SECTION 1

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STUDENT COMPETITION

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Herbicides Influence Bedding Plant Growth

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Nature of work: One concern with the use of preemergence herbicides in annual crops is growth suppression. Many of the preemergence herbicides registered for ornamental crops, such as Surflan,Barricade, Southern Weedgrass Control, Pendulum, Rout, and OH©2, have dinitroanaline herbicides as a component. Numerous crops form stubby and thickened primary roots devoid of secondary roots when treated with dinitroanaline herbicides (1). While growth of woody plants is generally not affected by these herbicides, limited information is available on the influence of these herbicides on bedding plant growth. Therefore, it is necessary to compare several formulations of these dinitroanalines to several other commonly used preemergence herbicides in various formulations.

Uniform plugs of Salvia splendens 'Hot Stuff' were potted into 2 quart containers on April 29, 1993. Containers were modified to view root growth by cutting out a 3 in. x 3 in. section, covering the section with acetate, and securing the piece of container back over the acetate. Modified containers were placed window down on a tilted rack. The growing medium was a 6 pine bark:1 sand (v:v) amended with 12 lb Osmocote 14©14©14, 1.5 lb Micromax , and 5 lb of 'dolomitic limestone/ yd^3. Treatments applied on May 3, 1993 were: Surflan 4AS, Barricade 65WDG, Southern Weedgrass Control 2.68G, and Pendulum 60WDG at 3 lb ai/A; Pennant 5G, Pennant 7.8E , Ronstar 2G, and Ronstar 50WP at 4 lb ai/A; and a nontreated control. Liquid herbicides were applied at 20 gpa with a continuous pressure of 40 psi supplied by a CO_2 backpack sprayer. Granular herbicides were applied with a hand held shaker. Each treatment consisted of 10 single plant replicates.

Number of actively growing root tips and foliar phytotoxicity ratings were taken weekly. Root ratings based on outer root ball coverage(1=0©20%, 2=21©40%, 3=41©60%, 4=61©80%, and 5=81©100%) and root dry weights, which included only roots extending beyond the initial cell volume, were determined at termination, 52 days after treatment (DAT). Growth indices ((height + width1 + width2)/3) and shoot dry weights were also taken at termination.

Results and Discussion: Root activity of salvia was generally greatest for the control, SWGC 2.68G, Ronstar 2G, and Pendulum 60WDG treated plants (Fig. 1). For example, 7 DAT Barricade 65WDG, Surflan 4AS, Pennant 5G, and Ronstar 50WP treated plants had 75%, 85%, 94%, and 100% fewer actively growing roots respectively than the control plants. A similar trend occurred at 14 DAT. At 21 DAT, control and SWGC 2.68G treated plants had more actively growing root tips than all other herbicides except Ronstar 2G, which was similar to SWGC 2.68G. At 28 DAT data were similar.

No living roots were detectable for Surflan 4AS, Barricade 65WDG, Pennant 7.8E, or Ronstar 50WP treated plants as plants were removed from containers at termination. Plants treated with Ronstar 2G and SWGC 2.68G had root ratings of 3.5 and 3.3, which were similar to those of control plants (3.5). Pennant 5G root ratings were 49% (1.7) less than the controls. Root dry weights for SWGC 2.68G and Ronstar 2G plants were statistically similar when compared to the control (2.6 g). Root dry weights of plants treated with Pennant 5G or Pendulum 60WDG were 1.7 g or 0.5 g respectively, 48% and 81% less than nontreated plants. Growth indices of ‘Hot Stuff’ salvia were not reduced when SWGC 2.68G, Pennant 5G, or Ronstar 2G was applied compared to the control plants. Pendulum 60WDG caused a 74% suppression in growth indices compared to the controls. Shoot dry weights were similar for SWGC 2.68G and Ronstar 2G when compared to nontreated plants.
Application of Pennant 5G resulted in a shoot dry weight of 11.8 g, while Pendulum 60WDG plants had a shoot dry weight of 3.1 g.

Foliar phytotoxicity resulted when plants were treated with flowable formulations; Surflan 4AS, Barricade 65WDG, Pennant 7.8E, or Ronstar 50WP. This injury steadily progressed causing death of all plants treated. Generally, no significant foliar injury occurred when SWGC 2.68G, Pennant 5G, and Ronstar 2G was applied. The only other significant injury occurred with Pendulum 60WDG.
Phytotoxicity ratings increased from 12% (3 DAT) to 85% (52 DAT) for Pendulum 60WDG treated plants.

