium* x *hortorum* and found that paclobutrazol effectively reduced height, even at very low concentrations (0.05 mg a.i./pot), but higher concentrations stopped plant stem elongation completely. Although time to flower was increased by 1 week, the number of inflorescences per plant was significantly reduced. Therefore, application of paclobutrazol to seed propagated geraniums was not recommended. Paclobutrazol application to *Tibouchina urvilleana* at rates of 1 and 5 $mg \cdot L^{-1}$ effectively controlled plant height (Johansen et al., 1999). Paclobutrazol applied at 32 $mg \cdot L^{-1}$ to *Osteospermum ecklonis* 'Calypso' resulted in compact plants that took 2 to 3 more to flower than the controls plants (Olsen and Andersen, 1995b).

Dutch-grown bleeding hearts (*Dicentra spectabilis*) showed significant delay of flowering with paclobutrazol application at 50 $mg \cdot L^{-1}$, however, treatment resulted in deeper green coloration of the leaves and adequate height control (Kim et al., 1999). *Ixia* leaf and flower stalk lengths were significantly reduced when paclobutrazol was applied

as a preplant corm soak (50 or 100 mg·L^{-1}), soil drench (0.25 or 0.50 mg a.i./pot), or spray (100 or 200 mg·L^{-1}; Wulster and Ombrello, 2000). However, no significant decrease in flower number or delay in flowering time was noticed. Gibson and Whipker's (2001) study on *Brassica oleracea* var. *acephala* revealed that concentrations of up to 80 mg·L^{-1} paclobutrazol were ineffective in controlling height of 'Nagoya Red,' but 'Osaka White' height increased with increasing concentrations. The height and width of pampas grass (*Cortaderia selloana*) were considerably reduced by application of paclobutrazol at 2 mg a.i./pot (Sellmer et al., 2001). The finding provided added advantages for growers because spacing between pots can be reduced as lateral growth control is increased. Paclobutrazol applied to 'First Lady' African marigold (*Tagetes erecta*) and 'Honeycomb' French marigold (*Tagetes patula*) , as either a single drench of 0.5 mg a.i. per pot or foliar application at 250 or 500 mg·L^{-1}, resulted in adequate but not excessive height control (Keever and Cox, 1989). The drench application appeared to be more persistent at controlling plant height after transplant in the landscape, possibly an undesirable trait.

Uniconazole is a triazole that can retard the growth of a wide spectrum of plant species (Sterret, 1988). Uniconazole applications of 15 or 30 mg·L^{-1} to 'Connecticut King' lilies showed significant growth retardant effect one week after application (Wang et al., 1990). *Lisianthus* height was effectively retarded by spray (10.0 mg·L^{-1} applied once or 5.0 mg·L^{-1} applied twice) or drench (1.60 mg a.i./pot) applications of uniconazole (Starman, 1991). The foliar spray delayed the days to flowering; while the drench actually accelerated the days to flowering. Whipker et al. (1995a) found that tuberous-rooted dahlias responded to the application of uniconazole at 0.24 or 0.47 mg a.i./pot.

Height of 'Golden Emblem' was reduced by uniconazole application, but not enough to make the crop marketable, while the height of 'Red Pygmy' was reduced enough to make the crop marketable. Uniconazole application at 15 mg·L^{-1} to *Oenothera fruticosa* resulted in a 31% reduction in plant height at flowering compared with controls and flower diameter was reduced by 36% (Clough et al., 2001).

Pot aster height control varied with cultivar when uniconazole was applied (Whipker et al., 1995b). With 'Purple Monarch,' a rate of ≥10 mg·L^{-1} uniconazole effectively reduced the height by ≥ 10%; while with 'Butterfly Blue,' uniconazole did not significantly affect height until the rate was ≥40 mg·L^{-1}. Dutch bleeding hearts responded to uniconazole with a significant decrease in height with application rates between 1 and 5 mg·L^{-1}, and no phytotoxicity was reported (Kim et al., 1999). Gibson and Whipker (2001) reported that plant height was negatively and linearly related to uniconazole concentration (2 to 32 mg·L^{-1}) for both 'Osaka White' and 'Nagoya Red' cultivars of *Brassica oleracea* var. *acephala*. Uniconazole provided consistent height control for *Canna* x *generalis* throughout container production (Bruner et al., 2001). However, the second flowering period was delayed three to seven days as a result of treatment and height control with 20, 40, or 60 mg·L^{-1} uniconazole was considered excessive, reducing the marketability of the plant.

Uniconazole applied at 5, 25, or 100 mg·L^{-1} to *Verbena rigida* drastically reduced plant height in comparison with nontreated controls. Time to flowering was not affected by treatment, and performance in the field was improved because incidence of lodging due to wind and rain was greatly reduced (Davis and Andersen, 1989). Uniconazole applied at 8 mg·L^{-1} to *Osteospermum ecklonis* resulted in plants with optimal

compactness (Olsen and Andersen, 1995a). Only a 1 or 2 day increase in time to flower was noted with uniconazole treatment; treated flowers were similar in size to control flowers; and no decrease in vase life was noted with 8 $mg \cdot L^{-1}$ treatment. A similar response was noted with *Osteospermum ecklonis* 'Calypso' when uniconazole was applied at 8 $mg \cdot L^{-1}$ with resulting adequate height control; it took 2 to 3 more days for uniconazole treated plants to flower than the controls plants (Olsen and Andersen, 1995b). Treatment of *Dianthus caryophyllus* 'Snowmass' with 7.5 $mg \cdot L^{-1}$ uniconazole resulted in desirable height control, whereas with higher rates, height control was too severe (Pobudkiewicz and Nowak, 1994). However, regardless of rate applied, no flower delay or reduction in flower size was noted.

Media pH and EC

The pH and electrical conductivity (EC) of media are two aspects which significantly influence plant growth. Both can be monitored and ranges identified where optimal plant growth occurs. Media pH is an expression of the activity of H^+ ions in the soil solution (Foth and Ellis, 1997). The general range of pH for greenhouse crops is between 5.4 and 6.8, but many greenhouses keep their pH between 5.6 and 6.2 in order to avert potential problems with nutrient deficiencies and toxicities. Pre-plant addition of lime to soilless media to raise pH is a common practice. Over time, when acidic fertilizers are used, the pH of the media tends to decrease (Elliott, 1996). Acidic fertilizers have nitrogen in the form of ammonium nitrate. As the fertilizer is taken up by the plant, the H^+ released from ammonium will acidify the media and media pH will decrease over time with fertilizer application (Dole and Wilkins, 1999). James and van Iersel (2001) found a linear correspondence of pH and time after transplant with pH

decreasing an average of one point over their seven week experiment. They also found the leachate pH of petunias (*Petunia* x *hybrida*) and begonias (*Begonia* x *semperflorens-cultorum*) fertigated with an acidic fertilizer consistently lower than that of petunias and begonias fertigated with a slightly basic fertilizer. Basic fertilizers provide nitrogen in the calcium and potassium nitrate form. Over time with treatment, media pH will rise as calcium or potassium are released into the media (Dole and Wilkins, 1999).

Electrical conductivity (EC) is an expression of the soluble salts, or total concentration of salts dissolved in the soil solution or root substrate at any given time (Whipker et al., 2001). High EC reduces plant growth by reducing plant water uptake. Symptoms of high EC include plants with a stunted appearance, slow growth, and limited root development. Insufficient leaching or high fertilizer application levels often results in rising EC levels (Whipker et al., 1999). Growers usually leach their media excessively in an effort to keep EC as low as possible without causing nutrient deficiencies (Ku and Hershey, 1996). When the concentration of soluble salts is too low, plant growth is generally slow and deficiency symptoms can be observed. Low EC can be a result of excessive leaching, too many irrigation cycles with clear water, or an injector system that is not working properly. Leaching fraction is calculated as the volume of solution leached divided by total volume of irrigation solution applied (Ku and Hershey, 1996). Excessive soluble salt levels can have the reverse effect of low EC where plant growth can be lush and excessive, and nutrient toxicity symptoms can be observed (Whipker et al., 2001).

Argo and Biernbaum (1994) found that containers with a barrier to prevent evaporation from the media had lower ECs in the top 10-cm of the media, than did those

containers without evaporative barriers. The limiting factors of plant growth and survival according to Campos and Reed (1993) are dissolved soluble salts in irrigation water and soluble salts that have accumulated in the medium from water-soluble fertilizers. Catanzaro et al. (1998) reported that leachate from pots fertilized with a slow release N source had lower EC than those fertilized with a liquid fertilizer. Ku and Hershey (1991) established that constant liquid fertilization with a leaching fraction of 0.4 results in a relatively steady level of soluble salts in the leachate.

Constant Liquid Feed

Constant liquid feed (CLF) or fertigation is the practice of mixing water-soluble fertilizer with irrigation water and applying it to a crop at every irrigation. Under CLF and no leach irrigations, medium water holding capacity can influence medium nutrient levels and fertilization frequency (Argo and Biernbaum, 1994). Factors such as cation exchange capacity (CEC), water-holding capacity, and evaporative water loss also influence nutrient availability to plants (Argo and Biernbaum, 1994). Nell et al. (1997) proposed a direct relationship between fertilizer concentration and potted plant longevity (poinsettia and chrysanthemum), higher fertilization levels result in decreased plant longevity and thus lower plant quality. Liquid fertilization is able to provide nutrition at appropriate levels for both root and shoot growth, but the root: shoot ratio may decrease with high fertilizer concentrations (Catanzaro et al., 1998).

Spathiphyllum and *Dieffenbachia* growth was enhanced with small increases in nutrient concentration (25 or 50 $mg \cdot L^{-1}$ N), with both species exhibiting increased total leaf area with increasing fertilizer concentrations up to 200 $mg \cdot L^{-1}$ N (Campos and Reed, 1993). Ku and Hershey (1996) fertigated poinsettias with 0, 100, 200 and 300 $mg \cdot L^{-1}$ N

and subjected each of these treatments to differing leaching fractions (LF): 0, 0.2, and 0.4. The poinsettias (*Euphorbia pulcherrima*) fertigated at 200 and 300 mg·L^{-1} N were more compact and darker green than those fertigated at 100 mg·L^{-1} N. Plant quality was not impacted by LF at 200 mg·L^{-1} N, but at 300 mg·L^{-1} N and 0 LF, plants showed signs of salinity stress. General fertilizer recommendations for poinsettias range from 250 to 300 mg·L^{-1} N for CLF. Adams et al. (1998) examined the impact fertilization with sulfur (S) and N had on growth and marketability of poinsettia 'Dark Red Annette Hegg;' they found the addition of S to fertilizer applied to poinsettias decreased the amount of N fertilizer necessary to produce marketable plants. Sulfur application at 25 mg·L^{-1} reduced the needed amount of N to 125 mg·L^{-1}. Kuehny et al. (2000) found that plant height was not influenced by fertilizer concentration. Fertilizer concentrations applied to poinsettias can be reduced if leachate levels are low. The lowered leachate levels enable nutrient concentrations to stay high enough to support optimum plant growth. Whipker et al. (1999) worked with several cultivars of double impatiens (*Impatiens walleriana*) and found that 'Blackberry Ice' a variegated cultivar exhibited wavy or rippled leaf surfaces when grown at N rates between 200 and 300 mg·L^{-1}, while no distortion was noted on 'Purple Magic,' a green-leaved cultivar. They also observed an increase in the EC of 'Blackberry Ice' plants in comparison with 'Purple Magic' plants after fertilization with 200 mg·L^{-1} N; this increase suggests that variegated double impatiens cultivars have a lower nutritional demand than green-leaved cultivars.

Thomas et al. (1998) working with container grown freesias (*Freesia* x *hybrida* found that fertilization with N increased foliage production, particularly leaf number, plant height and fresh weight. Melton and Dufault (1991) reported that N accounted for

the major variations in tomato (*Lycopersicon esculentum*) transplant height, leaf number and area, and stem diameter. As N concentration increased, both root and shoot growth increased. They also reported that P accounted for only minor variations in transplant characteristics. They conclude that 225 $mg \cdot L^{-1}$ N, 45 $mg \cdot L^{-1}$ K and 25 $mg \cdot L^{-1}$ P is necessary for optimum tomato transplant growth. Broschat and Klock-Moore (2000) studied the effects of P fertilization on growth of *Dypsis lutescens, Spathiphyllum* 'Figaro', *Ixora* 'Nora Grant', *Lycopersicon esculentum* 'Floramerica', *Tagetes erecta* 'Inca Gold' and *Capsicum annuum* 'Better Bell' and found that most container grown plants need minimal amounts of P for optimum growth, and that relative shoot or root growth does not increase, as popularly believed, with increasing P fertilization. Kraus et al. (2002) studied the importance of N form on nutrient uptake patterns in *Rudbeckia fulgida* 'Goldsturm'; they found fertilization with 100% NO_3 resulted in consistently lower amounts of N, K, Ca, and Mg present in roots and shoots versus fertilization with NH_4^+ alone or with a mixture of NO_3 and NH_4^+.

Colorimeter, Hue Angle (Hue °), and Chroma

The colorimeter, or chroma meter, is a tristimulus or three-filtered color analysis tool for measuring surface reflective color (Minolta, 1988). It makes use of red, green and blue filters that imitate human eye response to light and color. Diffuse, even lighting is provided to sample surface by a pulsed xenon arcon lamp. Reflected and incident light are measured by six silicon photocells, which are filtered to correspond with the CIE (Commission Internationale de l'Eclairage; International Commission on Illumination) Standard Observer Response. Absolute measurements can be taken in Yxy, L*a*b*,or L* C* H° coordinates in the Munsell color system (Minolta, 1988). A measured color

can be pinpointed in a three dimensional space using any of the above coordinates (McGuire, 1992; Voss, 1992).

The L*a*b* color space is also referred to as CIELAB, and is widely used to quantify object color in virtually all fields (Minolta, 1994). In the CIELAB color space L* quantifies with lightness and ranges from black = 0 to white = 100; a* and b* are chromaticity coordinates. Color direction is indicated by the a* and b* values. At values a* = 0 and b* = 0 the color grid is gray or achromatic. A positive a* ranges from red to purple while a negative a* can range from blue to green. Positive b* indicate yellow and a negative b* indicate blue (McGuire, 1992; Minolta, 1994). The largest an a* or b* value can be is ±60. The closer the a* and b* values are to 60, the greater their color saturation value (McGuire, 1992).

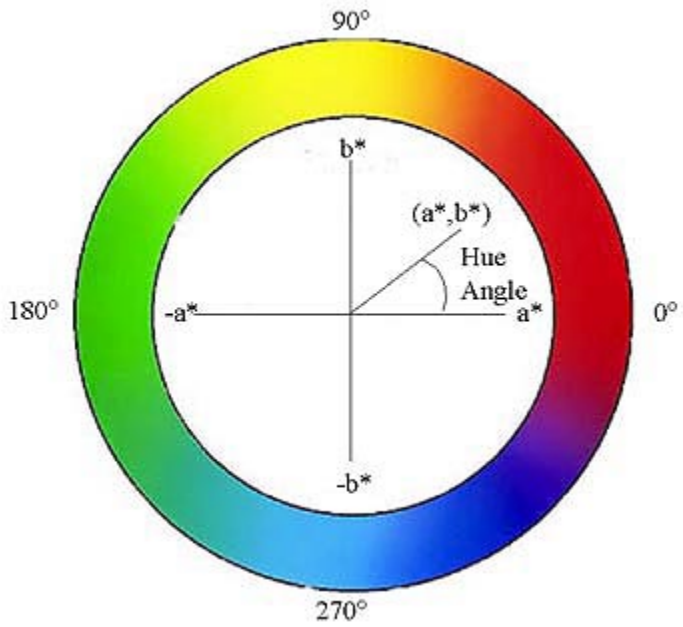

Figure 1.1. CIE-LAB hue sequence and hue-angle orientation.

The a* and b* values can be converted into hue angle (hue°) and chroma. Hue° is defined as pure color, whether a red, yellow, green, etc.; it is actually how we see a color.

Hue values are stepped counterclockwise on a 360° chromatic circle, significant angles are 0, 90, 180, and 270 which represent the red-purple, yellow, bluish-green, and blue hues, respectively (Gonnet, 1999; Wang and Camp, 2000). Chroma is the extent of divergence from gray toward pure chromatic color or the vividness or dullness of a color. The hue°can be determined by taking the arctangent of b*/a*, and $[(a^{*2} + b^{*2})^{1/2}]$ worked out yields chroma (McGuire, 1992). The hue° and chroma are much easier to equate with actual colors, and thus make analysis of data involving color much easier to understand.

For many objects the precision with which color is measured depends upon the research objectives. If a researcher is exploring botanical taxonomy, color is a general diagnostic tool (e.g. whether stems are gray or green in *Ilex*); but when trying to distinguish between cultivars, color is very important because many cultivars are indistinguishable save for slight color differences (Voss, 1992). Landschoot and Mancino (2000) compared two species of bentgrass (*Agrostis stolonifera* and *A. capillaris*) turf to determine if color differences could be detected using a chroma meter. In a previous bentgrass study, they found strong correlations between measured hue° and rate of fertilization. In this study, they found cultivars differed in their lightness, hue°, and chroma. When comparisons were made between detected values and visual color assessments, they found that hue° was the most consistent parameter at differentiating between cultivars. Adams et al. (1998) examined N and sulfur (S) fertilization rates and their impact on poinsettia foliage color and plant marketability. Lightness and chroma values of foliage decreased with increasing N, so foliage became duller and more gray in coloration. Hue° increased with increasing N levels and then leveled off, thus as N levels increased, the foliage became more green. Sulfur fertilization at 12.5 $mg \cdot L^{-1}$ resulted in

darker foliage, but no additional deepening in coloration was noted with higher S fertilization rates.

Krajayklang et al. (2000) reported that as color stage of *Capsicum annuum* fruit at harvest increased (became a darker red) L* values decreased, from 52 for a green fruit to 38 for a deep red fruit. Chroma increased from the green harvested fruit to the mature red fruit and then leveled off. The higher chroma values for red fruit indicated more brilliant coloration. Hue° decreased from 69° for yellow harvested fruits to 51° for red harvested fruits. Brand (1997) studied the impact of shade on leaf coloration of *Kalmia latifolia*; they found shade improved foliar color of the five cultivars tested. With added shade, the hue° of all cultivars increased linearly. In full sun average hue° was 118°, a yellowish green, in 60 percent shade cultivar hue° averaged about 132°, a much greener hue. Lightness and chroma decreased linearly with increasing shade across all cultivars, indicating that with increased shade foliage became more dull (darker green) in coloration.