Significance to Industry: Data collected indicates that SWGC 2.68Gis the safest dinitroanaline herbicide tested for use on ‘Hot Stuff’ salvia. It caused no suppression in root growth compared to the control. Generally, flowable dinitroanaline herbicides (Surflan 4AS, Barricade 65WDG, Pendulum 60WDG) as well as Pennant 7.8E and Ronstar 50WP resulted in plant mortality. Pennant 5G and Ronstar 2G caused limited suppression of root growth, however growth indices were similar and no significant foliar phytotoxicity occurred. Results show that flowable formulations of dinitroanalines and nondinitroanaline herbicides suppress plant growth. This data indicates that formulation should be a major consideration when selecting preemergence applied herbicides for bedding plant use.

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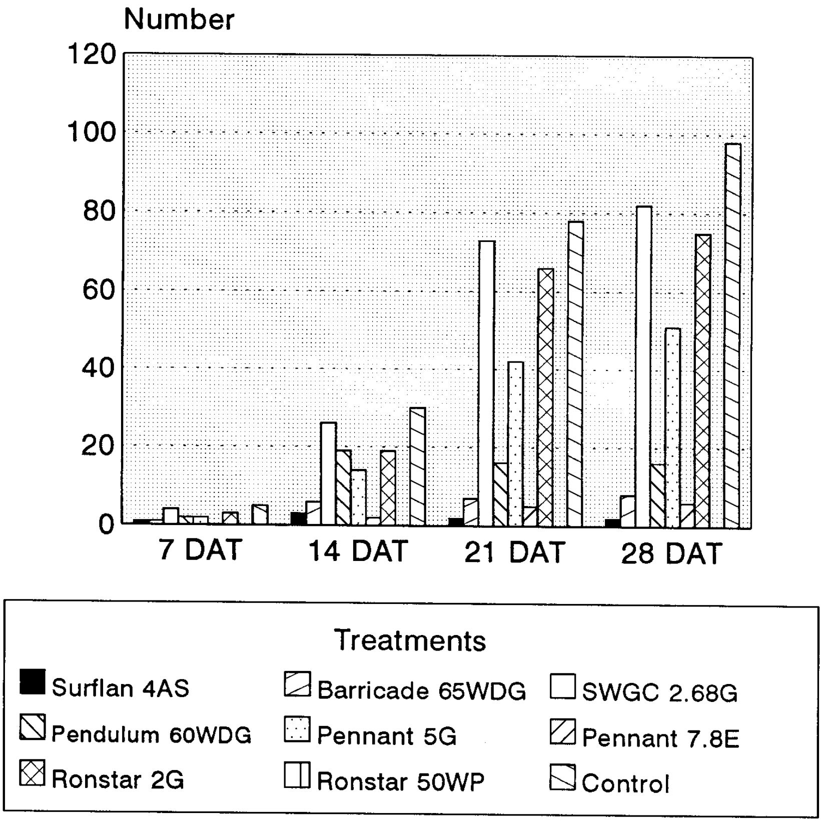
Fig. 1

Actively growing root tips for 'Hot Stuff salvia.



Duncan's Multiple Range Test, $P<0.05$:
7DAT(de,de,ab,cd,cd,e,bc,e,a), 14DAT(cd,cd,a,ab,bc,cd,ab,d,a)
21DAT(e,de,ab,d,c,de,b,e,a), 28DAT(e,de,b,d,c,de,b,e,a)

Initial Seedling Growth of Two Provenances of *Rhododendron catawbiense* in Response to Day/Night Temperature

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Nature of Work: *Rhododendron catawbiense* Michx. (catawba rhododendron) is indigenous to the mountains of West Virginia and Virginia, extending south to North Carolina, Georgia and Alabama. It is a highly prized landscape plant and has been used as a parent in many crosses (controlled pollinations) to provide cold hardy cultivars for the northeastern United States (4). The majority of species plants sold for landscape usage are harvested from native populations (1). Problems with this practice include depletion of native stands, an insufficient supply of native plants to meet demand, and resultant poor quality plants. Other methods of production, such as sexual propagation, have not been as widely utilized due in part to the lack of information.

Rhododendron catawbiense exhibits moderate heat tolerance (3); however, its southern range is limited (2). An isolated provenance of *R. catawbiense* occurs at a low elevation of 67 m (220 ft) in central North Carolina. Due to the location, it is suspected that the heat tolerance of this isolated provenance may be greater than provenances located in the mountainous regions [>1500 m (>4920 ft)]. If the low elevation population exhibits increased heat tolerance, the possibility then exists to expand the landscape range of *R. catawbiense* to warmer regions of the southeastern United States. Therefore, the objective of this study was to examine the effects of selected day/night temperatures on initial seedling growth of two provenances of *R. catawbiense;* one occurring at a high elevation in western North Carolina and the other growing in the Piedmont at a much lower elevation.

Seedlings of two provenances of *R. catawbiense* were propagated from seed collected from open-pollinated plants. One provenance was located in Yancey County, N.C., [1954 m (6410 ft)] (lat. 35°45'N, long. 82°16'W) and the second in Johnston County, N.C., [67 m (220 ft)] (lat. 3545'N, long. 78°12'W)]. After 22 months growth in a greenhouse, seedlings were transferred to the Southeastern Plant Environmental Laboratory (Phytotron) and placed in growth chambers. The study was a 4 x 4 factorial in a completely random design using nine single plant replications per provenance per temperature treatment. The two main factors were day temperatures of 18°, 22°, 26°, or 30°C (64°, 72°, 79°, or 86°F) in factorial combination with nights of 14°, 18°, 22°, or 26°C (57°, 64°, 72°, or 79°F).

After 18 weeks, the study was terminated and the plants were separated into leaves, stems, and roots which were dried at 70°C (1 58°F) for 72 hrs. Before drying, leaf area was measured with a LI-COR LI-3100 leaf area meter (LI-COR, Lincoln, Neb.). Dry weight data were utilized to calculate top dry weight (sum of leaf and stem dry weight) and root: top ratio (root dry weight: top dry weight). Data were subjected to general linear modeling procedures and regression analysis.

Results and Discussion: Seedling dry weight of the Yancey County provenance (high elevation) was significantly ($p < 0.05$) greater at all temperature combinations compared to seedling dry weight of the Johnston County (low elevation) provenance (data not presented). Thus, it appears that the Johnston County provenance does not possess greater heat tolerance than the Yancey County provenance. There were no significant interactions with provenances; therefore, data were averaged over both provenances and reanalyzed as above.

Leaf area (data not presented) and top dry weight (Fig. 1 A) were influenced similarly by day and night temperature and both increased quadratically with increasing day and night temperature. These data agree with findings of Malek (5) who reported that in the vegetative stage, dry matter production was strongly associated with leaf area development. During initial seedling growth, greatest top dry weight occurred at 22°/22°C (72°/72°F) and 26°/18°C (79°/64°F), which correlated with high leaf area ($r \geq 0.72$, $p \leq 0.001$) (data not presented) . Days of 1 8°C (64°F) in combination with nights of 14° and 1 8°C (57° and 64,F) and the day/night combination of 30°/14°C (86°/57°F) resulted in reduced top dry weight. There was no evidence that alternating temperature enhanced growth.

Root growth was more sensitive to day temperature than other growth parameters as root dry weight decreased linearly with increasing day temperature (Fig. 1 B). Optimal root growth occurred at 18°/1 8°C (64°/64°F) and 18°/1 4°C (64°/57°F) (data not presented). Root: top ratio decreased with increasing day temperature (data not presented). Day temperature as indicated by the root: top ratio, influenced carbohydrate allocation between the top and roots more than night temperature. As day temperature increased, the percentage of leaf dry matter increased at the expense of root dry matter (data not presented). Thus, continued exposure to high day temperatures could eventually lower seedling quality due to reduced root growth. Although temperature optima varied for particular growth parameters of *R. catawbiense,* day/night temperatures of 22°/22°C (72°172°F) to 26°/22°C (79°/72°F) would produce high quality plants.

Significance to the Nursery Industry: Surprisingly, the Johnston County provenance (low elevation) of *R. catawbiense* did not possess greater heat tolerance compared to the Yancey County provenance (high elevation). Thus, the possibility of using the former provenance to expand the landscape range of the species to the warmer regions of the southeast does not appear to exist. This research also determined that optimum growth of seedlings can be achieved utilizing day/night temperature regimes of 22°/22°C (72°C/72°F) to 26°/22°C (79°/72°F).