Rationale

Little cultural research has been done with Spiderwort (*Tradescantia virginiana*). Spiderwort is a versatile plant that is able to adapt to and grow well in a variety of environmental conditions. There are many varieties and cultivars available in a wide range of colors and sizes. It is also easily propagated by stem cuttings, where it roots at the nodes, making production of large numbers of plants feasible. Yet, it is relatively unknown with the general public despite its many virtues. Development of production guidelines for optimum fertilization and PGR rates would enable growers to produce this crop in a more efficient manner. Controlling the height and spread of *T. virginiana*

would also increase the length of time the crop is marketable to the consumer, because it would remain an aesthetically pleasing compact form in the pot for a longer time period. Plant growth regulator application may also darken foliage color so foliage is more attractive.

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CHAPTER 2: PLANT GROWTH REGULATOR RATES FOR HEIGHT SUPPRESSION OF *TRADESCANTIA VIRGINIANA* L.

Additional index words. *Tradescantia virginiana*, flurprimidol, paclobutrazol, uniconazole

Abstract. Little information is available on cultural requirements for greenhouse production of *Tradescantia virginiana*. We tested three plant growth regulators (PGRs) at ascending rates on *T. virginiana* 'Angel Eyes,' 'Blue Stone,' and 'Red Cloud' in an effort to find appropriate application levels. Plants were selected, blocked by size, and treatments applied two weeks after transplant. Each PGR was applied once at the following rates: paclobutrazol at 0, 40, 80, 120 or 160 mg·L^{-1}, uniconazole at 0, 15, 30, 45 or 60 mg·L^{-1}, or flurprimidol at 0, 15, 30, 45, 60 or 75 mg·L^{-1}. Most effective paclobutrazol rate for adequate height suppression was 120 mg·L^{-1}. Uniconazole at 30 to 45 mg·L^{-1} and flurprimidol at 45 to 60 mg·L^{-1} resulted in adequate height control. 'Blue Stone' and 'Red Cloud' appeared more responsive (greater reduction in height at rates applied) to both uniconazole and flurprimidol than 'Angel Eyes.' These results suggest cultivars respond in a different manner to PGRs applied to them; quality growth can be obtained for cultivars tested using these suggested rates. Chemical names used: α-(1-methylethyl)-α4-(trifuloromethoxy) phenyl-5-pyrimidinemethanol (flurprimidol); [(±)-(R*,R*)-β-((4-chlorophenyl) methyl)-α-(1,1,-dimethylethyl)-1H-1,2,4,-triazole-1-ethanol)] (paclobutrazol); ((E)-1-(p-chlorphenyl)-4,4-dimethyl-2-(1,2,4-triazol-1-yl-1-penten-3-ol)) (uniconazole).

Introduction

Tradescantia virginiana is an herbaceous perennial native to areas in North America. It is well adapted to sun and shade as well as both wet and dry areas in the landscape. These characteristics along with the numerous cultivars available and extended flowering period during the summer make them good landscape plants. In the landscape, the vigorous and spreading growth habit of spiderwort is desirable; for the greenhouse grower, it is a challenge. The spiderwort rapidly outgrows the pot it is placed in, becomes unsightly and lodges. This characteristic, especially noticeable late in the summer season, reduce crop marketability. Unfortunately little information is available about *Tradescantia virginiana* cultural requirements. Flurprimidol (FLU), paclobutrazol (PAC), and uniconazole (UNI) are plant growth regulators (PGRs) that control plant growth by inhibiting the synthesis of gibberellins. These PGRs have been examined in many studies.

Response to application of PGRs depends upon the plant. Plant height may be suppressed with or without bloom delay. Pobudkiewicz and Nowak (1994) studied *Dianthus caryophyllus* 'Snowmass' and obtained desirable height control with no adverse effects on flower size or number with foliar applications of 15 or 22.5 $mg \cdot L^{-1}$ (ppm) FLU. Consistent suppression of vegetative and flower stalk growth of *Canna* x *generalis* 'Florence Vaughn' was attained with foliar application of FLU at 50 $mg \cdot L^{-1}$ (ppm), but the suppression of flower stalk growth greatly reduced the salability of the plant (Bruner et al., 2000). *Buddleia davidii* 'Royal Red' treated with FLU applied as a foliar spray at 62.5 $mg \cdot L^{-1}$ (ppm) had suppressed shoot growth over a short time without any delay in flowering (Keever and Gilliam, 1994).

Paclobutrazol applied foliarly at rates of 25 or 100 mg·L^{-1} (ppm) to *Verbena rigida* adequately suppressed plant height without affecting time to flower (Davis and Andersen, 1989). Dutch-grown bleeding hearts (*Dicentra spectabilis*) had delayed flowering with PAC foliar application at 50 mg·L^{-1} (ppm), however, treatment resulted in deeper green coloration of the leaves and adequate height control (Kim et al., 1999). Foliar UNI application at 15 mg·L^{-1} (ppm) to *Oenothera fruticosa* resulted in a 31% reduction in plant height at flowering compared with controls and flower diameter was reduced by 36% (Clough et al., 2001). Gibson and Whipker (2001) reported that increasing the concentrations of UNI [2, 4, 8, 16, or 32 mg·L^{-1} (ppm)] foliar sprays reduced plant height in a linear manner for both 'Osaka White' and 'Nagoya Red' ornamental cabbage (*Brassica oleracea* var. *acephala*). This study examines the effect of PAC, UNI, and FLU on height, width, and flowering of *T. virginiana* plants.

Materials and Methods

The 6-week long PGR experiment was conducted in a double layer poly-house (25 Mar. to 20 May 2002). Three cultivars of *T. virginiana* were used in this experiment: 'Blue Stone,' 'Angel Eyes,' and 'Red Cloud' (54 cell size; Yoder Greenleaf Perennials, Leola PA). One hundred plugs per cultivar were planted in 10.8-cm (4.25") diameter (1180 cm^3) plastic containers using media containing: 65-75% bark fines (0-5/8"), 20-25% Canadian sphagnum peat moss, 9-15% perlite and a proprietary starter charge (Sierra Perennial Mix, Scott's Co., Merrifield OH) on 11 Mar. 2001. Three days before PGR application, 88 plants of each cultivar were selected for uniformity. Plugs were not

uniform in size so each chemical treatment was blocked by number of shoots and height. The experiment was a randomized complete block design with four replicates per PGR treatment.

Two weeks after transplant, PGRs were applied to actively growing plants using a hand-held CO_2 pressurized sprayer (R & D Sprayer, Opelousas LA) with an 800VS nozzle at 18 p.s.i. When PGRs were applied, the weather was partly cloudy and the temperature was 33 ºC (91.4 °F) with 22% relative humidity. Each PGR solution was evenly applied as a foliar spray at 210 $ml \cdot m^{-2}$ [manufacturers suggested rate 2 qt/100 ft^2 (1.89 $L \cdot 30.5\ m^{-2}$)] over a square meter area in which four plants from each treatment were placed. The PGRs applied were PAC (Bonzi, Syngenta Chem. Co. Greensboro, NC) at 0, 40, 80, 120, or 160 $mg \cdot L^{-1}$; UNI (Sumagic, Valent USA Corp. Marysville, Ohio) at 0, 15, 30, 45, or 60 $mg \cdot L^{-1}$; and FLU (TopFlor, SePRO Corp. Carmel, IN) at 0, 15, 30, 45, 60, or 75 $mg \cdot L^{-1}$. Data were collected every two weeks and included plant height (cm, from rim of pot to top of foliage), average width (cm, width at widest point and width perpendicular to that point), and percent plants flowering.

Response variables (plant height, plant width, and percent plants flowering) were measured every two weeks. Measurements taken over time on the same plants are often correlated. Univariate analysis of variance (ANOVA) F-tests for effects involving week and interactions with week rely on the Huynh-Feldt (H-F; Huynh and Feldt, 1970) condition. The H-F condition requires a certain correlation structure between all pairs of measurements. Sphericity test using the PRINTE option of the REPEATED statement of SAS's GLM Procedure evaluate the H-F condition (Marini et al., 1995). Because the three response variables rejected (P = 0.006, <0.001, and <0.001, respectively) the

sphericity test, these data were analyzed with a multivariate repeated-measures analysis using the REPEATED statement of SAS's GLM procedure (SAS Institute Inc. Cary, NC). No assumptions about repeated measures covariance structure are required by multivariate analysis (Marini et al., 1995). The *P* values from the multivariate ANOVA (MANOVA) are presented for the main effect of WEEK and all interactions involving WEEK. The *P* values for response variable main effects were obtained with tests of hypotheses for between-subject effects from repeated measures ANOVA. The *P* values generated in the REPEATED statement of SAS's GLM Procedure with the PROFILE transformation of the SUMMARY option are also presented for contrast variables (Marini et al., 1995).

Results and Discussion

Paclobutrazol. *Tradescantia virginiana* cultivars treated with paclobutrazol exhibited similar responses in height but not width or flowering over the 6-week experiment as indicated by the multivariate analysis of variance (MANOVA) for within-subject effects (Table 2.1). Within-subject effects test the hypothesis that response variables do not change over time, whereas between-subject effects, test the hypothesis that treatments do not affect the response variables, when averaged over time. The week x PAC rate interaction was significant; height was negatively related to PAC concentration on weeks 4 and 6, but not on week 2 (Table 2.2). Height increase was quadratically related to concentration from week 2 to 4, but the increase was linearly related to concentration from week 4 to 6. 'Blue Stone' was slightly smaller than 'Angel

Eyes' after height comparison without taking into account the effect of week (Tables 2.1 and 2.2).

For plant width two 2-way interactions (week x cultivar and week x rate) were significant (Table 2.1). From week 4 to 6 the width of 'Angel Eyes' increased more than for 'Blue Stone' (Tables 2.3 and 2.4). The control plants increased more in diameter from week 4 to 6 than week 2 to 4, but the opposite was true for the higher rates of PAC (Tables 2.3 and 2.4). Paclobutrazol did not affect the percentage of plants flowering. Flowering was affected by cultivar, with all cultivars differing from each other when compared with contrasts (Table 2.1). The increase in percentage plants flowering from week 2 to week 4 was similar for 'Blue Stone' and 'Red Cloud,' but 'Angel Eyes' did not flower (Tables 2.5 and 2.6).

The PAC rate that was most effective at reducing plant height was 120 $mg \cdot L^{-1}$ (ppm), regardless of cultivar. At this rate, plant height was 26.5% less than the non-treated control. Width of cultivars differed, but at 120 $mg \cdot L^{-1}$ (ppm) PAC, width of 'Angel Eyes' was suppressed by 14%, 'Blue Stone' by 21%, and 'Red Cloud' by 14% when compared with controls at 6 weeks after treatment. Application of PAC did not delay or inhibit flowering. No phytotoxicity was noted for any PAC rate. Unlike our study, Wulster and Ombrello (2000) noted significant delays in flowering time of *Ixia* hybrids after application of PAC at 100 or 200 $mg \cdot L^{-1}$ (ppm), but Cox and Keever (1988) noted foliar application of PAC to *Pelargonium* x *hortorum* at 20 or 40 $mg \cdot L^{-1}$ (ppm) did not affect days to flowering.

Uniconazole. Plant height was influenced by time and UNI rate, but not cultivar (Table 2.7). Height was also affected by the interactions for cultivar x rate, week x rate,

and week x cultivar. The relationship between height and rate was different for only 'Angel Eyes' and 'Blue Stone,' where height reduction with increasing UNI rates was greatest for 'Blue Stone' (Table 2.8). Pooled over cultivars, the change in plant height from week 2 to 4 was not related to rate, but the increase in height from week 4 to 6 was negatively and linearly related to rate (Table 2.9). From week 2 to 4 'Blue Stone' increased in height more than the other cultivars, but all three cultivars increased in height to a similar extent from week 4 to 6 (Table 2.9).

Plant width was influenced by the main effects of week and rate and the interactions were significant for week x cultivar and week x rate (Table 2.7). Pooled over cultivars, the increase in width was negatively and linearly related to rate from week 2 to 4, but the increase in width from week 4 to 6 was not related to rate (Tables 2.10 and 2.11). The increase in width from week 2 to 4 was greatest for 'Red Cloud' and least for 'Angel Eyes,' but the opposite was true for week 4 to 6 (Table 2.11).

The percentage of plants flowering was affected by the main effects of week and cultivar, and the interactions of week x cultivar and week x rate (Table 2.7). The increase in flowering from week 2 to 4 was similar for 'Blue Stone' and 'Red Cloud,' but 'Angel Eyes' did not flower. The increase in flowering from week 4 to 6 was greatest for 'Blue Stone' and least for 'Angel Eyes.' The increase in flowering from week 2 to 4 was linearly and negatively related to rate, but from week 4 to 6, rate did not effect flowering (Tables 2.12 and 2.13).

Response to UNI application depended on cultivar, and application rates need to be adjusted by cultivar vigor. Whipker et al. (1995) compared two cultivars of tuberous rooted dahlia (*Dahlia variabilis*) with drench UNI treatments and found 'Red Pygmy'

height was maintained at a marketable level while height of 'Golden Emblem' was not. Effective height control of *Tradescantia* appeared to be achieved with UNI application at 45 mg·L^{-1} (ppm). In the present study, height of all cultivars was controlled; 'Blue Stone' height was suppressed by 45%, 'Red Cloud' by 24% and 'Angel Eyes' by only 3% when compared with non-treated controls at 6 weeks after treatment. At the same application level, width was 13%, 23%, and 49% less than the control for 'Red Cloud,' 'Blue Stone,' and 'Angel Eyes,' respectively. Uniconazole did not delay flowering of any cultivars, nor was any phytotoxicity noted. Kim et al. (1999) reported no phytotoxicity after UNI application at 1 or 5 mg·L^{-1} to *Dicentra spectabilis*. Application of UNI at 5, 25, or 100 mg·L^{-1} (ppm) to *Verbena rigida* resulted in no delay in flowering while height was controlled (Davis and Andersen, 1989).

Flurprimidol. Plant height was affected by the main effects of week and FLU rate and the interactions of cultivar x FLU rate and week x FLU rate (Table 2.14). Height increase from week 4 to 6, but not week 2 to 4 was negatively and linearly related to FLU rate (Tables 2.15 and 2.16). Plant width was affected by week and cultivar, and the interactions of week x cultivar and week x FLU rate. Width increase from week 2 to 4 was not affected by cultivar, but from week 4 to 6 'Angel Eyes' increased in width more than 'Red Cloud' (Table 2.17). Width increase from week 2 to 4 was not related to FLU rate, but from week 4 to 6 the increase in width was negatively and linearly related to FLU rate (Tables 2.17 and 2.18). The percentage of flowering plants was affected by week, cultivar, and the interaction of week x cultivar (Table 2.14). Increases in flowering from week 2 to 4 were similar for 'Blue Stone' and 'Red Cloud,' but 'Angel Eyes' did

not flower. From week 4 to 6 flowering was greatest for 'Blue Stone' and least for 'Angel Eyes' (Tables 2.19 and 2.20).

The most effective FLU application rate for control of *Tradescantia* height was 45 $mg \cdot L^{-1}$ (ppm). Flurprimidol effect on height was similar for all cultivars. After FLU application at 45 $mg \cdot L^{-1}$ (ppm), average height was 20% shorter than non-treated controls. Width of plants differed by cultivar. At the recommended rate, 'Angel Eyes' width was suppressed 10%, 'Blue Stone' 15%, and 'Red Cloud' 18%. FLU rate did not affect time to flower or percentage flowering plants. A similar flowering response was noted with *Buddleia davidii* 'Royal Red' (Keever and Gilliam, 1994) and *Dianthus caryophyllus* 'Snowmass' (Pobudkiewicz and Nowak, 1994).

Summary. Paclobutrazol, UNI, and FLU were all effective in reducing *Tradescantia virginiana* height and width. Flurprimidol was the most effective PGR at reducing height of all cultivars tested during our experiment. Overall, it appears that 'Angel Eyes' is the cultivar least likely to respond to PGR application; it also had the lowest percentage of plants flowering when compared with other cultivars. 'Blue Stone' is the largest cultivar in height and also appeared to respond to lower PGR rates. 'Blue Stone' also had the highest percentage of flowering plants. 'Red Cloud' response in height and width usually ranged between the other two cultivars, and all three PGRs were able to effectively control height and width. Flowering percentages of 'Red Cloud' were similar to those of 'Blue Stone.'

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Table 2.1. Sources of variation and P-values from analysis of variance and multivariate analysis of variance for effect of paclobutrazol (PAC) on height, width, and flowering of *Tradescantia virginiana* over 6 week experiment. RC= 'Red Cloud'; AE= 'Angel Eyes'; BS= 'Blue Stone'.

		Response variable		
Source of variation	DF	Height	Width	Flowering
Week[z]	2	<0.001	<0.001	<0.001
Cultivar[y]	2	0.073	0.117	<0.001
RC vs. AE[y]	1	0.162	0.090	0.001
RC vs. BS[y]	1	0.364	0.843	0.001
AE vs. BS[y]	1	0.024	0.059	<0.001
PAC rate[y]	4	0.127	0.429	0.459
Linear[y]	1	0.013	0.062	0.367
Quadratic[y]	1	0.373	0.828	0.799
Cultivar x rate[y]	8	0.961	0.548	0.534
RC vs. AE x PAC rate[y]	1	0.473	0.431	0.144
RC vs. BS x PAC rate[y]	1	0.951	0.066	0.461
AE vs. BS x PAC rate[y]	1	0.436	0.282	0.461
Week x cultivar[z]	4	0.819	0.022	<0.001
Week x RC vs. AE[z]	2	0.899	0.259	0.008
Week x RC vs. BS[z]	2	0.741	0.105	0.006
Week x AE vs. BS[z]	2	0.475	0.006	<0.001
Week x PAC rate[z]	8	0.011	0.004	0.505

Week x rate linear [z]	2	0.001	0.001	0.577
Week x rate quadratic [z]	2	0.082	0.029	0.862
Week x cultivar x PAC rate [z]	16	0.670	0.405	0.659
Week x RC vs. AE x PAC rate [z]	2	0.412	0.801	0.357
Week x RC vs. BS x PAC rate [z]	2	0.382	0.661	0.733
Week x AE vs. BS x PAC rate [z]	2	0.269	0.378	0.672

[z] Results from MANOVA tests of hypothesis for within-subject (measurement taken repeatedly on each plant) effects.

[y] Tests the hypothesis that treatments (between-subjects effects) have no effect on the response variables, ignoring within-subject effects. This is the treatment effect averaged over all weeks.

Table 2.2. Effect of paclobutrazol (PAC) rate on average plant height of three *Tradescantia virginiana* cultivars. Lower table represents *P* values from profile analysis of plant height. These analyses of variance are for the transformed variables representing the differences between adjacent weeks.