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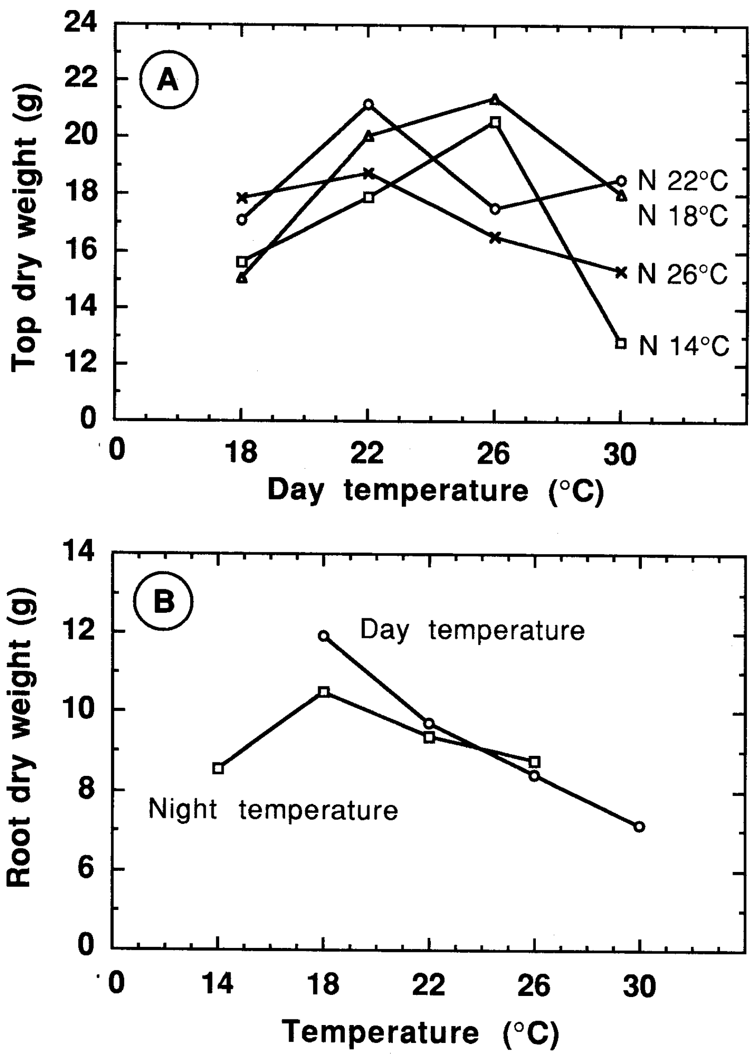

Fig. 1. Effects of day and night (N) temperature on initial seedling growth of *Rhododendron catawbiense:* (A) top dry weight and (B) root dry weight. Data are averaged over both provenances. In *A* each symbol is a mean of nine observations. In B [effects of day temperature (averaged over all night temperatures) and night temperature (averaged over day temperatures)] each symbol represents a mean of 36 observations.

Effects of Uniconazole on Photosynthesis, Dark Respiration, and Water Use Efficiency of 'Spectabilis' Forsythia

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Nature of Work: Previous investigations have reported increased levels of photosynthesis (PN) for 'Spectabilis' forsythia treated with the plant growth regulator uniconazole (Valent U.S.A. Corporation, Walnut Creek, Calif.) (Thetford et al., 1992). Decreased plant size also occurs as a result of uniconazole inhibiting gibberellin biosynthesis (Warren et al., 1991). This paradox between suppressed plant size and increased levels of PN for uniconazole treated plants remains to be resolved.

Morphological changes in uniconazole treated plants can reduce water use as a result of altered canopy size, leaf area reduction or altered stomatal development (Gao et al., 1988, Hsiao and Acevedo, 1974). Water use efficiency (WUE), a physiological characteristic often used to assess a plants ability to withstand water stress, may be a useful tool for determining the effects of uniconazole application on water use of woody plants. The following experiment was initiated to: 1) investigate the effects of uniconazole on carbon efficiency of 'Spectabilis' forsythia via PN and dark respiration and 2) determine if uniconazole induced changes in plant morphology influence water use or water use efficiency of 'Spectabilis' forsythia.

A greenhouse experiment was conducted at North Carolina State University in which rooted stem cuttings of 'Spectabilis' forsythia were potted into 4-liter (#1) black plastic containers (7 July 1992) filled with a calcined clay substrate (Turface). Prior to uniconazole application container tops were covered with white polyethylene to minimize evaporative water losses. Treatments were a single foliar application of uniconazole (12/15 ml per plant of a 170 ppm solution) or a nontreated control (water) applied on 4 August, with ten plants per treatment in a randomized complete block design. Water loss by transpiration was obtained by weighing containers daily.

Net photosynthesis (PN) was determined as previously described (Thetford et al., 1992). P_N measurements were conducted between 10:00 and 12:00 AM (morning) and repeated between 1:00 and 3:00 PM (afternoon) 47 and 53 DAT. Leaf dark respiration was measured similarly with measurements commencing 1 min. immediately after the CO_2 concentration increased. Leaf dark respiration was measured between 10:00 PM and 2:00 AM 47 and 53 DAT. At termination of the experiment, plants were separated into leaves, stems, and roots and dried at

70°C (158°F) for 96 h. Before drying, total leaf area was determined using a LI-COR 3000 leaf area meter (LI-COR, Lincoln, Neb.). WUE was determined on the basis of total plant dry weight (WUE = total plant dry weight / water loss by transpiration). Differences among treatments ($P \leq 0.1$) were determined (within sample dates where appropriate) using analysis of variance procedures (SAS Institute, Inc., Cary, N.C.).

Results and Discussion: Uniconazole suppressed leaf area 36%. Leaf area suppression creates the concentrating effects that may contribute to the elevated carbon exchange rates of uniconazole treated plants (Dalziel and Lawrence, 1984). The sample date (47, 53 DAT) by treatment (uniconazole, control) and time of measurement (morning, afternoon) by treatment interactions were nonsignificant for P_N indicating a similar treatment effect for all sample times. P_N averaged across both sample dates and both sample times was elevated for uniconazole treated plants (Table 1). A similar increase in P_N for uniconazole treated 'Spectabilis' forsythia was previously reported (Thetford et al., 1992).

The sample date by treatment interaction was nonsignificant for leaf dark respiration indicating a similar response to treatments for both measurement dates. Leaf dark respiration averaged across both sample dates increased 19% for uniconazole treated plants (Table 1). High levels of P_N for uniconazole treated plants were consistently followed by high levels of leaf dark respiration. These responses suggest the concentrating effects of uniconazole induced leaf area suppression which compress the photosynthetic apparatus of treated plants also concentrate the respiratory functions resulting in higher levels of photosynthesis and respiration.

By 53 DAT uniconazole decreased total water use of 'Spectabilis' forsythia 59%. Changes in WUE appear related to changes in total leaf area. A 4% increase in WUE of uniconazole treated plants indicates improved efficiency as dry weight accumulation was increased per kg of water transpired.

Significance to Industry: Results herein demonstrate how uniconazole induced leaf area reduction can influence P_N, leaf dark respiration and total water use of woody landscape plants. Water use efficiency of uniconazole treated plants was improved by 4% for plants having a 36% reduction in leaf area. This suggests altered levels of water use for uniconazole treated plants result primarily from altered canopy size and leaf area and are not necessarily related to an alteration in the efficiency by which carbon is assimilated.

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Table 1. Net photosynthesis and leaf dark respiration of ‘Spectabilis’ forsythia following application of uniconazole.[z]

Uniconazole (ppm)	Net photosynthesis	Leaf dark respiration
0	15.5	1.04
170	21.5	1.24
Significance	0.0001	0.04

[z]Net photosynthesis and respiration units = mg CO_2/dm^2 /sec.

Effects of Growth Stage, Branch Position and IBA Concentration on Rooting Stem Cuttings of 'Yoshino' Cryptomeria

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Nature of Work: Japanese cedar, *(Cryptomeria japonica* (L. f.) D. Don), an evergreen, is a widely used timber species in the Orient. It is also considered a sacred tree in Japan with great landscape value (1). Japanese cedar is gaining popularity not only in the northeastern United States, but also in the hot and humid southeast. The species prefers a rich, deep, acidic, moist soil but will tolerate heavy clay both during dry and wet periods (2, 7).

There are many cultivars of Japanese cedar that have a wide range of ornamental characteristics and uses. One popular cultivar is 'Yoshino'. It has a conical form reaching a height of 15-18 m, (50-60 ft) with drooping branches. 'Yoshino' has no major insect or disease problems (2, 7), has a fast growth rate and makes an excellent evergreen screen. It is currently being recommended as a replacement for Leyland cypress, (*X Cupressocyparis leylandii* (A. B. Jacks and Dallim.) Dallim. and A. B. Jacks).

Current recommendations for vegetative propagation of 'Yoshino' *Cryptomeria* by stem cuttings are conflicting (2, 3, 4, 5, 6). Therefore, the objectives of this study were to investigate the effects of growth stage, branch position, and IBA treatment on rooting stem cuttings of 'Yoshino' *Cryptomeria.*

The experiment, a randomized complete block design with a 4 x 4 factorial arrangement of treatments was replicated six times with a replication of five cuttings. The main factors were four concentrations (0, 3000, 6000, 9000 ppm) of 1 H-indole-3-butyric acid (IBA) in 50% isopropanol and four branch positions: [(A) tips (terminal 20 cm (7.8 in) of second-order laterals, (B) distal ends (terminal 10 cm (4 in) of second-order laterals, (C) proximal ends (basal 10 cm) of tips of second-order laterals or (D) tips (terminal 10 cm) of third-order laterals].