Rate ($mg \cdot L^{-1}$)	Height (cm)		
	Week 2	Week 4	Week 6
0	13.6[z]	16.3	24.5
40	14.1	14.7	21.8
80	13.0	14.0	20.9
120	14.6	17.2	18.0
160	13.9	14.3	18.0

	Week	
Treatments	2 – 4	4 – 6
Mean[y]	0.737	<0.001
Cultivar[x]	0.557	0.649
RC vs. AE[x]	0.664	0.774
RC vs. BS[x]	0.522	0.535
AE vs. BS[x]	0.285	0.366
PAC rate[x]	0.039	0.140
Linear[x]	0.028	0.018
Quadratic[x]	0.025	0.495
Cultivar x PAC rate[x]	0.622	0.346
RC vs. AE x PAC rate[x]	0.468	0.195
RC vs. BS x PAC rate[x]	0.358	0.465
AE vs. BS x PAC rate[x]	0.104	0.566

[z] Average of all cultivars and replicates for each treatment level and week.

[y] *P* values for change in plant height for adjacent weeks pooled over all treatments.

[x] *P* values for the main effects and interactions on the change in plant height between adjacent weeks.

Table 2.3. Effect of paclobutrazol (PAC) rate on plant width of *Tradescantia virginiana*.

Cultivar	Rate ($mg \cdot L^{-1}$)	Width (cm)		
		Week 2	Week 4	Week 6
'Angel Eyes'	0	16.9[z]	25.5	41.5
	40	22.5	28.3	42.0
	80	20.3	24.6	37.3
	120	25.3	24.6	35.8
	160	22.0	29.4	35.3
'Blue Stone'	0	29.1	33.0	46.8
	40	26.0	30.0	34.0
	80	25.1	30.5	37.0
	120	27.6	35.0	37.0
	160	18.0	25.0	34.8
'Red Cloud'	0	20.4	32.8	43.8
	40	22.4	29.4	37.0
	80	21.1	30.9	40.1
	120	22.6	32.9	38.0
	160	24.6	33.8	37.5

[z]Values are means of 4 replicates for each treatment.

Table 2.4. *P* values from profile analysis of *Tradescantia virginiana* plant width. These analyses of variance are for the transformed variables representing the differences between adjacent weeks.

	Week	
Treatments	2 – 4	4 – 6
Mean[z]	<0.001	<0.001
Cultivar[y]	0.375	0.025
RC vs. AE[y]	0.193	0.098
RC vs. BS[y]	0.827	0.265
AE vs. BS[y]	0.277	0.007
PAC rate[y]	0.621	0.048
Linear[y]	0.330	0.056
Quadratic[y]	0.528	0.269
Cultivar x PAC rate[y]	0.479	0.475
RC vs. AE x PAC rate[y]	0.783	0.886
RC vs. BS x PAC rate[y]	0.370	0.539
AE vs. BS x PAC rate[y]	0.243	0.637

[z] *P* value for change in the response variables for adjacent weeks pooled over all treatments.

[y] *P* values for the main effects and interactions on the change in plant width between adjacent weeks.

Table 2.5. Effect of paclobutrazol (PAC) rate on percent of plants flowering of *Tradescantia virginiana*.

Cultivar	Rate ($mg \cdot L^{-1}$)	Percent Flowering		
		Week 2	Week 4	Week 6
'Angel Eyes'	0	0 [z]	0	0
	40	0	0	0
	80	0	0	0
	120	0	0	0
	160	0	0	0
'Blue Stone'	0	0	50	75
	40	0	50	100
	80	25	75	100
	120	0	25	75
	160	0	75	100
'Red Cloud'	0	0	25	25
	40	0	0	75
	80	0	50	50
	120	0	50	50
	160	0	50	50

[z]Values are means of 4 replicates for each treatment.

Table 2.6. *P* values from profile analysis of percent *Tradescantia virginiana* plants flowering. These analyses of variance are for the transformed variables representing the differences between adjacent weeks.

	Week	
Treatments	2 – 4	4 – 6
Mean[z]	<0.001	0.512
Cultivar[y]	0.002	0.079
RC vs. AE[y]	0.013	0.761
RC vs. BS[y]	0.274	0.038
AE vs. BS[y]	0.006	0.073
PAC rate[y]	0.671	0.329
Linear[y]	0.292	0.483
Quadratic[y]	0.592	0.767
Cultivar x PAC rate[y]	0.780	0.416
RC vs. AE x PAC rate[y]	0.302	1.000
RC vs. BS x PAC rate [y]	0.438	0.667
AE vs. BS x PAC rate [y]	0.795	0.667

[z] *P* value for change in the percentage flowering plants for adjacent weeks pooled over all treatments.

[y] *P* values for the main effects and interactions on the change in percentage flowering plants between adjacent weeks.

Table 2.7. Sources of variation and P-values from analysis of variance and multivariate analysis of variance for effect of uniconazole (UNI) rate on height, width, and flowering of *Tradescantia virginiana* plants over 6 week experiment. RC= 'Red Cloud'; AE= 'Angel Eyes'; BS= 'Blue Stone'.

		Response variable		
Source of variation	DF	Height	Width	Flowering
Week[z]	2	<0.001	<0.001	<0.001
Cultivar[y]	2	0.121	0.069	<0.001
RC vs. AE[y]	1	0.127	0.021	0.007
RC vs. BS[y]	1	0.653	0.218	0.026
AE vs. BS[y]	1	0.051	0.263	<0.001
UNI rate[y]	4	0.009	0.005	0.453
Linear[y]	1	0.002	0.002	0.084
Quadratic[y]	1	0.188	0.506	0.804
Cultivar x rate[y]	8	0.027	0.553	0.865
RC vs. AE x UNI rate[y]	1	0.401	0.401	0.213
RC vs. BS x UNI rate[y]	1	0.242	0.934	0.371
AE vs. BS x UNI rate[y]	1	0.048	0.448	0.720
Week x cultivar[z]	4	0.001	<0.001	<0.001
Week x RC vs. AE[z]	2	0.944	0.001	0.001
Week x RC vs. BS[z]	2	0.001	0.004	0.004
Week x AE vs. BS[z]	2	0.001	<0.001	<0.001
Week x UNI rate[z]	8	0.014	0.002	0.002

Week x rate linear[z]	2	0.001	0.002	0.002
Week x rate quadratic[z]	2	0.518	0.351	0.351
Week x cultivar x UNI rate[z]	16	0.638	0.083	0.083
Week x RC vs. AE x UNI rate[z]	2	0.057	0.548	0.548
Week x RC vs. BS x UNI rate[z]	2	0.825	0.396	0.396
Week x AE vs. BS x UNI rate[z]	2	0.172	0.238	0.238

[z] Results from MANOVA tests of hypothesis for within-subject (measurement taken repeatedly on each plant) effects.

[y] Tests the hypothesis that treatments (between-subjects effects) have no effect on the response variables, ignoring within-subject effects. This is the treatment effect averaged over all weeks.

Table 2.8. Effect of uniconazole (UNI) rate on plant height of *Tradescantia virginiana*.

Cultivar	Rate ($mg \cdot L^{-1}$)	Height (cm)		
		Week 2	Week 4	Week 6
'Angel Eyes'	0	14.3[z]	16.5	23.3
	15	15.1	13.1	20.9
	30	14.8	17.0	23.0
	45	14.3	15.8	22.8
	60	13.4	15.4	20.5
'Blue Stone'	0	16.1	18.0	27.6
	15	11.4	14.5	19.4
	30	12.3	15.3	18.1
	45	10.8	14.3	15.0
	60	12.0	16.4	18.4
'Red Cloud'	0	11.1	14.4	24.1
	15	13.9	15.6	25.0
	30	13.6	15.6	20.9
	45	13.1	12.4	18.4
	60	13.5	15.1	17.3

[z]Values are means of 4 replicates for each treatment.

Table 2.9. *P* values from profile analysis of *Tradescantia virginiana* plant height after treatment with uniconazole (UNI) at ascending rates. These analyses of variance are for the transformed variables representing the differences in height between adjacent weeks.

	Week	
Treatments	2 – 4	4 – 6
Mean[z]	0.770	<0.001
Cultivar[y]	0.001	0.774
RC vs. AE[y]	0.737	0.982
RC vs. BS[y]	<0.001	0.530
AE vs. BS[y]	0.003	0.544
UNI rate[y]	0.471	0.007
Linear[y]	0.403	0.004
Quadratic[y]	0.415	0.562
Cultivar x UNI rate[y]	0.808	0.426
RC vs. AE x UNI rate[y]	0.272	0.068
RC vs. BS x UNI rate[y]	0.962	0.553
AE vs. BS x UNI rate[y]	0.292	0.207

[z] *P* value for change in plant height for adjacent weeks pooled over all treatments.

[y] *P* values for the main effects and interactions on the change in plant height between adjacent weeks.

Table 2.10. Effect of uniconazole (UNI) rate on plant width of *Tradescantia virginiana*.

Cultivar	Rate ($mg \cdot L^{-1}$)	Width (cm)		
		Week 2	Week 4	Week 6
'Angel Eyes'	0	20.6[z]	30.4	45.1
	15	15.1	13.1	20.9
	30	14.8	17.0	23.0
	45	14.3	15.8	22.8
	60	13.4	15.4	20.5
'Blue Stone'	0	23.1	34.9	47.6
	15	25.2	30.9	41.1
	30	24.3	27.4	32.3
	45	23.4	30.8	36.7
	60	24.0	28.5	35.6
'Red Cloud'	0	26.3	38.5	42.8
	15	22.8	42.0	45.5
	30	22.5	39.5	41.5
	45	23.0	24.3	37.5
	60	21.0	26.8	32.5

[z]Average of replicates for each treatment level and date.

Table 2.11. *P* values from profile analysis of *Tradescantia virginiana* plant width after treatment with uniconazole (UNI) at ascending rates. These analyses of variance are for the transformed variables representing the differences in width between adjacent weeks.

	Week	
Treatments	2 – 4	4 – 6
Mean[z]	<0.001	<0.001
Cultivar[y]	0.003	0.009
RC vs. AE[y]	0.482	0.003
RC vs. BS[y]	0.001	0.226
AE vs. BS[y]	0.008	0.009
UNI rate[y]	0.033	0.082
Linear[y]	0.003	0.208
Quadratic[y]	0.499	0.147
Cultivar x UNI rate[y]	0.084	0.519
RC vs. AE x UNI rate[y]	0.278	0.693
RC vs. BS x UNI rate[y]	0.726	0.185
AE vs. BS x UNI rate[y]	0.460	0.347

[z] *P* value for change in plant width for adjacent weeks pooled over all treatments.

[y] *P* values for the main effects and interactions on the change in width of plants between adjacent weeks.

Table 2.12. Effect of uniconazole (UNI) rate on flowering of *Tradescantia virginiana*.

Cultivar	Rate ($mg \cdot L^{-1}$)	Percent Flowering		
		Week 2	Week 4	Week 6
'Angel Eyes'	0	0[z]	0	25
	15	0	0	25
	30	0	0	25
	45	0	0	0
	60	0	0	25
'Blue Stone'	0	0	50	75
	15	0	25	100
	30	0	75	75
	45	25	25	50
	60	0	25	75
'Red Cloud'	0	0	100	100
	15	0	50	50
	30	0	50	50
	45	0	75	75
	60	0	0	25

[z]Average of replicates for each treatment level and date.

Table 2.13. *P* values from profile analysis of percent *Tradescantia virginiana* plants flowering after treatment with uniconazole (UNI) at ascending rates. These analyses of variance are for the transformed variables representing the differences between adjacent weeks.

	Week	
Treatments	2 – 4	4 – 6
Mean[z]	<0.001	0.391
Cultivar[y]	0.006	0.001
RC vs. AE[y]	0.002	0.005
RC vs. BS[y]	0.141	0.006
AE vs. BS[y]	0.012	0.431
UNI rate[y]	0.149	0.199
Linear[y]	0.036	0.448
Quadratic[y]	0.716	0.521
Cultivar x UNI rate[y]	0.161	0.667
RC vs. AE x UNI rate[y]	0.070	0.196
RC vs. BS x UNI rate[y]	0.295	0.267
AE vs. BS x UNI rate[y]	0.431	0.852

[z] *P* value for change in the percentage flowering plants for adjacent weeks pooled over all treatments.

[y] *P* values for the main effects and interactions on the change in percentage flowering plants between adjacent weeks.

Table 2.14. Sources of variation and P-values from analysis of variance and multivariate analysis of variance for effect of flurprimidol (FLU) rate on height, width, and flowering of *Tradescantia virginiana* plants over 6 week experiment. RC= 'Red Cloud'; AE= 'Angel Eyes'; BS= 'Blue Stone'.

		Response variable		
Source of variation	DF	Height	Width	Flowering
Week[z]	2	<0.001	<0.001	<0.001
Cultivar[y]	2	0.219	0.006	<0.001
FLU rate[y]	4	0.009	0.083	0.980
Linear[y]	1	0.001	0.496	0.910
Quadratic[y]	1	0.881	0.993	0.472
Cultivar x rate[y]	8	0.046	0.365	0.351
RC vs. AE[y]	1	0.084	0.012	0.004
RC vs. BS[y]	1	0.438	0.144	0.002
AE vs. BS[y]	1	0.331	0.001	<0.001
Week x cultivar[z]	4	0.576	0.052	<.001
Week x FLU rate[z]	8	0.041	0.001	0.722
Week x rate linear[z]	2	0.001	0.001	0.406
Week x rate quadratic[z]	2	0.688	0.648	0.973
Week x cultivar x FLU rate[z]	16	0.088	0.112	0.355
Week x RC vs. AE[z]	2	0.994	0.038	0.001
Week x RC vs. BS[z]	2	0.316	0.707	<0.001
Week x AE vs. BS[z]	2	0.367	0.031	<0.001

[z] Results from MANOVA tests of hypothesis for within-subject (measurement taken repeatedly on each plant) effects.

[y] Tests the hypothesis that treatments (between-subjects effects) have no effect on the response variables, ignoring within-subject effects. This is the treatment effect averaged over all weeks.

Table 2.15. Effects of flurprimidol (FLU) rate on height of three cultivars of *Tradescantia virginiana*.

Cultivar	Rate ($mg \cdot L^{-1}$)	Plant height (cm)		
		Week 2	Week 4	Week 6
'Angel Eyes'	0	14.4[z]	15.4	20.8
	15	16.1	16.3	25.0
	30	16.9	17.6	23.3
	45	13.0	15.9	21.0
	60	16.6	17.0	21.6
	75	13.0	13.1	19.0
'Blue Stone'	0	14.4	14.5	26.0
	15	16.4	16.5	20.6
	30	13.8	15.8	20.0
	45	12.5	14.3	17.9
	60	15.6	17.6	20.3
	75	12.1	17.4	19.8
'Red Cloud'	0	16.8	18.1	24.1
	15	13.3	14.1	23.5
	30	14.8	16.5	24.5
	45	12.4	14.4	18.1
	60	12.4	12.6	17.4
	75	12.5	14.6	17.0

[z] Values are means of 4 replicates for each treatments.

Table 2.16. *P* values from profile analysis of plant width. These analyses of variance are for the transformed variables representing the differences between adjacent weeks.

	Week	
Treatments	2 – 4	4 – 6
Mean[y]	0.002	<0.001
Cultivar[x]	0.328	0.988
RC vs. AE[x]	0.940	0.966
RC vs. BS[x]	0.185	0.882
AE vs. BS[x]	0.210	0.916
FLU rate[x]	0.257	0.142
Linear[x]	0.106	0.012
Quadratic[x]	0.496	0.439
Cultivar x FLU rate[x]	0.384	0.119
RC vs. AE x FLU rate[x]	0.718	0.299
RC vs. BS x FLU rate[x]	0.107	0.477
AE vs. BS x FLU rate[x]	0.050	0.742

[z] Average of all cultivars and replicates for each treatment level and week.

[y] *P* values for change in plant height for adjacent weeks pooled over all treatments.

[x] *P* values for the main effects and interactions on the change in plant height between adjacent weeks.

Table 2.17. Effect of flurprimidol (FLU) rate on plant width of *Tradescantia virginiana*.

Cultivar	Rate ($mg \cdot L^{-1}$)	Width (cm)		
		Week 2	Week 4	Week 6
'Angel Eyes'	0	16.0[z]	25.5	44.0
	15	19.3	26.9	39.9
	30	18.3	33.1	47.1
	45	21.1	30.6	39.8
	60	20.1	28.8	42.6
	75	21.3	30.4	34.3
'Blue Stone'	0	24.4	32.1	46.6
	15	23.1	31.0	42.9
	30	25.8	33.5	45.6
	45	25.3	31.3	40.0
	60	24.6	35.0	38.8
	75	24.9	37.9	39.4
'Red Cloud'	0	22.5	38.1	45.3
	15	21.4	31.6	44.0
	30	24.4	32.7	43.9
	45	21.8	29.1	37.0
	60	26.0	34.3	38.0
	75	21.8	30.6	37.0

[z]Values are means of 4 replicates for each treatments.

Table 2.18. *P* values from profile analysis of *Tradescantia virginiana* plant width after treatment with flurprimidol (FLU) at ascending rates. These analyses of variance are for the transformed variables representing the differences in width between adjacent weeks.

	Week	
Treatments	2 – 4	4 – 6
Mean[y]	<0.001	<0.001
Cultivar[x]	0.598	0.041
RC vs. AE[x]	0.936	0.019
RC vs. BS[x]	0.405	0.699
AE vs. BS[x]	0.361	0.046
FLU rate[x]	0.354	0.005
Linear[x]	0.218	0.002
Quadratic[x]	0.452	0.421
Cultivar x FLU rate[x]	0.052	0.294

[z] *P* value for change in plant width for adjacent weeks pooled over all treatments.

[y] *P* values for the main effects and interactions on the change in width of plants between adjacent weeks.

Table 2.19. Effect of flurprimidol (FLU) rate percentage of *Tradescantia virginiana* plants flowering.

Cultivar	Rate ($mg \cdot L^{-1}$)	Percent Flowering		
		Week 2	Week 4	Week 6
'Angel Eyes'	0	0[z]	0	0
	15	0	0	25
	30	0	0	25
	45	0	0	25
	60	0	0	0
	75	0	0	25
'Blue Stone'	0	25	25	100
	15	25	75	75
	30	0	25	75
	45	0	50	100
	60	0	50	100
	75	0	25	100
'Red Cloud'	0	0	75	75
	15	0	25	25
	30	0	25	75
	45	0	50	50
	60	0	75	75
	75	0	75	75

[z]Average of replicates for each treatment level and date.

Table 2.20. *P* values from profile analysis of percent *Tradescantia virginiana* plants flowering after treatment with uniconazole (UNI) at ascending rates. These analyses of variance are for the transformed variables representing the differences between adjacent weeks.

	Week	
Treatments	2 – 4	4 – 6
Treatments	<0.001	0.052
Mean[y]	0.001	0.003
Cultivar[x]	0.749	0.540
RC vs. AE[x]	0.087	<0.001
RC vs. BS[x]	0.007	0.057
FLU rate[x]	0.283	0.817
Linear[x]	0.820	0.833
Quadratic[x]	0.518	0.486
Cultivar x FLU rate[x]	<0.001	0.018

[z] *P* value for change in the percentage flowering plants for adjacent weeks pooled over all treatments.

[y] *P* values for the main effects and interactions on the change in percentage flowering plants between adjacent weeks.

CHAPTER 3: FERTILIZATION RATES FOR QUALITY CONTAINER GROWTH OF *TRADESCANTIA VIRGINIANA* L.

Additional index words. *Tradescantia virginiana*, Nitrogen, Phosphorus, Hue°, Chroma

Abstract. Little information is available on greenhouse production of *Tradescantia virginiana*. To determine fertilizer needs we conducted two experiments. First, three cultivars of *T. virginiana* were grown with four rates of an acidic fertilizer 15N-6.9P-14.1K (15-16-17) in an effort to find the range of nutrition for acceptable growth and flowering. The second experiment utilized results from the first experiment to examine the response of two *T. virginiana* cultivars to a basic fertilizer 15N-0P-12.5K (15-0-15) at rates of 100 and 200 $mg \cdot L^{-1}$ (ppm) N. Treatments were applied in 350 mL (11.8 oz.) aliquots when plants and pots weighed 70 to 80% of saturated weight (Exp. 1) or when soil moisture levels were between 20% and 30% (Exp. 2). For experiment 1, N rates between 100 and 200 $mg \cdot L^{-1}$ resulted in marketable plants. 'Blue Stone' was the largest cultivar, in both height (cm) and dry weight (g). Nitrogen levels of 300 $mg \cdot L^{-1}$ (ppm) stunted the growth of 'Blue Stone,' while 'Red Cloud' and 'Angel Eyes' were similar in size and the highest fertilizer rate did not reduce their plant height. Foliage of 'Angel Eyes' had more green coloration, while the foliage color of 'Red Cloud' and 'Blue Stone' were lower in hue angle (hue°) and thus had more yellowish-green coloration; 'Angel Eyes' also had the highest chroma at the experiment's end and the most attractive foliage. In the second experiment, there was little difference in height, width and flowering for 'Red Cloud' and 'Lilac Frost' with fertilizer rate. Foliage color of 'Red Cloud' was

lower in hue° (more yellow) and higher in chroma (more brilliant coloration) than 'Lilac Frost' foliage. Quality of all plants treated with 100 and 200 mg·L^{-1} (ppm) N were similar at the end of both experiments.

Introduction

Spiderworts (*Tradescantia virginiana*) are versatile landscape plants. They adapt well to both wet and dry environs as well as sun and part shade. They are herbaceous perennials native to the woodlands of North America. Many cultivars are available; cultivars differ in plant size, leaf width, and flower color. Flower colors range from white to deep purple with many blues and pinks in between. Unfortunately little information is available as to the cultural requirements of these plants.

Constant liquid feed (CLF) is a popular method of irrigating plants whereby both water and fertilizer are supplied to the plant at the same time. Studies have been conducted to examine the nutrition requirements of bedding plants and some herbaceous perennials. Ku and Hershey (1996) fertigated poinsettias (*Euphorbia pulcherrima*) with 0, 100, 200 and 300 mg·L^{-1} (ppm) N ; and plants fertigated at 200 and 300 mg·L^{-1} (ppm) N were more compact and darker green than those fertigated at 100 mg·L^{-1} N. *Spathiphyllum* and *Dieffenbachia* growth was enhanced with low nutrient concentrations [25 or 50 mg·L^{-1}(ppm)]. Both species exhibited increased total leaf area with rising fertilizer concentrations up to 200 mg·L^{-1} (ppm) N (Campos and Reed, 1993).

Color can be measured objectively with chroma meters, which are three-filtered color analysis tools; they measure colors and pinpoint them in three dimensional space using a set of three coordinates, usually L* a* b* which can be used to calculate L* C*

h°. In the LAB color space, L* quantifies with lightness and ranges from black = 0 to white = 100; a* and b* are chromaticity coordinates. Color direction is indicated by the a* and b* values. At values a* = 0 and b* = 0 the color grid is gray or achromatic. A positive a* ranges from red to purple while a negative a* can range from blue to green. Positive b* indicates yellow and a negative b* indicates blue (McGuire, 1992; Minolta, 1994). The maximum a* or b* value is ±60. The closer the a* and b* values are to 60 the greater their color saturation value (McGuire, 1992). The a* and b* values can be converted into hue angle (hue°) and chroma (C*). Hue° is defined as pure color, whether a red, yellow, green, etc.; it is actually how we see a color. Hue° values are stepped counterclockwise on a 360° chromatic circle. Significant angles are 0, 90, 180, and 270 which represent the red-purple, yellow, bluish-green, and blue hues, respectively. Chroma is the extent of divergence from gray toward pure chromatic color or the vividness or dullness of a color (Gonnet, 1999; Wang and Camp, 2000). The objectives of this research were to identify fertilizer application rates for production of *Tradescantia* and to evaluate the visual quality of different cultivars grown with varying N rates.

Materials and Methods

Experiment 1. Two experiments were conducted to determine fertilizer rates that promote high quality, but not lush, growth. The first experiment occurred over a 10-week period from 25 Mar. to 8 May 2002. Three *Tradescantia virginiana* cultivars, Blue Stone, Red Cloud, and Angel Eyes, were received as plugs (54 cell size, Yoder Green Leaf, Lancaster PA) on 11 Mar. 2002 and transplanted into 10.8-cm (4.25”) diameter

(1480 cm^3) plastic containers. Media used for transplant contained: 65-75% bark fines (0-5/8"), 20-25% Canadian sphagnum peat moss, 9-15% perlite and a proprietary starter charge (Sierra Perennial Mix, Scott's Co., Marysville OH). Plants were grown in a double layer polyethylene greenhouse located on the Virginia Tech Campus in Blacksburg, VA. Plants were fertilized with four rates of 15N-6.9P-14.1K water-soluble fertilizer which contained micronutrients (Peter's Peat Lite Special 15-16-17, Scott's Co.). Average temperatures over the course of the experiment during day were 28.7± 4.6 °C (82.6 °F) and during night were 17.6 ± 1.9 °C (63.7°F).

Fertilizer treatments began 2 weeks after transplant and consisted of 0, 100, 200, and 300 $mg \cdot L^{-1}$ (ppm) nitrogen (N) applied as a constant liquid feed. Irrigation frequency was based on a 20% to 30% leaching fraction and pot weight. Pot weight was determined by weighing pots at saturation point then multiplying that weight by 0.65 and 0.7. When the weight of the pot was between these two numbers, plants were irrigated with 350 ml (11.8 oz.) of nutrient solution at the desired $mg \cdot L^{-1}$ (ppm) fertilizer rate. The experiment was a 3 x 4 factorial in a randomized complete block design with four replications per cultivar per fertilizer concentration. Sixteen plants per cultivar were utilized for this experiment. Plugs were not uniform, so plants were blocked according to shoot number and size to help control variation.

Data collected included plant height (cm, from rim of pot) and average width (cm, width at widest point and width perpendicular to that point) every four weeks. Media pH and electrical conductivity (EC), determined by pour through extraction method (Wright, 1986), percentage plants flowering, and chroma meter measurements (Minolta, Chroma Meter Cr-200, Osaka Japan) to determine foliage color using CIELAB [CIE: Commission

Internationale de l'Éclairage (International Commission on Illumination); LAB: L* a* b*; Hunter and Harold, 1987)] were recorded every two weeks. Before each use the chroma meter was calibrated to a white tile with standardized L* a* b* values. The a* b* values, as measured by colorimeter, were converted to hue angle (hue°) and chroma values using SAS data statements (SAS Institute Inc. Cary, NC). At the end of the experiment, plants were harvested and shoots were dried at 65.5 °C (150 °F). The dry weights were measured and the shoots ground. Then 0.2 g of tissue from each sample was digested and digested samples were subjected to TKN (QuikChem method 13-107-06-2-D, Zellweger Analytics, Milwaukee WI) and TKP (QuikChem method 13-115-01-1-B, Zellweger Analytics) for tissue N and phosphorus (P) levels.

Response variables (plant height, plant width, percent plants flowering, media pH and EC, hue° and chroma) were measured every two weeks. Measurements taken over time on the same plants are often correlated. Univariate analysis of variance (ANOVA) F tests for effects involving week and interactions with week rely on the Huynh-Feldt (H-F, 1970) condition. The H-F condition requires a certain correlation structure between all pairs of measurements. Sphericity test using the PRINTE option of the REPEATED statement of SAS's GLM Procedure evaluate the H-F condition (Marini et al., 1995). Because all response variables rejected ($P < 0.05$) the sphericity test, these data were analyzed with a multivariate repeated-measures analysis using the REPEATED statement of SAS's GLM procedure (SAS Institute Inc. Cary, NC). No assumptions about repeated measures covariance structure are required by multivariate analysis (Marini et al., 1995). *P* values from the multivariate ANOVA (MANOVA) are presented for the main effect of WEEK and all interactions involving WEEK. *P* values for response variables main

effects were obtained with tests of hypotheses for between-subject effects from repeated measures ANOVA. *P* values generated in the REPEATED statement of SAS's GLM Procedure with the PROFILE transformation of the SUMMARY option are also presented for contrast variables (Marini et al., 1995). Single-degree-of-freedom contrasts were used to compare cultivars and interaction involving cultivars.

Experiment 2. The second experiment began 9 July 2002 and continued for 8 weeks, ending with plant harvest on 2 Sept. 2002. Two cultivars of *T. virginiana*, 'Lilac Frost' and 'Red Cloud,' arrived on 20 June 2002 and were transplanted into 10.8-cm (4.25") diameter (1480 cm^3) plastic containers on 24 June 2002. The potting media contained 45% peat, 15% perlite, 15% vermiculite, and 25% bark (Fafard 3B, Fafard Inc. Anderson, SC). Plants were treated with either 100 or 200 $mg \cdot L^{-1}$ (ppm) N, provided by a 15N-0P-12.5K (Dark Weather Feed 15-0-15 Scott's Co.) fertilizer with micronutrients. These fertilizer rates were based on results from the first experiment. The plants were grown in a glass greenhouse. Average temperatures throughout the experiment were 30.5 ± 3.5 °C (86.9 °F) during the day and 20.9 ± 1.5 °C (69.6 °F) during the night.

Fertilizer treatments began 2 weeks after transplant, and they were applied as a constant liquid feed. Irrigation frequency was based on a 20% to 30% leaching fraction and the theta probe (Delta-T Devices Ltd., Cambridge U.K.) The theta probe measures the volumetric soil moisture content by responding to changes in the dielectric constant of the soil. Plants were irrigated with 350 ml (11.8 oz.) of nutrient solution at the desired N concentration when moisture levels of plants and pots were between 20% and 25% (as measured by the theta probe). The experiment was a 2 x 2 factorial in a randomized complete block design with five replications per cultivar per fertilized level combination.

Every two weeks after treatment, data were recorded for plant height (cm, measured from rim of pot to top of foliage), average width (cm, width at widest point and width perpendicular to that point), pH and EC or soluble salt levels in medium as determined by the pour through extraction method (Wright, 1986), and presence of flowers. Leaf color was measured with a colorimeter using CIELAB. At the end of the experiment plants were rated subjectively on a scale of 1 to 4; where 1= a dead plant and 4= a plant that is healthy and actively growing. Plants were then harvested and shoots were dried at 65.5 °C. The dry weights were recorded, the shoots were ground, and 0.2 g of tissue from each sample was digested, and digested samples were subjected to TKN and TKP for tissue N and P content. Data were subjected repeated measures analysis of variance with SAS's GLM procedure for same reasons as discussed above.

Results and Discussion

Experiment 1: *Tradescantia virginiana* cultivars treated with four fertilizer rates exhibited similar responses in height but not width or flowering when compared over a 10-week experiment using multivariate analysis of variance (MANOVA) for within-subject effects (Table 3.1). Within subject effects compare change over time (week) with each response variable (height, width, and percent flowering plants). Week x cultivar effects were highly significant for both change in height and width but not flowering. 'Red Cloud' and 'Angel Eyes' were similar in height over the experiment, while 'Blue Cloud' was the tallest cultivar after week 6 (Table 3.2). 'Angel Eyes' was the widest cultivar, 'Red Cloud' next, and the cultivar with the narrowest width was 'Blue Stone' (Table 3.3). Percent plants flowering among cultivars did not increase over time (Table

3.4). Plant height, width, and percentage of plants flowering responded quadratically to the N rate over time (Table 3.1). The 'Blue Stone' vs. 'Red Cloud' x N rate interaction for both height and width was significant. 'Blue Stone' plants treated with 100 $mg \cdot L^{-1}$ N had maximum height and width, while 'Red Cloud' plants were largest with 200 $mg \cdot L^{-1}$ N (Tables 3.2 and 3.3).

Height: Mean plant height by cultivar, fertilizer rate and time is shown in Table 3.2. 'Red Cloud' and 'Angel Eyes' had small increases in plant height from week 2 and 6 when compared with 'Blue Stone' which had a greater height increase (Tables 3.2 and 3.5). From week 6 to 10 cultivar height changed similarly to each other. From week 2 to 6 and 6 to 10 the slope of N rate effect on height was quadratic. Fertilizer rate did not interact with cultivar (Table 3.1).

Kuehny et al. (2000) reported that poinsettia plant height was not influenced by fertilizer concentration. We examined our *Tradescantia* plants at similar leaching fractions and found that cultivar height differed with the rate of N applied. 'Blue Stone' and 'Angel Eyes' were tallest after N application at 100 $mg \cdot L^{-1}$ N, while 'Red Cloud' was tallest after N application at 200 $mg \cdot L^{-1}$ N.

Width: From week 2 to 6 'Red Cloud' and 'Blue Stone' had similar increases in plant width, while 'Angel Eyes' had the greatest width increase at rates greater than 100 $mg \cdot L^{-1}$ (ppm) N (Table 3.3 and 3.5). 'Angel Eyes' and 'Red Cloud' had smaller increases in width from week 6 to 10 while 'Blue Stone' width increased to the largest extent. Cultivars responded similarly to fertilizer rate. Width changed quadratically with increasing fertilizer rates from week 2 to 6 and week 6 to 10.

Whipker et al. (1999) studied the effect of fertilizer concentration on growth of double impatiens (*Impatiens walleriana*). They found that both impatiens cultivars examined had a larger diameter after being fertilized for 9 weeks with 100 $mg \cdot L^{-1}$ N in comparison with those plants fertilized with 50 or 200 $mg \cdot L^{-1}$ N. Out results were slightly different, but still consistent in that the cultivars responded in a similar manner. The three *T. virginiana* cultivars we grew were the widest after treatment with 200 $mg \cdot L^{-1}$ N for a 10 week period.

Percent plants flowering: The percentage of flowering plants was affected by cultivar (Table 3.1); 'Red Cloud' and 'Angel Eyes' had a lower percentage of plants flowering than 'Blue Stone,' which had 100% plants flowering (Table 3.4). Fertilization rate also affected percent plants flowering. The 'Red Cloud' vs. 'Blue Stone' x N rate interaction was significant because 'Red Cloud' plants which were not fertilized had consistently lower percent plants flowering than did non-fertilized 'Blue Stone' plants. The week x cultivar x N rate interaction was significant for percent plants flowering; 'Angel Eyes' differed from both 'Red Cloud' and 'Blue Stone' in having fewer plants flowering when they were not fertilized (Table 3.4).

The percentages of plants flowering did not change during the experiment (Table 3.4). From week 2 to 6 and 6 to 10 there were no cultivar differences in percent plants flowering (Table 3.4 and 3.5). Fertilizer rate impacted percentage plants flowering in a quadratic manner from week 2 to 6. This effect was especially noticeable between 'Red Cloud' and both 'Angel Eyes' and 'Blue Stone' which had consistently higher percentages of plants flowering for plants which were not fertilized.

Whipker et al. (1999) examined fertilization rate impact on double impatiens flowering. Impatiens plants of both cultivars fertilized with 50 $mg \cdot L^{-1}$ N had the higher percentages of blooms per unit leaf area, but the plants were slightly smaller in comparison with plants fertilized at higher N rates. We had consistently high percentages of plants blooming with N treatments at or above 100 $mg \cdot L^{-1}$ N, for all the cultivars. 'Angel Eyes' was the only cultivar at the end of our 10 week experiment which did not have 100 percent of the plants blooming regardless of N rate. Cultivar impacts the percentage of plants flowering.

Media pH: Media pH of all cultivars fell within an acceptable range. A pH range from 5.0 to 5.9 might be considered quite broad and on the low side by a grower, but the *T. virginiana* plants used in our experiment grew well under these fairly acidic conditions. Media pH was affected by the N rate applied, and decreased in a linear manner with increasing fertilizer rate from week 2 to 4, week 4 to 6, and week 6 to 8 (Tables 3.6, 3.7, and 3.8). Averaged over time, 'Angel Eyes' displayed a greater decrease in pH with increasing N rates than did 'Red Cloud' or 'Blue Stone.' The 'Red Cloud' vs. 'Angel Eyes' x N rate interaction was significant because the slope was greater for 'Angel Eyes' than for 'Red Cloud.' From week 2 to 4 the decline in media pH was greatest for 'Angel Eyes.' From week 6 to 8 media pH decreased less for 'Angel Eyes' than for 'Blue Stone.' Averaged over all treatments, pH increased from week 8 to 10, but the increase was not affected by any experimental factors (Tables 3.7 and 3.8). In general, media pH was negatively related to fertilizer rate and pH declined over time.

James and van Iersel (2001) found a linear correspondence of pH and time after transplant with pH decreasing an average of one point over their 7-week experiment after

fertilizing petunias (*Petunia* x *hybrida*) and begonias (*Begonia* x *semperflorens-cultorum*) with an acidic fertilizer. Our results agree with theirs, we also utilized an acidic fertilizer and averaged a drop in pH of approximately one point over our 10-week experiment.

Media EC: Media EC increased with increasing N rates. Media EC was affected by cultivar (Table 3.7), with 'Red Cloud' having consistently higher EC values than either 'Angel Eyes' or 'Blue Stone' (Table 3.9). Media EC rose more rapidly as fertilizer concentration was increased. The week x cultivar interaction was significant because EC for 'Red Cloud' was greater than for 'Blue Stone' after week 4. Media EC was affected by cultivar only from week 4 to 6. 'Angel Eyes' media EC declined for plants fertilized with 0 to 200 $mg \cdot L^{-1}$ (ppm) N then leveled off for plants fertilized with 300 $mg \cdot L^{-1}$ (ppm) N; 'Blue Stone' media EC declined in a quadratic manner with increasing fertilizer rate; 'Red Cloud' media EC dropped in larger increments with increasing fertilizer rates (Tables 3.9 and 3.10).