Forty terminal cuttings were taken from each of six, 10-year-old trees growing in the N. C. State University Arboretum, Raleigh, NC on four dates, each date representing a different growth stage: Aug. 7,1992 (softwood); Nov. 6,1992 (semi-hardwood); Jan. 15,1993 (hardwood); and Mar. 12,1993 (pre-budbreak). Budbreak occurred about April 12,

1993. Cuttings were collected throughout the entire crown of a tree. During preparation of cuttings for auxin treatment, lower branches, not needles, were stripped from the basal 4 cm (1.6 in) of each cutting.

Auxin treatments were applied by immersing the basal 1 cm (.4 in) of a cutting into an IBA solution for 1 sec and allowed to air dry for 15 min. Following auxin application, cuttings were inserted to a depth of 4 cm (1.6 in) in a raised greenhouse bench containing a medium of 4 peat: 3 perlite (by vol.). Cuttings were maintained under natural photoperiod at day/night temperatures of 24/16 C (75/60 F) and misted daily for 6 sec every 3.3 min from 7 A. M. to 8 P. M.

Cuttings were harvested after 12 weeks and data recorded. Data included % rooted, root number, root length, root area, and root dry weight (dried at 70 C (158 F) for 72 hr.). A cutting was considered rooted if it had one primary root > 1 mm in length.

Results and Discussion: Hardwood cuttings taken Jan. 15,1993 had the highest % rooting of all the growth stages (Fig. 1). On this date, branch position affected all measured variables. Second-order laterals and the proximal half of second-order laterals yielded the highest rooting percentages, 87 and 72%, respectively. Root area and root dry weight were also highest for these branch positions. However, the distal half of second-order laterals and tips of third order laterals rooted in lower percentages, 55 and 12%, respectively. Greatest % rooting, root number, and root length occurred for cuttings treated with 3000 and 9000 ppm IBA (data not shown). Second-order laterals and proximal portions of second-order laterals had the highest root number and root length (data not shown).

Significance to Industry: 'Yoshino' *Cryptomeria* can be easily propagated vegetatively by rooting stem cuttings. Although, cuttings can be rooted at any time of the year (growth stage), % rooting exceeding 80% can be achieved by taking hardwood cuttings in January consisting of second-order laterals and the proximal half of second-order laterals treated with 3000 to 9000 ppm IBA.

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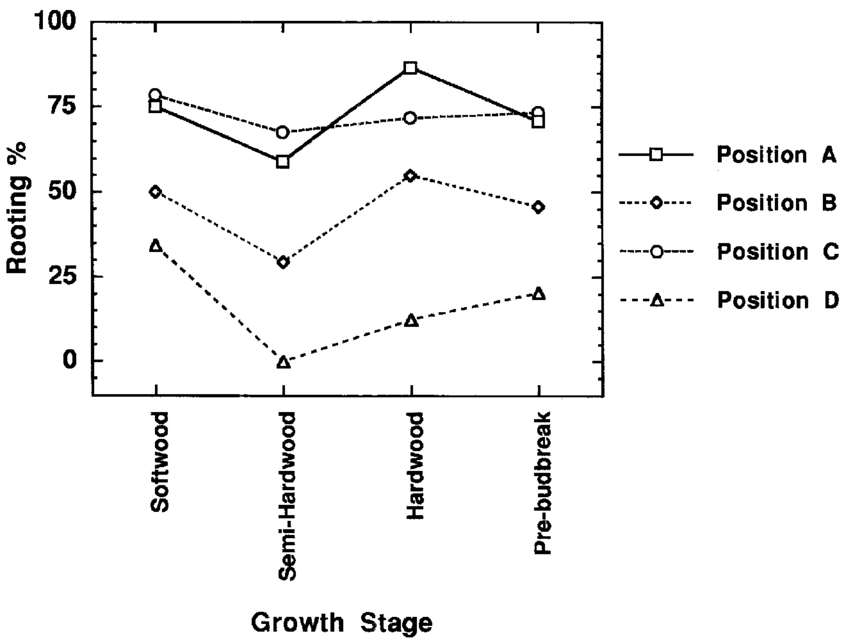

Figure 1. Effect of growth stage and branch position on percent rooting of stem cuttings of Cryptomeria japonica 'Yoshino'.