Whipker et al. (1999) examined double impatiens cultivar differences in response to N rate; they found 'Blackberry Ice,' a variegated cultivar, required less N fertilizer than 'Purple Magic,' a green-leaved cultivar. They also noted that 'Blackberry Ice' had higher EC values than 'Purple Magic' after fertilization with 200 $mg \cdot L^{-1}$ N. This increase suggested that variegated double impatiens cultivars have a lower nutritional demand than green-leaved cultivars. In our experiment we noted that 'Red Cloud' had higher EC values than either 'Blue Stone' or 'Angel Eyes.' These higher EC values could in part be due to plant size. 'Red Cloud' is the smallest cultivar and this could possibly impact the amount of soluble salts it is able to take up. Or the higher EC values

could be due to the lower nutritional demands of 'Red Cloud' in comparison with the other cultivars.

Hue angle (hue°): Hue°, color we actually perceive, i.e., red, orange, green, etc., was affected by cultivar and the week x cultivar interaction was significant (Table 3.6). 'Red Cloud' hue° values averaged about 118° (yellowish-green) whereas 'Angel Eyes' and 'Blue Stone' hue° values averaged around 125° [greenish-yellow (Table 3.11)]. From week 4 to 8 the change in hue° increased linearly with increasing fertilizer rate, but the non-fertilized control hue° decreased for 'Angel Eyes' and 'Blue Stone.' From week 8 to 10 'Red Cloud' hue° increased by about 1% for plants fertilized with 0 to 200 $mg \cdot L^{-1}$ (ppm) N, whereas, the hue° of 'Blue Stone' increased about 4% for plants fertilized with 100 to 300 $mg \cdot L^{-1}$ (ppm) N (Tables 3.11 and 3.12). Hue° of 'Angel Eyes' was consistently higher across all treatments than the hue° of 'Red Cloud' and 'Blue Stone,' which means that the foliage of 'Angel Eyes' had more green coloration, while the foliage of 'Red Cloud' and 'Blue Stone' had lower hue° and thus were more yellowish green. Nitrogen rate did not affect hue° (Table 3.6). The hue° values of each cultivar at 100 and 200 $mg \cdot L^{-1}$ N are quite similar.

Landschoot and Mancino (2000) compared two species of bentgrass (*Agrostis stolonifera* and *A. capillaris*) turf to determine if color differences could be detected using a chroma meter. In a previous bentgrass study, they found strong correlations between measured hue° and rate of fertilization. In this study, they found cultivars differed in their hue°. When comparisons were made between detected values and visual color assessments, they found that hue° was the most consistent parameter for differentiating between similar plants. Two of the *Tradescantia* cultivars we examined,

Angel Eyes and Red Cloud, had similar hue° at the recommended fertilization rates, but 'Blue Stone' was different, so hue° could be used to detect cultivar color differences. Adams et al. (1998) examined N and sulfur (S) fertilization rates and their impact on poinsettia foliage color; they found that hue° increased from 120° to 135° with increasing N levels and then leveled off, thus as N levels increased, foliage became greener. We found the foliage hue° of *Tradescantia* did increase with increasing N rates, instead the foliage hue angles were very similar with increasing N rates.

Chroma: Chroma changed over time (Table 3.6). Chroma of 'Red Cloud' increased from week 2 to 4 with ascending fertilization rates (Tables 3.13 and 3.14). Chroma of 'Blue Stone' increased at 0 and 300 $mg \cdot L^{-1}$ (ppm) N from week 2 to week 4, but chroma of plants fertilized with 100 and 200 $mg \cdot L^{-1}$ (ppm) N decreased (foliage darker or more dull). The chroma of 'Angel Eyes' increased for all fertilization rates from week 2 to 4. 'Angel Eyes' chroma values remained relatively similar from week 4 to 8, but the chroma of 'Red Cloud' decreased with increasing fertilizer rates. From week 8 to 10 the change in chroma of 'Blue Stone' differed from 'Angel Eyes.' Chroma of 'Angel Eyes' decreased (color became more dull) for 0 and 200 $mg \cdot L^{-1}$ (ppm) fertilization levels, while at 100 and 300 $mg \cdot L^{-1}$ (ppm) N rates chroma increased (color brighter). 'Blue Stone' had decreases in chroma for plants fertilized with 100 to 300 $mg \cdot L^{-1}$ (ppm) N, but chroma of plants which were not fertilized increased.

Adams et al. (1998) study on impact of N and S fertilization on poinsettia foliage color also examined the lightness and chroma values of foliage. They found that chroma decreased from 30 to 18 with increasing N fertilization rates. During our experiment chroma changed with cultivar, but N rate only affected foliage color when comparisons

were made between cultivars, no consistent decrease in chroma was found with increasing N rates. 'Blue Stone' had the greenest hue° at 100 and 200 $mg \cdot L^{-1}$ N and also had the lowest chroma at those N rates. This low chroma resulted in the foliage appearing duller and darker. While N rate had a more variable impact on 'Red Cloud' chroma with lower values at 100 and 300 $mg \cdot L^{-1}$ and higher values at 0 and 200 $mg \cdot L^{-1}$, 'Angel Eyes' chroma increased over the 10 week experiment approximately 3 points when plants were fertilized with 100, 200 or 300 $mg \cdot L^{-1}$ N. 'Angel Eyes' had the highest chroma for plants which had been fertilized at the experiment's end.

Shoot dry weight: Shoot dry weights were affected by the main effects of cultivar and fertilizer rate and the cultivar x fertilizer rate interaction was significant (Table 3.15). Dry weights of all cultivars changed in a quadratic manner with increasing N rates. Dry weight of 'Blue Stone' was higher than the other cultivars, which did not differ from each other (Tables 3.15 and 3.16). Although there was a quadratic response to fertilizer rate for all cultivars, the maximum dry weight occurred at 200 $mg \cdot L^{-1}$ (ppm) N for 'Angel Eyes' and 'Red Cloud,' and at 100 $mg \cdot L^{-1}$ (ppm) N for 'Blue Stone.' Shoot dry weight of 'Blue Stone' was significantly higher than both 'Red Cloud' and 'Angel Eyes' (Table 3.16).

Melton and Dufault (1991) studied fertilizer impacts on tomato (*Lycopersicon esculentum*) transplant growth. They found that shoot dry weights increased in a linear manner with increasing N rates. We found that our *Tradescantia* shoot dry weights were greatest at 200 $mg \cdot L^{-1}$ (ppm) N for two cultivars and greatest at 100 $mg \cdot L^{-1}$ (ppm) N for the other. Van Iersel et al. (1998) compared growth responses of impatiens and petunia. The shoot dry weight of petunia increased in a linear manner with increasing N rates,

while the shoot dry weight of the impatiens responded in a manner similar to our *Tradescantia* cultivars and peaked at 336 $mg \cdot L^{-1}$ (ppm) N, their next to highest N rate.

Shoot N and P: Nitrogen and P concentrations in the tissue were significantly affected by both cultivar and N rate (Table 3.15). A positive quadratic response for percent N and P present in shoots occurred with increasing N rates. 'Blue Stone' had considerably lower N values when compared with 'Angel Eyes' and 'Red Cloud,' except at the 200 $mg \cdot L^{-1}$ (ppm) N fertilization level where 'Blue Stone' and 'Red Cloud' had similar values (4.74% and 4.85%, respectively) and 'Angel Eyes' had only 4.54% (Tables 3.15 and 3.16). Phosphorus values for 'Red Cloud' increased with increasing fertilization rates while for 'Angel Eyes' and 'Blue Stone' the values decreased from 200 to 300 $mg \cdot L^{-1}$ (ppm) N. 'Angel Eyes' had consistently lower P values when compared with 'Blue Stone' and 'Angel Eyes' regardless of fertilizer rate (Tables 3.15 and 3.16). Hue° values correlated positively with both percent shoot N (R^2= 0.348) and percent shoot P (R^2= 0.310); with increasing N rates the hue° values and percent shoot N and P increased. Chroma values correlated negatively with both percent shoot N (R^2= -0.478) and percent shoot P (R^2= -0.534); with increasing N rates the chroma values decreased while percent shoot N and P increased. The correlation values for hue° and percent N and P were low. This indicated that hue° can not be consistently used to predict percent shoot N or P content. The correlation values for chroma and percent shoot N and P were slightly higher, but still not significant enough for use as predictors of *Tradescantia* shoot N and P content.

Shoot N content peaked for all cultivars at the 200 $mg \cdot L^{-1}$ (ppm) N application level. These N percentages of 4.54, 4.74, and 4.85 for 'Angel Eyes', 'Blue Stone' and

'Red Cloud,' respectively, are well within the N percentages set forth as average by Mills and Jones (1996). Shoot P levels were consistently higher than those averages stated by Mills and Jones (1996) as standard. They found 0.52% to be the standard P level in *T. virginiana* shoots, while for all three cultivars we examined, P levels were either at or above 0.99% when their fertilization level was at 100 $mg \cdot L^{-1}$ (ppm) N. We noted no toxicity symptoms on our plants with these higher P levels.

Summary. Height of cultivars differed. 'Blue Stone' was the tallest cultivar; 'Angel Eyes' was the widest, and 'Red Cloud' plants were the smallest at 10 weeks after treatments began. At 100 and 200 $mg \cdot L^{-1}$ N all three cultivars had 100% flowering from six weeks into the experiment until the experiment's end at 10 weeks. 'Blue Stone' had greater dry weight and height reduction in comparison with other cultivars when fertilized at 300 $mg \cdot L^{-1}$ (ppm) N. Shoot dry weights of 'Angel Eyes' and 'Red Cloud' were similar when they were fertilized with 100 and 200 $mg \cdot L^{-1}$ N, while the dry weight of 'Blue Stone' at these rates was about 15 g heavier. Nitrogen rates between 100 and 200 $mg \cdot L^{-1}$ appeared to produce the most marketable plants.

Experiment 2. *Plant height and width.* Plant height was not affected by any treatment factors (Tables 3.17 and 3.18), from week 2 to 4 plant width increased, but the increase was not affected by cultivar or fertilizer rate (Table 3.19). 'Red Cloud' fertilized with 200 $mg \cdot L^{-1}$ (ppm) N decreased in height by 4 cm from week 4 to week 6, while the decrease in 'Lilac Frost' height at both N rates was less severe. The N rates we chose to apply appear to promote similar plant growth response, while the growth habit of the cultivars still differ.

Media pH and EC. Neither N rate or cultivar had an impact on the pH range (Table 3.17). The N rate x cultivar interaction was significant for pH, for 'Lilac Frost' pH was highest for 200 $mg \cdot L^{-1}$ (ppm) N, while for 'Red Cloud' media pH was highest for 100 $mg \cdot L^{-1}$ (ppm) N (Table 3.20). James and van Iersel (2001) found the leachate pH of petunias and begonias fertigated with an acidic fertilizer consistently lower than that of petunias and begonias fertigated with a slightly basic fertilizer. The results of our experiment conflict with theirs. Instead of having media pH of plants fertilized with a basic fertilizer lower than the pH of those plants fertilized with an acidic fertilizer, the pH ranges of both experiments for plants fertilized with either 100 or 200 $mg \cdot L^{-1}$ (ppm) N were similar, with no increase in media pH with the basic fertilizer.

Both cultivar and fertilizer rate affected media EC (Table 3.17). Electrical conductivity increased with increasing N rates for both cultivars; electrical conductivity for 'Red Cloud' was higher than for 'Lilac Frost' (Table 3.21). These results are similar to our first experiment where it appeared that 'Red Cloud' is a cultivar which takes up lower levels of soluble salts provided by the fertilizer, when compared with other *Tradescantia* cultivars.

Plant color. Hue° and chroma were affected by cultivar but not N rate (Table 3.22). The hue° of 'Red Cloud' was slightly lower (slightly more yellow) than that of 'Lilac Frost' and the chroma of 'Red Cloud' was slightly higher (more brilliant) than 'Lilac Frost' (Table 3.23). Landschoot and Mancino (2000) were able to differentiate between two species of bentgrass turf by comparing hue°. The results of this experiment differed from our first experiment; we were not able to determine cultivar by hue° alone. The hue° and chroma values were very similar by the experiment's end and little

difference in foliage color could be seen. 'Red Cloud' foliage had a slight yellowish tinge and brighter coloration than 'Lilac Frost,' but these differences were not significant.

Plant quality, dry weight, percent N and P. Nitrogen rate did not affect quality of plants, nor did quality differ due to cultivar (Table 3.24). The N rate applied influenced shoot dry weight, with plants fertilized with 100 $mg \cdot L^{-1}$ (ppm) N weighing less than those plants fertilized with 200 $mg \cdot L^{-1}$ (ppm) N. Shoot dry weight also differed by cultivar (Table 3.26). 'Lilac Frost' was the larger of the two cultivars, since it had the larger dry weight. Plants fertilized with 200 $mg \cdot L^{-1}$ N were larger than those fertilized with 100 $mg \cdot L^{-1}$ N, but their quality ratings were similar. Therefore, it appears that fertilizing with 100 $mg \cdot L^{-1}$ N is adequate for sustaining plant growth and quality.

Nitrogen content in shoots differed significantly with N rate applied and with cultivar (Table 3.24). 'Lilac Frost' had consistently higher levels of N in shoots compared with 'Red Cloud' (Tables 3.25 and 3.26). While plants fertilized with 100 $mg \cdot L^{-1}$ N contained less N than those fertilized with 200 $mg \cdot L^{-1}$ (ppm) N (Tables 3.23 and 24). Percent N in shoots was lower than the average set forth by Mills and Jones (1996), and since no P was present in the fertilizer, the percent P in shoots was extremely low, yet still closer to the 0.52% suggested by Mills and Jones (1996) than the P levels found in shoots in our previous experiment.

Percent P in shoots did not differ by cultivar or N rate (Tables 3.24 and 3.25). The percent N present in 'Red Cloud' shoots decreased 1% in experiment 2, when compared with the percent N present in 'Red Cloud' shoots in experiment 1. Phosphorus levels in shoots also decreased in experiment 2 when compared with experiment 1, but that was expected because no P was present in the fertilizer, but plant growth response to these

low levels of P was not negative. The findings of the Broschat and Klock-Moore (2000) study support the results of our second experiment. They examined the effects of P fertilization on the growth of six plant species (*Dypsis lutescens, Spathiphyllum* 'Figaro', *Ixora* 'Nora Grant', *Lycopersicon esculentum* 'Floramerica', *Tagetes erecta* 'Inca Gold' and *Capsicum annuum* 'Better Bell'), and found that most container plants need minimal amounts of P for optimum growth.

Summary. The nitrogen levels we chose to apply resulted in plants which were similar in appearance to each other. At the experiment's end, there was no difference in height or width between plants fertilized with 100 and 200 $mg \cdot L^{-1}$ (ppm) N. The pH range, although we used a basic fertilizer, was very similar to that of the previous experiment. The difference in media EC between N rates was expected, but fertilizer rate did not influence plant quality. 'Red Cloud' had consistent high quality ratings while those of 'Lilac Frost' were a little lower, but overall differences were not significant. Neither cultivar flowered readily over the experiment, possibly due to the lateness of the summer season.

The results of both experiments suggest that the 100 or 200 $mg \cdot L^{-1}$ (ppm) N levels are acceptable fertilization levels regardless of cultivar. *Tradescantia virginiana* cultivars differ in foliage color, but foliage color was similar for plants fertilized at either 100 or 200 $mg \cdot L^{-1}$ (ppm) N. We also found that *T. virginiana* grow well under acidic conditions, so media pH values down to ~5.0 will not negatively impact plant growth, foliage, or flowering. Cultivars differed in height, but among the four cultivars we studied, N rates between 100 and 200 $mg \cdot L^{-1}$ (ppm) produced uniform plants in size and quality. We recommend these plants be fertilized with 100 $mg \cdot L^{-1}$ (ppm) N. Plant

quality, height, flowering, and color will all be acceptable, and the plants will be marketable.

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Table 3.1. P-values for main effects, interactions, and contracts from repeated measures analysis of variance for effect of four nitrogen (N) rates (15-16-17) on plant height, width and percent flowering of *Tradescantia virginiana* over a 10 week experiment. AE= 'Angel Eyes', BS= 'Blue Stone', and RC= 'Red Cloud.'

		Response variables		
Source	DF	Height	Width	% Flowering
Week[z]	2	<0.001	0.001	0.677
Cultivar[y]	2	<0.001	0.144	0.001
RC vs. AE[y]	1	0.528	0.443	0.288
RC vs. BS[y]	1	<0.001	0.052	0.005
AE vs. BS[y]	1	0.001	0.226	0.001
N rate[y]	3	<0.001	<0.001	0.001
Linear[y]	1	0.005	0.009	0.006
Quadratic[y]	1	<0.001	<0.001	0.001
Cultivar x N rate[y]	6	0.168	0.010	0.015
RC vs. AE x N rate[y]	1	0.496	0.334	0.062
RC vs. BS x N rate[y]	1	0.051	0.005	0.009
AE vs. BS x N rate[y]	1	0.191	0.055	0.405
Week x cultivar[z]	4	<0.001	0.001	0.839
Week x RC vs. AE[z]	2	0.351	0.002	0.610
Week x RC vs. BS[z]	2	<0.001	0.004	0.610
Week x AE vs. BS[z]	2	<0.001	0.028	1.000
Week x N rate[z]	6	<0.001	0.001	0.001

Week x rate linear[z]	2	0.069	0.001	0.008
Week x rate quadratic[z]	2	<0.001	0.001	0.001
Week x cultivar x N rate[z]	12	0.862	0.219	0.001
Week x RC vs. AE x N rate[z]	2	0.731	0.766	0.016
Week x RC vs. BS x N rate[z]	2	0.678	0.166	0.005
Week x AE vs. BS x N rate[z]	2	0.640	0.443	0.648

[z]Results from MANOVA tests of hypothesis for within-subject (measurement taken repeatedly on each plant) effects.

[y]Tests the hypothesis that treatments (between-subjects effects) have no effect on the response variables, ignoring within-subject effects. This is the treatment effect averaged over all weeks.

Table 3.2. Effect of fertilizer rate (15-16-17) on plant height of three *Tradescantia virginiana* cultivars.

Cultivar	N rate ($mg \cdot L^{-1}$)	Plant height (cm)		
		wk 2	wk 6	wk 10
'Angel Eyes'	0	15.1[z]	18.1	16.6
	100	18.1	26.5	42.6
	200	19.0	26.8	30.5
	300	16.5	25.1	27.9
'Blue Stone'	0	16.4	28.5	25.9
	100	16.0	34.0	47.3
	200	16.4	32.3	40.3
	300	15.6	29.5	32.5
'Red Cloud'	0	17.0	19.8	15.0
	100	18.5	24.0	30.3
	200	18.3	26.8	34.0
	300	19.3	25.8	26.8

[z]Values are means of 4 replicates for each treatment.

Table 3.3. Effect of fertilizer rate (15-16-17) on plant width of three *Tradescantia virginiana* cultivars.

Cultivar	N rate ($mg \cdot L^{-1}$)	Plant width (cm)		
		wk 2	wk 6	wk 10
'Angel Eyes'	0	28.8[z]	21.3	41.5
	100	34.5	57.9	63.1
	200	26.6	54.9	65.0
	300	30.4	50.9	55.3
'Blue Stone'	0	33.9	50.5	56.3
	100	35.1	50.4	58.3
	200	35.0	52.1	61.8
	300	30.6	48.5	57.8
'Red Cloud'	0	35.7	39.8	37.9
	100	33.2	52.6	54.5
	200	34.3	50.6	57.1
	300	35.1	52.9	56.3

[z]Average of replicates for each treatment level and date.

Table 3.4. Effect of fertilizer rates (15-16-17) on percent plants flowering of three *Tradescantia virginiana* cultivars.

Cultivar	N rate ($mg \cdot L^{-1}$)	Percent plants flowering		
		wk 2	wk 6	wk 10
'Angel Eyes'	0	50[z]	50	50
	100	100	100	100
	200	50	100	100
	300	75	75	75
'Blue Stone'	0	100	100	100
	100	100	100	100
	200	100	100	100
	300	100	100	100
'Red Cloud'	0	100	100	100
	100	50	100	100
	200	100	100	100
	300	75	100	100

[z]Average of replicates for each treatment level and date.

Table 3.5. *P* values from profile analysis of *Tradescantia virginiana* plant height and width. These analyses of variance are for the transformed variables representing the differences between adjacent weeks.

	Plant height		Plant width		Percent Flowering	
	Week		Week		Week	
Treatments	2 – 6	6 – 10	2 – 6	6 – 10	2 – 6	6 – 10
Mean[z]	<0.001	0.001	<0.001	<0.001	0.677	1.0
Cultivar[y]	<0.001	0.409	0.004	0.001	0.839	1.0
RC vs. AE[y]	0.492	0.259	0.001	0.228	0.610	1.0
RC vs. BS[y]	<0.001	0.239	0.260	0.003	0.610	1.0
AE vs. BS[y]	<0.001	0.960	0.024	0.054	1.00	1.0
N rate[y]	0.050	<0.001	0.002	0.005	0.001	1.0
Linear[y]	0.066	0.273	0.004	0.008	0.008	1.0
Quadratic[y]	0.038	<0.001	0.006	0.018	0.001	1.0
Cultivar x N rate[y]	0.877	0.698	0.065	0.852	0.001	1.0
RC vs. AE x N rate[y]	0.891	0.425	0.463	0.929	0.016	1.0
RC vs. BS x N[y]	0.447	0.767	0.082	0.623	0.005	1.0
AE vs. BS x N rate[y]	0.371	0.615	0.302	0.561	0.648	1.0

[z] *P* values for change in plant height for adjacent weeks pooled over all treatments.

[y] *P* values for the main effects and interactions on the change in plant height, width and percentage of plants flowering between adjacent weeks.

Table 3.6. P-values for main effects, contrasts, and interactions from repeated measures analysis of variance for effect of four nitrogen (N) rates (15-16-17) on media pH and electrical conductivity (EC), and plant hue° and chroma of *Tradescantia virginiana* over a 10-week experiment. AE= 'Angel Eyes', BS= 'Blue Stone', and RC= 'Red Cloud.'

		Response variables			
Source	DF	pH	EC	Hue°	Chroma
Week[z]	2	<0.001	<0.001	0.001	<0.001
Cultivar[y]	2	0.456	0.005	0.001	0.124
RC vs. AE[y]	1	0.217	0.002	0.001	0.724
RC vs. BS[y]	1	0.637	0.028	0.008	0.056
AE vs. BS[y]	1	0.441	0.270	0.152	0.115
N rate[y]	3	<0.001	<0.001	0.098	0.077
Linear[y]	1	<0.001	<0.001	0.886	0.021
Quadratic[y]	1	0.661	<0.001	0.055	0.434
Cultivar x N rate[y]	6	0.430	0.490	0.638	0.074
RC vs. AE x N rate[y]	1	0.027	0.115	0.384	0.178
RC vs. BS x N rate[y]	1	0.578	0.095	0.328	0.412
AE vs. BS x N rate[y]	1	0.090	0.924	0.912	0.034
Week x cultivar[z]	4	0.049	0.004	0.001	<0.001
Week x RC vs. AE[z]	2	0.014	0.102	0.001	0.029
Week x RC vs. BS[z]	2	0.897	0.001	0.102	0.001
Week x AE vs. BS[z]	2	0.043	0.109	0.027	0.001

Week x N rate[z]	6	0.001	<0.001	0.052	0.147
Week x rate linear[z]	2	0.001	<0.001	0.158	0.089
Week x rate quadratic[z]	2	0.048	<0.001	0.038	0.143
Week x cultivar x N rate[z]	12	0.181	0.349	0.081	0.004
Week x RC vs. AE x N rate[z]	2	0.022	0.584	0.613	0.558
Week x RC vs. BS x N rate[z]	2	0.551	0.057	0.006	0.008
Week x AE vs. BS x N rate[z]	2	0.249	0.223	0.027	0.005

[z]Results from MANOVA tests of hypothesis for within-subject (measurement taken repeatedly on each plant) effects.

[y]Tests the hypothesis that treatments (between-subjects effects) have no effect on the response variables, ignoring within-subject effects. This is the treatment effect averaged over all weeks.

Table 3.7. Effect of nitrogen rate (15-16-17) on media pH of three *Tradescantia virginiana* cultivars.

Cultivar	N rate ($mg \cdot L^{-1}$)	Media pH (week)				
		2	4	6	8	10
'Angel Eyes'	0	6.3[z]	5.8	6.2	5.9	5.9
	100	6.1	5.7	5.3	5.3	5.7
	200	6.1	5.3	5.4	5.4	5.3
	300	5.9	5.0	4.9	4.9	5.0
'Blue Stone'	0	6.2	5.7	5.8	5.7	5.8
	100	6.0	5.5	5.6	5.4	5.7
	200	5.8	5.3	5.3	5.3	5.5
	300	5.9	5.1	5.1	5.0	5.2
'Red Cloud'	0	6.2	5.6	5.8	5.5	5.7
	100	5.9	5.5	5.6	5.5	5.7
	200	5.8	5.2	5.5	5.4	5.5
	300	5.7	5.1	5.1	5.0	5.3

[z]Average of 4 replicates for each treatment level and date.

Table 3.8. *P* values from profile analysis of media pH of *Tradescantia virginiana*. These analyses of variance are for the transformed variables representing the differences between adjacent weeks.

	Media pH			
	Week			
Treatments	2 – 4	4 – 6	6 – 8	8 – 10
Mean[z]	<0.001	0.006	<0.001	<0.001
Cultivar[y]	0.396	0.833	0.474	0.375
RC vs. AE[y]	0.220	0.789	0.292	0.268
RC vs. BS[y]	0.910	0.549	1.00	0.852
AE vs. BS[y]	0.264	0.739	0.292	0.198
N rate[y]	0.001	0.040	0.007	0.253
Linear[y]	0.001	0.014	0.001	0.786
Quadratic[y]	0.033	0.957	0.923	0.479
Cultivar x N rate[y]	0.039	0.337	0.020	0.692
RC vs. AE x N rate[y]	0.036	0.113	0.193	0.912
RC vs. BS x N rate[y]	0.251	0.929	0.146	0.599
AE vs. BS x N rate[y]	0.317	0.134	0.008	0.524

[z] *P* values for change in media pH for adjacent weeks pooled over all treatments.

[y] *P* values for the main effects and interactions on the change in media pH between adjacent weeks.

Table 3.9. Effect of nitrogen rates (15-16-17) on media electrical conductivity (EC) of three *Tradescantia virginiana* cultivars.

Cultivar	N rate ($mg \cdot L^{-1}$)	Media EC ($mS \cdot cm$) Week				
		2	4	6	8	10
'Angel Eyes'	0	0.52[z]	0.26	0.18	0.18	0.13
	100	1.09	0.67	0.61	0.57	0.66
	200	1.80	2.20	1.77	1.40	1.80
	300	2.68	3.81	4.24	3.45	4.92
'Blue Stone'	0	0.70	0.36	0.26	0.21	0.18
	100	1.36	1.01	0.72	0.60	0.60
	200	2.18	2.10	1.57	1.54	2.25
	300	2.81	3.87	3.86	3.76	5.13
'Red Cloud'	0	0.62	0.32	0.23	0.27	0.22
	100	1.25	0.91	0.95	0.72	0.86
	200	1.98	2.28	2.62	2.09	2.96
	300	2.91	4.08	4.68	4.09	5.42

[z]Average of 4 replicates for each treatment level and date.

Table 3.10. *P* values from profile analysis of media electrical conductivity (EC) of *Tradescantia virginiana*. These analyses of variance are for the transformed variables representing the differences between adjacent weeks.

	Media EC			
	Week			
Treatments	2 – 4	4 – 6	6 – 8	8 – 10
Mean[z]	0.003	0.715	0.001	<0.001
Cultivar[y]	0.479	0.001	0.248	0.767
RC vs. AE[y]	0.973	0.014	0.865	0.478
RC vs. BS[y]	0.303	<0.001	0.129	0.635
AE vs. BS[y]	0.288	0.048	0.176	0.812
N rate[y]	<0.001	0.001	0.070	<0.001
Linear[y]	<0.001	0.002	0.009	<0.001
Quadratic[y]	<0.001	0.001	0.824	0.009
Cultivar x N rate[y]	0.828	0.043	0.607	0.768
RC vs. AE x N rate[y]	0.949	0.191	0.729	0.995
RC vs. BS x N rate[y]	0.588	0.014	0.162	0.970
AE vs. BS x N rate[y]	0.633	0.215	0.084	0.965

[z] *P* values for change in media EC for adjacent weeks pooled over all treatments.

[y] *P* values for the main effects and interactions on the change in media EC between adjacent weeks.

Table 3.11. Effect of nitrogen rates (15-16-17) on hue^{o} of three *Tradescantia virginiana* cultivars.

Cultivar	N rate ($mg \cdot L^{-1}$)	Hue^{o} Week			
		2	4	8	10
'Angel Eyes'	0	126[z]	125	123	125
	100	124	123	124	123
	200	128	123	122	123
	300	123	123	124	123
'Blue Stone'	0	123	122	119	117
	100	122	123	123	128
	200	122	122	125	128
	300	122	121	123	127
'Red Cloud'	0	114	115	118	119
	100	109	116	120	123
	200	116	117	123	124
	300	93.0	117	121	116

[z]Average of 4 replicates for each treatment level and date.

Table 3.12. *P* values from profile analysis of hue° of *Tradescantia virginiana*. These analyses of variance are for the transformed variables representing the differences between adjacent weeks.

	Hue°		
	Week		
Treatments	2 – 4	4 – 8	8 – 10
Mean[z]	0.732	0.007	0.239
Cultivar[y]	0.104	0.011	0.392
RC vs. AE[y]	0.035	0.004	0.744
RC vs. BS[y]	0.351	0.035	0.323
AE vs. BS[y]	0.221	0.356	0.192
N rate[y]	0.200	0.122	0.564
Linear[y]	0.889	0.047	0.668
Quadratic[y]	0.190	0.171	0.179
Cultivar x N rate[y]	0.464	0.674	0.260
RC vs. AE x N rate[y]	0.239	0.992	0.448
RC vs. BS x N rate[y]	0.469	0.257	0.028
AE vs. BS x N rate[y]	0.644	0.261	0.138

[z] *P* values for change in hue° for adjacent weeks pooled over all treatments.

[y] *P* values for the main effects and interactions on the change in hue° between adjacent weeks.

Table 3.13. Effect of nitrogen rates (15-16-17) on chroma of three *Tradescantia virginiana* cultivars.

Cultivar	N rate ($mg \cdot L^{-1}$)	Chroma			
		Week			
		2	4	8	10
'Angel Eyes'	0	28.2[z]	28.9	29.6	26.7
	100	28.0	29.6	28.4	30.7
	200	25.1	32.1	32.2	30.1
	300	28.8	29.4	26.6	30.0
'Blue Stone'	0	33.3	33.9	34.6	38.3
	100	34.2	30.6	31.1	21.5
	200	35.4	33.2	25.6	18.6
	300	34.5	35.3	28.1	21.0
'Red Cloud'	0	29.7	33.0	27.8	29.9
	100	26.6	34.6	29.9	23.5
	200	30.3	33.6	26.8	27.8
	300	21.1	31.2	28.5	25.1

[z]Average of 4 replicates for each treatment level and date.

Table 3.14. *P* values from profile analysis of chroma of *Tradescantia virginiana*. These analyses of variance are for the transformed variables representing the differences between adjacent weeks.

	Chroma		
	Week		
Treatments	2 – 4	4 – 8	8 – 10
Mean[z]	0.001	0.001	0.009
Cultivar[y]	0.001	0.104	0.035
RC vs. AE[y]	0.046	0.037	0.349
RC vs. BS[y]	0.001	0.454	0.092
AE vs. BS[y]	0.047	0.167	0.011
N rate[y]	0.702	0.315	0.112
Linear[y]	0.254	0.097	0.262
Quadratic[y]	0.792	0.755	0.069
Cultivar x N rate[y]	0.103	0.304	0.018
RC vs. AE x N rate[y]	0.512	0.378	0.176
RC vs. BS x N rate[y]	0.397	0.031	0.236
AE vs. BS x N rate[y]	0.847	0.185	0.014

[z] *P* values for change in chroma for adjacent weeks pooled over all treatments.

[y] *P* values for the main effects and interactions on the change in chroma between adjacent weeks.

Table 3.15. Sources of variation and P-values from analysis of variance for effect on dry weight, percent shoot nitrogen (N) and percent shoot phosphorus of *Tradescantia virginiana* after treatment with four nitrogen (N) rates (15-16-17) over a 10-week experiment. AE= 'Angel Eyes', BS= 'Blue Stone', and RC= 'Red Cloud'.

	Response variables		
Treatments	Dry weight	Percent N	Percent P
Mean[z]	<0.001	<0.001	<0.001
Cultivar[y]	<0.001	0.004	0.003
RC vs. AE[y]	0.319	0.591	0.002
RC vs. BS[y]	<0.001	0.008	0.005
AE vs. BS[y]	<0.001	0.002	0.684
N rate[y]	<0.001	<0.001	<0.001
Linear[y]	<0.001	<0.001	<0.001
Quadratic[y]	<0.001	<0.001	<0.001
Cultivar x N rate[y]	0.006	0.068	0.001
RC vs. AE x N rate[y]	0.947	0.038	0.004
RC vs. BS x N rate[y]	0.058	0.348	0.477
AE vs. BS x N rate[y]	0.067	0.235	0.025

[z] *P* values for change in response variables over all treatments.

[y] Tests the hypothesis that treatments (between-subjects effects) have no effect on the response variables, ignoring within-subject effects.

Table 3.16. Effect of nitrogen (N) rate (15-16-17) on shoot dry weight, N, and phosphorus (P) content in three *Tradescantia virginiana* cultivars.

Cultivar	N rate ($mg \cdot L^{-1}$)	Dry weight (g)	Percent N	Percent P
'Angel Eyes'	0	22.6[z]	1.86[z]	0.298
	100	39.7	3.84	1.09
	200	42.9	4.54	1.48
	300	38.8	4.42	1.22
'Blue Stone'	0	31.5	1.15	0.235
	100	55.6	3.40	0.988
	200	54.8	4.74	1.60
	300	42.9	3.89	1.32
'Red Cloud'	0	21.8	1.43	0.275
	100	38.1	3.63	1.24
	200	41.7	4.85	1.49
	300	38.0	4.52	1.56

[z]Average of 4 replicates for each treatment level.

Table 3.17. Sources of variation and *P*-values from analysis of variance for effect of N rate on height, width, pH and electrical conductivity (EC) of two cultivars *Tradescantia virginiana*. Fertilizer 15-0-15.

		Response variables			
Source	DF	Height	Width	pH	EC
Week[z]	3	0.174	0.001	0.085	0.004
N rate[y]	1	0.844	0.091	0.108	<0.001
Cultivar[y]	1	0.343	0.004	0.463	0.013
N rate x cultivar[y]	1	0.287	0.174	0.013	0.183
Week x N rate[z]	3	0.842	0.283	0.569	0.005
Week x cultivar[z]	3	0.723	0.903	0.936	0.317
Week x N rate x cultivar[z]	3	0.446	0.093	0.379	0.368

[z]Results from MANOVA tests of hypothesis for within-subject (measurement taken repeatedly on each plant) effects

[y]Tests the hypothesis that treatments (between-subjects effects) have no effect on the response variables, ignoring within-subject effects. This is the treatment effect when averaged over all weeks.

Table 3.18. Height of *Tradescantia virginiana* cultivars irrigated with 2 different nitrogen levels (15-0-15). Lower section represents the *P* values from profile analysis of plant height. These analyses of variance are for the transformed variables representing the differences between adjacent weeks. Lower portion

Cultivar	N Rate	Height (cm)			
		Week 2	Week 4	Week 6	Week 8
'Lilac Frost'	100	16.7[z]	17.6	18.4	16.3
	200	18.5	17.1	19.9	17.8
'Red Cloud'	100	18.7	17.6	20.8	21.8
	200	18.5	17.8	19.1	17.3

	Week 2- 4	Week 4-6	Week 6-8
Mean	0.569[y]	0.026	0.146
N rate	0.637	0.975	0.401
Cultivar	0.7463	0.782	0.311
N rate x cultivar	0.505	0.243	0.401

[z] Values are means of 5 replicates for each treatment

[y] *P* values for the main effects and interactions on the change in plant height between adjacent weeks.

Table 3.19. Width of *Tradescantia virginiana* cultivars irrigated with 2 different nitrogen levels (15-0-15). Lower section represents the *P* values from profile analysis of plant width. These analyses of variance are for the transformed variables representing the differences between adjacent weeks.