The Effect of Reduced Water Supply on Cold Hardiness of *Rhododendron* 'Catawbiense Boursault'

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Nature of Work: Rhododendrons are one of the most popular ornamental woody plants grown in temperate zones worldwide. In the southeastem United States freezing temperatures occur often enough to cause winter injury to these plants. Since favorable cold hardening temperatures do not always precede damaging freezes, alternative ways to induce cold hardiness have been tried [5, 10]. One such alternative is the cultural practice of limiting water supply [2]. Artificial tissue dehydration resulting in increased cold hardiness has been reported in various plants [3, 6] . Low water supply is effective in reducing top growth, thus increasing cold hardiness, especially if accompanied by fairly high temperatures [4]. The purpose of this study was to determine whether growing *Rhododendron* 'Catawbiense Boursault' under conditions of limited water supply has a positive effect on its cold hardiness.

One year old plants were greenhouse grown in 1-gallon containers. The growing medium was "Metro Mix 300" (Grace Siem Hort. Co., Milpitas, CA). Three watering regimes were compared: wet - 1200/600 ml, medium - 800/400 ml, and dry - 400/200 ml of water per container, per week, where the first number refers to the period between August 24 and October 2, 1992, and the second number to the period between October 2 and January 10, 1993. Following the first freeze test on January 10, watering was withheld until February 21, when the second freeze test was conducted. There were 3 replications of 10 plants for each watering regime, and replications were arranged in a randomized complete block design.

Water content of the growing medium was monitored with dme domain reflectometg (TDR). Plant water status parameters, including bound water content and osmotic potential, as estimated from pressure/volume curve, dry matter content and desiccation rate of detached leaves were determined on September 7 as well as on both freeze test dates (January 10 and February 21). Visual evaluation of freeze injury using a rating scale of 0 (no injury), 1 (less than 50% of tissue injured), 2 (more than 50% of tissue injured), and 3 (all tissue dead), was performed on leaves after they had been frozen in a freezing bath to -22°F (-30°C) in 2-degree increments.

Results and Discussion: Differences in water content of the growing medium were measured for the three watering regimes (Fig.1). Differences in water content between wet and medium regimes were small. In January, leaves of plants grown under the dry regime were less injured than leaves of plants under wet and medium regimes at temperatures above -0.4°F (-18°C) (Fig.2). In February, following the period of 6 weeks of imposed drought, cold hardiness of plants under wet and medium regimes increased to a level comparable with plants under the dry regime, while the latter maintained the same cold hardiness as in January (Fig.2) . Differences in cold hardiness between plants under dry versus wet or medium regimes were not correlated with bound water content, osmotic potential, dry matter content, or desiccation rate, except for the desiccation rate measured in February, when leaves of plants under the dry regime had a higher rate (i.e. 1.25% water content/ hr) than leaves of plants under wet or medium regimes (i.e. 0.87% and 0.85% water content/hr, respectively).

Yelenosky [9] in his studies on *Citrus* trees determined that water-stress-induced and low-temperature-induced cold hardening had similar impact on tree survival. To the contrary, Utsunomiya [8] reported that water stress was not effective in increasing cold hardiness of *Psidium* until plants stopped growing due to lower temperatures. However, Chen & Li [1] demonstrated that effects of water stress, low temperature, and short days on the increase of cold hardiness in *Comus stolonifera* were additive. In our experiment, January cold hardiness of *Rhododendron* 'Catawbiense Boursault' plants grown under nonstressful water supply conditions (wet and medium regimes) was much below what is considered typical for this group of hybrids [7]. Possibly, either preceding temperatures, day length, or both, did not favor the acclimation process in those plants under central Georgia conditions. Plants under reduced water supply conditions (dry regime) were able to acclimate and develop tolerance to much lower temperatures. A similar level of low temperature tolerance was developed in plants grown under nonstressful conditions following a period of drought in midwinter. However, it is unlikely that such a period of drought could be reproduced outside in winter in anticipation of a coming freeze.

Significance to Industry: Numerous ornamental woody plants may be unable to acclimate on time or to the required level if grown outside their natural range where their internal development rhythm is not synchronized with existing environmental conditions. It is difficult, if not impossible, to manipulate day length or temperature in order to stimulate hardening of woody ornamental plants. This experiment demonstrated that developing watering regime strategies to promote cold hardiness is a reasonable approach and produces positive results. In addition, it provides opportunities for water conservation. Further research is needed to determine most appropriate timing of reducing water supply and the level of this reduction for individual crops.