Cultivar	N Rate	Width (cm)			
		Week 2	Week 4	Week 6	Week 8
'Lilac Frost'	100	42.1[z]	46.9	44.4	44.1
	200	41.6	47.4	47.1	45.7
'Red Cloud'	100	34.1	38.2	39.7	39.0
	200	40.5	46.2	42.1	41.0

	Week 2- 4	Week 4-6	Week 6-8
Mean	<0.001 [y]	0.142	0.090
N rate	0.424	0.043	0.971
Cultivar	0.816	0.512	0.634
N rate x cultivar	0.863	0.019	0.797

[z] Values are means of 5 replicates for each treatment

[y] *P* values for the main effects and interactions on the change in plant height between adjacent weeks.

Table 3.20. pH of *Tradescantia virginiana* cultivars irrigated with 2 different nitrogen levels (15-0-15). Lower section represents the *P* values from profile analysis of media pH. These analyses of variance are for the transformed variables representing the differences between adjacent weeks.

Cultivar	N Rate	pH			
		Week 2	Week 4	Week 6	Week 8
'Lilac Frost'	100	5.6[z]	5.7	5.6	5.4
	200	5.5	5.7	5.8	5.5
'Red Cloud'	100	5.6	5.9	5.7	5.6
	200	5.5	5.5	5.6	5.3

	Week 2- 4	Week 4-6	Week 6-8
Mean	0.026[y]	0.714	0.054
N rate	0.361	0.159	0.572
Cultivar	0.877	0.902	0.572
N rate x cultivar	0.107	0.625	0.849

[z] Values are means of 5 replicates for each treatment

[y] *P* values for the main effects and interactions on the change in plant height between adjacent weeks.

Table 3.21. Electrical conductivity (EC) of *Tradescantia virginiana* cultivars irrigated with 2 different nitrogen levels. Lower section represents the *P* values from profile analysis of media EC. These analyses of variance are for the transformed variables representing the differences between adjacent weeks.

Cultivar	N Rate	EC ($mS \cdot cm^{-2}$)			
		Week 2	Week 4	Week 6	Week 8
'Lilac Frost'	100	1.06[z]	0.56	0.58	0.98
	200	1.43	1.35	1.73	2.87
'Red Cloud'	100	1.17	0.78	0.81	1.20
	200	2.12	2.10	2.62	2.74

	Week 2- 4	Week 4-6	Week 6-8
Mean	0.003 [y]	0.002	0.003
N rate	0.010	0.004	0.407
Cultivar	0.542	0.539	0.088
N rate x cultivar	0.842	0.593	0.094

[z] Values are means of 5 replicates for each treatment

[y] *P* values for the main effects and interactions on the change in plant height between adjacent weeks.

Table 3.22. Sources of variation and *P*-values from analysis of variance for effect of N rate on hue° and chroma of two cultivars *Tradescantia virginiana*. Fertilizer 15-0-15.

		Response variables	
Source	DF	Hue°	Chroma
Week[z]	3	0.002	0.001
N rate[y]	1	0.286	0.115
Cultivar[y]	1	0.003	0.001
N rate x cultivar[y]	1	0.765	0.457
Week x N rate[z]	3	0.935	0.872
Week x cultivar[z]	3	0.334	0.331
Week x N rate x cultivar[z]	3	0.102	0.593

[z]Results from MANOVA tests of hypothesis for within-subject (measurement taken repeatedly on each plant) effects

[y]Tests the hypothesis that treatments (between-subjects effects) have no effect on the response variables, ignoring within-subject effects. This is the treatment effect when averaged over all weeks.

Table 3.23. Hue° and chroma of *Tradescantia virginiana* cultivars irrigated with 2 different nitrogen levels (15-0-15).

Cultivar	N Rate	Hue°		Chroma	
		Week 4	Week 8	Week 4	Week 8
'Lilac Frost'	100	124[z]	125	25.5	22.8
	200	123	125	27.1	23.4
'Red Cloud'	100	120	125	31.1	24.5
	200	121	122	33.2	28.4

[z]Average of 5 replicates for each treatment level and date.

Table 3.24. Sources of variation and P-values from analysis of variance for effect on % shoot nitrogen (N) and % shoot phosphorus of *Tradescantia virginiana* after treatment with two nitrogen (N) rates (15-0-15) over a 8 week experiment.

		Response variables			
Source	DF	Quality	Dry weight (g)	% N	% K
N rate[z]	1	0.564	0.031	0.002	0.196
Cultivar	1	0.100	0.001	0.030	0.587
N rate x cultivar	1	0.564	0.720	0.392	0.656

[z]Tests the hypothesis that N rate and cultivar have no effect on the response variables.

Table 3.25. Quality of *Tradescantia virginiana* cultivars irrigated with 2 different nitrogen levels (15-0-15).

Cultivar	N Rate	Quality	Dry weight (g)	% N	% P
'Lilac Frost'	100	3.6[z]	17.9	2.95	0.190[z]
	200	3.8	21.0	3.53	0.172
'Red Cloud'	100	4.0	13.0	2.76	0.210
	200	4.0	15.3	3.13	0.174

[z]Average of 5 replicates for each treatment level.

Table 3.26. Mean comparison for dry weight and percent nitrogen (N) after 8 week experiment with 2 N rates and 2 cultivars. Means followed by the same letter are not significantly different.

	Dry weight (g)	% N
'Lilac Frost'	19.4a	3.24a
'Red Cloud'	14.1b	2.94b
200 $mg \cdot L^{-1}$ N	18.2c	3.33c
100 $mg \cdot L^{-1}$ N	15.4d	2.86d

CHAPTER 4: NITROGEN RATE HAS NO IMPACT ON EFFECTIVENESS OF PLANT GROWTH REGULATORS IN SUPPRESSING GROWTH OF *TRADESCANTIA VIRGINIANA* L.

Additional index words. Flurprimidol, paclobutrazol, uniconazole, nitrogen, phosphorus, hue°, chroma

Abstract. Limited cultural information is available about greenhouse production of *Tradescantia virginiana*. This study examines the effect of fertilization rates on the persistence of growth control provided by selected plant growth regulators (PGRs). Nitrogen (N) was applied to two cultivars of *T. virginiana* at 100 and 200 $mg \cdot L^{-1}$ (ppm) with a 15N-6.9P-14.1K (15-16-17) complete water soluble fertilizer. Plant growth regulator treatments included a non-treated control, paclobutrazol at 120 $mg \cdot L^{-1}$, uniconazole at 45 $mg \cdot L^{-1}$, and flurprimidol at 45 $mg \cdot L^{-1}$. Plants of both cultivars fertilized with 200 $mg \cdot L^{-1}$ N were taller than those fertilized with 100 $mg \cdot L^{-1}$ N, regardless of PGR treatment. 'Lilac Frost' was wider when fertilized at 100 $mg \cdot L^{-1}$ N and 'Red Cloud' was wider when fertilized with 200 $mg \cdot L^{-1}$ N. Flurprimidol appears to be the most effective PGR, at the rates we tested, at suppressing both height and width when comparing cultivars and N rates. 'Lilac Frost' foliage was darker green and more dull in coloration than 'Red Cloud' foliage, which had more yellowish coloration. 'Lilac Frost' foliage became darker green (higher hue°) as a result of PGR application, but 'Red Cloud' foliage color was not affected by PGR. 'Lilac Frost' was larger than 'Red Cloud.' Quality of plants was not affected by treatment. PGR application did not improve

marketability of plants when compared with non-treated controls. Chemical names used: α-(1-methylethyl)-α4-(trifuloromethoxy) phenyl-5-pyrimidinemethanol (flurprimidol); [(±)-(R*,R*)-β-((4-chlorophenyl) methyl)-α-(1,1,-dimethylethyl)-1H-1,2,4,-triazole-1-ethanol)] (paclobutrazol); ((E)-1-(p-chlorphenyl)-4,4-dimethyl-2-(1,2,4-triazol-1-yl-1-penten-3-ol)) (uniconazole).

Introduction

Tradescantia virginiana is an herbaceous perennial native to regions in North America; it is versatile in the landscape and adapts well to sun and shade as well as wet and dry conditions. These characteristics along with the numerous cultivars available and extended flowering period during the summer make it a good landscape plant. Cultivars differ in height, growth habit, leaf width, and flower size and color. Unfortunately little is known about their cultural requirements for growth in a greenhouse.

Studies examining the effect of plant growth regulators (PGRs) on plant development are quite common. Olsen and Andersen (1995) reported *Osteospermum ecklonis* 'Calypso' plants treated with foliar application of flurprimidol (FLU) at 45 $mg \cdot L^{-1}$ (ppm), paclobutrazol (PAC) at 32 $mg \cdot L^{-1}$, or uniconazole (UNI) at 8 $mg \cdot L^{-1}$ were more compact in both height and width than non-treated controls; all PGR treatments delayed flowering by 2 to 3 days. *Dianthus caryophyllus* 'Snowmass' foliar treatment with 15 or 22.5 $mg \cdot L^{-1}$ FLU or 7.5 $mg \cdot L^{-1}$ UNI resulted in adequate height reduction and no delay in time to flower or flower size (Pobudkiewicz and Nowak, 1994). Johansen et

al. (1999) reported height of *Tibouchina urvilleana* was effectively suppressed after application of FLU at 0.15 $mg \cdot L^{-1}$ or PAC at 1 or 5 $mg \cdot L^{-1}$.

Studies have also been conducted which examine the effect of nitrogen (N) rate on plant growth and quality. Campos and Reed (1993) reported enhanced growth of *Spathiphyllum and Dieffenbachia* after small increases in nutrient concentration (25 or 50 $mg \cdot L^{-1}$ (ppm) N). Adams et al. (1998) examined the impact of fertilization with sulfur (S) and N on growth and marketability of poinsettia (*Euphorbia pulcherrima*) 'Dark Red Annette Hegg;' they found the addition of S to fertilizer applied to poinsettias decreased the amount of N fertilizer necessary to produce marketable plants. Sulfur application at 25 $mg \cdot L^{-1}$ reduced the needed amount of N to 125 $mg \cdot L^{-1}$ from industry standard recommendations of 250 and 300 $mg \cdot L^{-1}$ N. The objective of this research were to determine if N rate impacted the length of time PGRs suppressed plant height. We also wanted to objectively quantify any change in foliage color that may occur due to application of PGRs or N rate.

Materials and Methods

The experiment began July 9, 2002 and ran for 8 weeks, ending with plant harvest on Sept. 2, 2002. Two cultivars of *T. virginiana*, 'Lilac Frost' and 'Red Cloud,' arrived on June 20, 2002 and 40 plugs (54 cell size, Yoder Green Leaf, Lancaster PA) per cultivar were transplanted in to 10.8-cm (4.25") diameter (229.4 cm^3) plastic containers on June 24, 2002. The media used to pot up plants contained 65-75% bark fines (0-5/8"), 20-25% Canadian sphagnum peat moss, 9-15% perlite and a proprietary starter charge (Sierra Perennial Mix, Scott's Co., Marysville, Ohio). The plants were grown in a glass

greenhouse. Average temperatures throughout the 8-week experiment were 30.5°± 3.5 °C (86.9 °F) during the day and 20.9° ± 1.5° C (69.6 °F) during the night.

Two weeks after transplant, plant growth regulators (PGRs) were applied to the plants and fertilizer regimen began. The water-soluble 15N-6.9P-14.1K (Peter's Peat Lite Special 15-16-17, Scott's Co.) fertilizer was applied at either 100 or 200 $mg \cdot L^{-1}$ (ppm) N to each plant treated with a PGR. The PGR treatments included a control with no PGR application, PAC (Bonzi, Syngenta Chem. Co., Greensboro, NC) applied one time at 120 $mg \cdot L^{-1}$, UNI (Sumagic, Valent USA Corp., Marysville, Ohio) applied once at 45 $mg \cdot L^{-1}$, and FLU (TopFlor, SePRO Corp., Carmel, IN) applied one time 45 $mg \cdot L^{-1}$. PGRs were applied to actively growing plants using a hand-held CO_2 pressurized sprayer (R & D Sprayers, Opelousas, LA) with an 800VS nozzle at 30 p.s.i. The weather was sunny and the temperature when PGRs were applied was 28 ºC (82.4 °F) with 68% relative humidity. Each PGR solution was evenly applied at 210 ml/m^2 [manufacturers suggested rate 2 qt/100 ft^2 (1890 ml $\cdot 30.5\ m^{-2}$)] over a square meter area in which five plants from each treatment were placed.

Every 2 weeks after treatment data were collected for height (cm, from rim of pot), average width (cm, width at widest point and width perpendicular to that point), media pH and soluble salt levels determined by pour through extraction method (Wright, 1986), and presence of flowers. Colorimeter measurements (Minolta, Chroma Meter Cr-200, Osaka, Japan) were taken twice, at 4 and 8 weeks after treatment (WAT). Colorimeter readings were taken to determine foliage color using CIELAB (CIE: Commission Internationale de l'Éclairage (International Commission on Illumination); LAB: L*,a*,b*; Hunter and Harold, 1987). Before each use the chroma meter was

calibrated to a white tile with standardized L* a* b* values. The a* b* values, as measured by colorimeter, were converted to hue angle (hue°) and chroma values using SAS (SAS Institute Inc. Cary, NC). Color is three-dimensional and can be more easily understood using L*, chroma and hue° values. L* is a measure of color value or lightness from where black = 0 and white = 100. Chroma is the degree of color from gray (0) to pure color (100). The actual color perceived is the hue°, i.e., red, yellow, green, etc. (McGuire, 1992). At 8 WAT, plants were harvested and shoots were dried at 65.5° C, and dry weights were measured.

Response variables (plant height, plant width, media pH and EC) were measured every two weeks. Measurements taken over time on the same plants are often correlated. Univariate analysis of variance (ANOVA) F tests for effects involving week and interactions with week rely on the Huynh-Feldt (H-F, 1970) condition. The H-F condition requires a certain correlation structure between all pairs of measurements. Sphericity test using the PRINTE option of the REPEATED statement of SAS's GLM Procedure evaluate the H-F condition (Marini et al., 1995). Because all four response variables rejected (P = 0.006, 0.015, <0.001, and <0.001, respectively) the sphericity test, these data were analyzed with a multivariate repeated-measures analysis using the REPEATED statement of SAS's GLM procedure (SAS Institute Inc. Cary, NC). No assumptions about repeated measures covariance structure are required by multivariate analysis (Marini et al., 1995). P values from the multivariate ANOVA (MANOVA) are presented for the main effect of WEEK and all interactions involving WEEK. P values for response variables main effects were obtained with tests of hypotheses for between-subject effects from repeated measures ANOVA.

Results and Discussion

Growth responses. *Tradescantia virginiana* plants treated with four PGRs and two N rates exhibited similar responses in height and width when compared over an 8-week experiment using multivariate analysis of variance (MANOVA) for within-subject effects (Table 4.1). Within subject effects compare change over time (week) for each response variable (height, width, pH, and EC). Between-subject effects are used to test the hypothesis that treatments such as PGR, N rate, PGR x N rate, etc. have no effect on the response variables ignoring within-subject effects.

Nitrogen rate affected plant height. Plants treated with 100 $mg \cdot L^{-1}$ N were smaller (for most treatments) than those treated with 200 $mg \cdot L^{-1}$ N (Table 4.2). The significant PGR x cultivar interaction for plant height was due to the sensitivity of 'Red Cloud'(height more suppressed) to UNI while 'Lilac Frost' appeared to have greatest height suppression with FLU application (Tables 4.1 and 4.2). 'Lilac Frost' increased in height more than 'Red Cloud,' over time, regardless of treatment applied. Height of 'Red Cloud' increased more from week 2 to 4 and week 4 to 6, than 'Angel Eyes' across all treatments for both time periods (Tables 4.2 and 4.3). From week 6 to 8, N rate appeared to have a greater impact on plant height; plants treated with 100 $mg \cdot L^{-1}$ N decreased in height, whereas plants treated with 200 $mg \cdot L^{-1}$ N increased in height. This decrease in plant height was partially due to *Tradescantia* plants' tendency to lodge, after they have reached a certain height, and partially to stem strength. Stem strength of plants fertilized with 200 $mg \cdot L^{-1}$ N may have been greater than those fertilized with 100 $mg \cdot L^{-1}$ N, so instead of lodging they continued to have vertical growth. Melton and Dufault (1991) reported increasing N concentrations increased both tomato (*Lycopersicon esculentum*)

plant height and stem diameter. This increase in height and diameter correlates with our results because as our N rates increased plant height increased, and less lodging was seen. Olsen and Andersen (1995) reported height control of *Osteospermum ecklonis* 'Calypso' after treatment with FLU (45 mg·L^{-1}) and UNI (8 mg·L^{-1}), but PAC at 32 mg·L^{-1} did not suppress plant height to a desirable level. Our results showed no decrease in height after PGR application when plants were compared with the non-treated controls.

Average plant width was affected by a PGR x cultivar interaction (Table 4.1). the widths of cultivars changed differently. 'Lilac Frost' and 'Red Cloud' had similar changes in width from week 2 to 4 for the non-treated control, PAC, and FLU treated plants, but with UNI treatment width of 'Red Cloud' increased less than 'Lilac Frost' plants treated with UNI (Tables 4.3 and 4.4). Width of 'Red Cloud' but not 'Lilac Frost' increased from week 4 to 6. From week 6 to 8 a PGR x N rate x cultivar interaction was found for the change in width. The width of 'Lilac Frost' plants fertilized with 100 mg·L^{-1} N increased more than those fertilized with 200 mg·L^{-1} N for all PGR treatments except UNI and the control. 'Red Cloud' plants fertilized with 200 mg·L^{-1} N increased in width more than those fertilized with 100 mg·L^{-1} N at all treatments except FLU and the control. Thomas et al. (1998) found fertilizing *Freesia* x *hybrida* with increasing N rates increased plant width. Olsen and Andersen (1995) reported decreased plant diameter after FLU (45 mg·L^{-1}), PAC (32 mg·L^{-1}) and UNI (8 mg·L^{-1}) application to *Osteospermum*, but under our conditions and rates, *Tradescantia* plant width was not suppressed.

Media pH and EC. Media pH was affected by N rate and N rate x cultivar over time and with main effects compared with pooled time (Table 4.1). Media pH of both cultivars treated with 100 mg·L^{-1} N was consistently higher than the pH of plants treated

with 200 mg·L^{-1} N (Table 4.5). 'Red Cloud' medium pH for plants fertilized with 200 mg·L^{-1} N decreased over time more than the pH of 'Lilac Frost' plants fertilized with 200 mg·L^{-1} N. Media pH for both cultivars fertilized at 100 mg·L^{-1} N was similar (Table 4.5). The only significant *P*-values from the profile analysis for media pH was between week 4 and 6 when 'Lilac Frost' pH changed very little and 'Red Cloud' pH decreased at all but two treatment levels (Tables 4.5 and 4.6). James and van Iersel (2001) found an average one point linear decrease in media pH over their 7 week experiment examining ebb and flood production of *Petunia* x *hybrida* and *Begonia* x *semperflorens-cultorum*. We found the media pH of *Tradescantia* plants fertilized with 100 mg·L^{-1} N remained constant over our 8-week experiment. Media pH of plants fertilized with 200 mg·L^{-1} N depended on cultivar. 'Lilac Frost' media pH stayed in a consistent range, while media pH of 'Red Cloud' decreased a quarter of a point over 8 weeks.

Media EC was affected by both N rate and cultivar over the experiment (Table 4.1). The change in media EC due to N rate and cultivar occurred between week 2 and 4 and week 4 and 6 (Table 4.7). Electrical conductivity for plants fertilized with 200 mg·L^{-1} N tended to increase while those fertilized with 100 mg·L^{-1} N declined (Tables 4.6 and 4.7). Media EC values of 'Red Cloud' plants fertilized with 200 mg·L^{-1} N were consistently higher than the EC values of 'Lilac Frost' plants fertilized with 200 mg·L^{-1} N. The N rate x cultivar interaction from week 2 to 4 was the result of EC values for 'Lilac Frost' decreasing from week 2 to 4 regardless of N rate applied; while, EC values of 'Red Cloud' increased for plants fertilized with 200 mg·L^{-1} N and decreased for those plants fertilized with 100 mg·L^{-1} N (Tables 4.6 and 4.7).

Plants fertilized with 200 mg·L^{-1} N had lower pH and higher EC values than those plants fertilized with 100 mg·L^{-1} N. Whipker et al. (1999) examined cultivar differences in response to N rate; they found 'Blackberry Ice' a variegated cultivar of double impatiens (*Impatiens walleriana*) required less N fertilizer than 'Purple Magic,' a green-leaved double impatiens cultivar. They also noted that 'Blackberry Ice' had higher EC values than 'Purple Magic' after fertilization with 200 mg·L^{-1} N. We found similar trends with our *Tradescantia* cultivars, but the EC difference after fertilization with 200 mg·L^{-1} N can be attributed to shoot number and foliage width. 'Red Cloud' had higher EC values, when fertilized with 200 mg·L^{-1} N, than 'Lilac Frost.' 'Red Cloud' had fewer shoots and thinner foliage than 'Lilac Frost;' these physical characteristics possibly impacted the amount of soluble salts 'Red Cloud' was able to take up.

Color responses. Hue° and chroma were affected by cultivar, and there was a significant cultivar x PGR interaction (Table 4.8). For both cultivars and most treatments, hue° increased over time (plants became slightly greener, Table 4.9). Only non-treated 'Lilac Frost' plants fertilized with 100 mg·L^{-1} N and 'Red Cloud' plants treated with FLU and fertilized at 100 mg·L^{-1} N had a decrease in hue° over time (became more yellow). Hue° of both cultivars after treatment with PAC increased slightly (plants greener), when compared with non-treated controls. 'Lilac Frost' treated with UNI at both fertilization levels had higher hue° values than non-treated controls, while hue° of FLU treated plants were similar to those of the control plants. Hue° of 'Red Cloud' plants were similar across all treatments, and non-treated controls had the slightly lower hue° (were more yellow).

Landschoot and Mancino (2000) measured color differences between two bentgrass species (*Agrostis stolonifera* and *A. capillaries*), and found that measuring the hue° of these species was the most effective way to differentiate between the two. The two cultivars of *Tradescantia* we examined differed in hue°, and it would be possible to distinguish between cultivars by looking at their hue°. 'Lilac Frost' foliage was darker green and more dull in coloration than 'Red Cloud' foliage, which had more yellowish coloration. 'Lilac Frost' foliage did become darker green (higher hue°) as a result of PGR application, but 'Red Cloud' foliage color was not affected by PGR. Adams et al. (1998) found that poinsettia (*Euphorbia pulcherrima*) hue° increased with increasing N rates. We did not find that to be true of the plants in our experiment, we found no difference in hue° with N rate applied.

Chroma (brilliance or dullness of a certain hue°) differed significantly between cultivars and a cultivar x PGR interaction occurred (Table 4.8). Chroma of both cultivars decreased over time (Table 4.10). The chroma of 'Red Cloud' was consistently higher than that of 'Lilac Frost.' Adams et al. (1998) found that poinsettia chroma decreased with increasing N fertilization rates. Chroma of our *Tradescantia* plants did not decrease consistently with increasing N rates or PGR treatments, no trend in chroma could be established looking only at N rate.

Dry weight and plant quality. Plant shoot dry weight was influenced significantly by cultivar and by N rate at a P =0.063, but not by PGR (Table 4.11). 'Lilac Frost' had consistently higher shoot dry weights than 'Red Cloud' and plants fertilized with 100 $mg \cdot L^{-1}$ (ppm) N had consistently lower dry weights than those plants fertilized with 200 $mg \cdot L^{-1}$ (ppm) N (Table 4.12). Quality was not affected an experimental factors (Table

4.11). Quality ratings were similar between N rates and cultivars (Table 4.12). 'Lilac Frost' was the larger than 'Red Cloud.' Quality of plants was not affected by treatment. PGR application did not improve marketability of plants in comparison with non-treated controls.

Summary. Due to results of the White (2003) experiment, we expected the PGR rates chosen in this experiment to result in adequate height suppression. Unfortunately, no height suppression was detected when plants were treated with PGRs. The lack of height suppression could possibly be due to slower plant growth rate during the late summer season when these PGRs were applied. The White (2003) PGR experiment occurred over a spring growing season when *Tradescantia* plants were growing quickly. The nutrition rates we applied did not affect plant quality. *Tradescantia* cultivars can be fertilized with 100 $mg \cdot L^{-1}$ (ppm) N and marketable plants will be produced.

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Table 4.1. Sources of variation an *P*-values from analysis of variance for effect of four plant growth regulators (PGR) and two nitrogen (N) rates on height, width, media pH, and media electrical conductivity (EC) of *Tradescantia virginiana* over an 8 week experiment. LF= 'Lilac Frost' and RC= 'Red Cloud'.

Source	DF	Response variables			
		Height (cm)	Width (cm)	pH	EC ($mS \cdot cm^{-1}$)
Week[z]	3	<0.001	<0.001	0.121	<0.001
PGR[y]	3	0.073	0.859	0.335	0.398
N rate[y]	1	0.035	0.412	<0.001	<0.001
Cultivar [y]	1	0.668	0.354	0.494	0.002
PGR x N rate[y]	3	0.858	0.808	0.855	0.832
PGR x cultivar[y]	3	0.027	0.010	0.940	0.532
N rate x cultivar[y]	1	0.096	0.461	0.016	0.004
PGR x N rate x cultivar[y]	3	0.582	0.494	0.546	0.785
Week x PGR[z]	9	0.267	0.119	0.386	0.849
Week x N rate[z]	3	0.157	0.637	0.079	<0.001
Week x cultivar[z]	3	0.038	<0.001	0.006	<0.001
Week x PGR x N rate[z]	2	0.413	0.242	0.912	0.718
Week x PGR x cultivar[z]	2	0.589	0.01	0.755	0.461
Week x N rate x cultivar[z]	2	0.651	0.887	0.031	0.081
Week x PGR x N rate x cultivar[z]	2	0.321	0.060	0.463	0.878

[z] Results from MANOVA tests of hypothesis for within-subject (measurement taken repeatedly on each plant) effects.

[y] Tests the hypothesis that treatments (between-subjects effects) have no effect on the response variables, ignoring within-subject effects. This is the treatment effect when averaged over all weeks.

Table 4.2. Effect of plant growth regulator (PGR) and nitrogen (N) rate on plant height of two *Tradescantia virginiana* cultivars.

			Plant height (cm)			
		N rate	Weeks after treatment			
Cultivar	PGR	($mg \cdot L^{-1}$)	2	4	6	8
'Lilac Frost'	Control	100	16.0[z]	16.7	17.8	18.5
		200	15.4	15.6	16.1	16.6
	Paclobutrazol	100	12.9	14.9	17.0	16.9
		200	14.2	15.9	16.6	18.0
	Uniconazole	100	13.5	15.8	16.3	15.8
		200	14.8	17.5	17.5	18.2
	Flurprimidol	100	13.1	14.7	16.1	14.9
		200	15.0	15.0	13.9	14.7
'Red Cloud'	Control	100	14.4	14.1	14.7	14.9
		200	16.4	17.0	17.2	17.1
	Paclobutrazol	100	15.2	15.2	18.1	15.6
		200	16.4	16.7	19.3	20.5
	Uniconazole	100	11.4	11.6	15.1	13.4
		200	12.0	12.2	15.6	16.0
	Flurprimidol	100	15.3	15.3	13.3	14.8
		200	15.4	17.4	17.7	16.2

[z]Values are means of 5 replicates for each treatment.

Table 4.3. *P* values from profile analysis of *Tradescantia virginiana* plant height and width. These multivariate analyses of variance are for the transformed variables representing the differences between adjacent weeks.

	Height (cm)			Width (cm)		
	Week			Week		
Source	2 – 4	4 – 6	6 – 8	2 – 4	4 – 6	6 – 8
Mean[z]	0.079	<0.001	0.712	<0.001	0.002	0.857
PGR[y]	0.586	0.153	0.707	0.404	0.031	0.843
N rate[y]	0.969	0.152	0.034	0.436	0.358	0.821
Cultivar[y]	0.013	0.045	0.117	0.002	0.007	0.273
PGR x N rate[y]	0.524	0.807	0.122	0.312	0.677	0.047
PGR x cultivar[y]	0.367	0.211	0.913	0.004	0.564	0.269
N rate x cultivar[y]	0.419	0.537	0.833	0.994	0.422	0.759
PGR x N rate x cultivar[y]	0.168	0.986	0.144	0.753	0.122	0.019

[z] *P* value for change in the response variables for adjacent weeks pooled over all treatments.

[y] *P* values for the main effects and interactions on the change in plant width between adjacent weeks.

Table 4.4. Effect of plant growth regulator (PGR) and nitrogen (N) rate on plant width of two *Tradescantia virginiana* cultivars.

			Plant width (cm)			
		N rate	Weeks after treatment			
Cultivar	PGR	($mg \cdot L^{-1}$)	2	4	6	8
'Lilac Frost'	Control	100	34.7[z]	43.2	43.3	42.9
		200	31.9	40.8	40.5	40.7
	Paclobutrazol	100	28.1	37.4	38.8	40.1
		200	29.6	38.4	39.8	39.0
	Uniconazole	100	33.1	43.2	43.1	41.0
		200	32.7	46.0	47.2	46.8
	Flurprimidol	100	29.2	39.1	39.7	39.7
		200	29.5	39.4	38.7	37.0
'Red Cloud'	Control	100	31.0	35.9	36.2	39.0
		200	31.9	41.0	42.2	39.0
	Paclobutrazol	100	27.9	38.1	44.1	41.4
		200	33.9	41.9	45.7	47.8
	Uniconazole	100	32.4	32.6	38.0	38.4
		200	31.5	34.5	34.8	38.6
	Flurprimidol	100	32.3	39.1	39.7	40.5
		200	33.4	38.5	40.5	39.3

[z]Values are means of 5 replicates for each treatment.

Table 4.5. Effect of plant growth regulator (PGR) and nitrogen (N) rate on media pH of two *Tradescantia virginiana* cultivars.

		pH			
		Weeks after treatment			
Cultivar	N rate ($mg \cdot L^{-1}$)	2	4	6	8
'Lilac Frost'	100	5.42[z]	5.42	5.47	5.45
	200	5.23	5.06	5.26	5.41
'Red Cloud'	100	5.45	5.53	5.48	5.55
	200	5.26	5.16	5.06	5.00

[z]Values are means of 5 replicates for each treatment.

Table 4.6. *P* values from profile analysis of *Tradescantia virginiana* media pH and electrical conductivity (EC). These analyses of variance are for the transformed variables representing the differences between adjacent weeks.

	pH			EC ($mS \cdot cm^{-1}$)		
	Week			Week		
Source	2 – 4	4 – 6	6 – 8	2 – 4	4 – 6	6 – 8
Mean[z]	0.268	0.867	0.059	0.003	<0.001	0.962
PGR[y]	0.455	0.107	0.502	0.753	0.470	0.864
N rate[y]	0.150	0.830	0.273	<0.001	0.046	0.099
Cultivar[y]	0.562	0.029	1.00	0.003	<0.001	0.668
PGR x N rate[y]	0.752	0.665	0.774	0.169	0.869	0.826
PGR x cultivar[y]	0.854	0.755	0.187	0.855	0.107	0.721
N rate x cultivar[y]	0.885	0.226	0.166	0.039	0.293	0.076
PGR x N rate x cultivar[y]	0.455	0.155	0.271	0.551	0.904	0.636

[z] *P* value for change in the response variables for adjacent weeks pooled over all treatments.

y P values for the main effects and interactions on the change in plant width between adjacent weeks.

Table 4.7. Effect of plant growth regulator (PGR) and nitrogen (N) rate on media electrical conductivity (EC) of two *Tradescantia virginiana* cultivars.

		EC ($mS \cdot cm^{-1}$)			
		Weeks after treatment			
Cultivar	N rate ($mg \cdot L^{-1}$)	2	4	6	8
'Lilac Frost'	100	1.38[z]	1.03	1.12	1.60
	200	2.10	2.06	2.24	1.88
'Red Cloud'	100	1.24	0.953	1.40	1.33
	200	2.15	2.44	3.16	3.12

[z]Values are means of 5 replicates for each treatment.

Table 4.8. Sources of variation an *P*-values from analysis of variance for effect of four plant growth regulators (PGR) and two nitrogen (N) rates on hue° and chroma of *Tradescantia virginiana* over an 8 week experiment. LF= 'Lilac Frost' and RC= 'Red Cloud'.

		Response Variables	
Source	DF	Hue°	Chroma
Week[z]	1	0.003	<0.001
PGR[y]	3	0.209	0.352
N rate[y]	1	0.984	0.746
Cultivar[y]	1	<0.001	<0.001
PGR x N rate[y]	3	0.505	0.544
PGR x cultivar[y]	3	0.007	0.009
N rate x cultivar[y]	1	0.985	0.969
PGR x N rate x cultivar[y]	3	0.715	0.303
Week x PGR[z]	3	0.357	0.545
Week x N rate[z]	1	0.757	0.836
Week x cultivar[z]	1	0.600	0.085
Week x PGR x N rate[z]	1	0.994	0.912
Week x PGR x cultivar[z]	3	0.654	0.842
Week x N rate x cultivar[z]	1	0.661	0.751
Week x PGR x N rate x cultivar[z]	3	0.146	0.213

[z] Results from MANOVA tests of hypothesis for within-subject (measurement taken repeatedly on each plant) effects.

[y] Tests the hypothesis that treatments (between-subjects effects) have no effect on the response variables, ignoring within-subject effects. This is the treatment effect when averaged over all weeks.

Table 4.9. Hue° of *Tradescantia virginiana* cultivars treated with four plant growth regulators (PGR) and two nitrogen (N) levels.

Cultivar	PGR	N Rate	Hue°	
		($mg \cdot L^{-1}$)	Week 4	Week 8
'Lilac Frost'	Control	100	124 [z]	124
		200	123	124
	Paclobutrazol	100	124	126
		200	124	128
	Uniconazole	100	124	126
		200	123	124
	Flurprimidol	100	120	125
		200	122	124
'Red Cloud'	Control	100	119	122
		200	119	119
	Paclobutrazol	100	118	123
		200	120	121
	Uniconazole	100	120	122
		200	121	122
	Flurprimidol	100	122	121
		200	121	123

[z]Values are means of 5 replicates for each treatment.

Table 4.10. Chroma of *Tradescantia virginiana* cultivars treated with four plant growth regulators (PGR) x two nitrogen levels (15-0-15).

Cultivar	PGR	N Rate	Chroma	
		($mg \cdot L^{-1}$)	Week 4	Week 8
'Lilac Frost'	Control	100	25.2[z]	21.1
		200	27.3	23.9
	Paclobutrazol	100	25.6	23.0
		200	24.6	20.0
	Uniconazole	100	25.7	24.5
		200	26.2	26.0
	Flurprimidol	100	26.7	23.6
		200	24.6	24.2
'Lilac Frost'	Control	100	33.3	27.9
		200	33.3	28.3
	Paclobutrazol	100	33.7	27.4
		200	33.2	31.0
	Uniconazole	100	31.5	27.5
		200	31.7	27.5
	Flurprimidol	100	29.2	27.5
		200	30.6	24.0

[z]Values are means of 5 replicates for each treatment.

Table 4.11. Sources of variation and P-values from analysis of variance for effect on dry weight and plant quality[z] of *Tradescantia virginiana* after treatment with four plant growth regulators (PGR) x two nitrogen (N) rates at end of 8 week experiment.

	Response variables	
Source	Dry weight (g)	Quality
PGR	0.584	0.817
N rate	0.063	0.112
PGR x N rate	0.833	0.625
Cultivar	0.002	0.337
PGR x cultivar	0.676	0.817
N rate x cultivar	0.244	0.748
PGR x N rate x cultivar	0.525	0.464

Table 4.12. Dry weight (g) and quality[z] of *Tradescantia virginiana* cultivars treated with four plant growth regulators (PGR) x two nitrogen levels (15-0-15) over an 8 week experiment.

Cultivar	N Rate ($mg \cdot L^{-1}$)	Dry Weight (g)	Quality
'Lilac Frost'	100	14.5[y]	3.55
	200	17.4	3.35
'Red Cloud'	100	12.5	3.75
	200	13.2	3.45

[z] Quality measurements were based on a scale of 1 to 4, 1= a plant that is dead or near death and 4= a plant that is healthy and actively growing.

[y]Values are means of 5 replicates for each treatment.

VITA

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Education

2001 - 2003 Virginia Tech Blacksburg, VA
M.S. in Horticultural Science

- 2003 Graduate Summa Cum Laude
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1998 – 2000 Clemson University Clemson, SC
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- 2001 American Society for Horticultural Science (ASHS) Clemson University Horticulture Student of the year.
- 2000 Graduated Summa Cum Laude
- 1999 2nd place Bryson L. James Student Research Competition at SNA conference.

1996 - 1998 Lee University Cleveland, TN

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Mathematics: 620 Verbal: 620 Analytical: 620

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2001 - 2003 Horticulture Department, Virginia Tech Blacksburg, VA
Teaching and Research Assistant

- Teaching duties: class administration, lecture, lab, grade assignment.
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- Two seminars "Irrigation: water quality and strategy" and "Growth regulation of greenhouse crops" at 2002 Basic Greenhouse Production Seminar.

2000 - 2001 Horticulture Department, Clemson Univ. Clemson, SC
Landscape Design Teaching Assistant

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Publications

Scoggins, H. and S. White. 2003. Plant nutrition: in Greenhouse Operator's Certification Manual.

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