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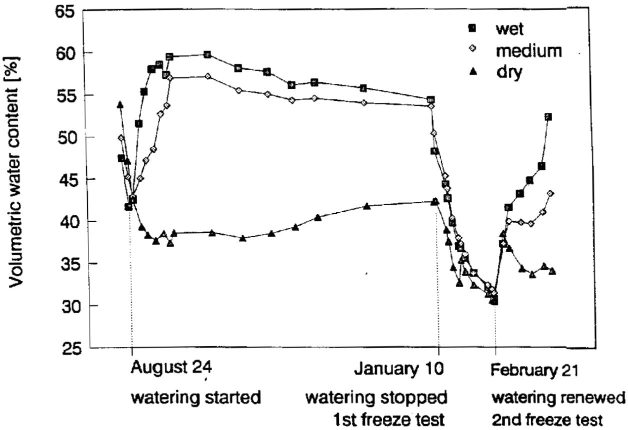
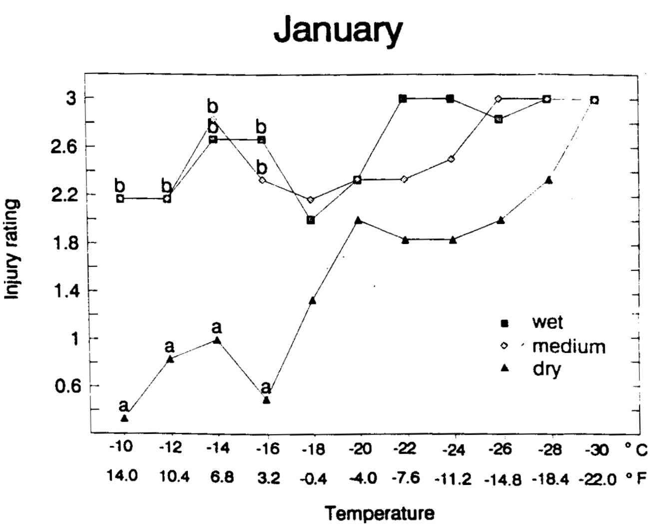


Fig. 1. Volumetric water content of growing medium depending on watering regime.



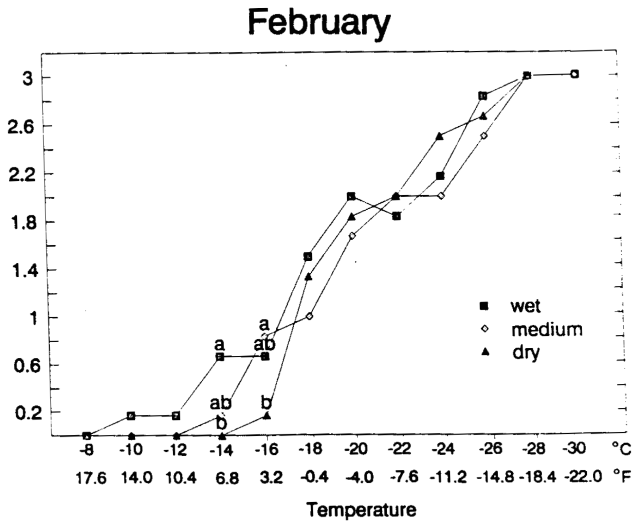


Fig. 2. Injury rating of *Rhododendron* 'Catawbiense Boursault' leaves in January and February freeze tests depending on watering regime (a,b - mean separation by HSD test, P=0.05; data points not marked by letters are not significantly different).

Nitrogen Partitioning in Hybrid Geranium Production

Patricia R. Knight, D. Joseph Eakes, and Charles H. Gilliam

Alabama

Nature of the Work: Because of the need to conserve water at and limit nutrient runoff from greenhouse operations, alternative methods of irrigation and fertilization are being examined. Subirrigation, over the past decade, has gained popularity as a production method and has several advantages over conventional overhead irrigation. Subirrigation not only reduces water and fertilizer usage by requiring less fertilizer initially and recycling water within the system, but it also reduces labor and produces more uniform plant growth (1,2).

The use of controlled release fertilizers has also been investigated as a means of reducing nutrient levels in greenhouse runoff. Controlled release fertilizers have been proven to increase plant retention of nitrogen and reduce the amount of nitrogen in container leachates (3,4). Little information is available concerning the partitioning of nitrogen under various irrigation and fertilization systems. Therefore, the objective of this study was to compare the fate of nitrogen and the growth of hybrid geranium in conventional overhead irrigation and subirrigation systems using 2 methods of fertilizer application.

Uniform plugs of Pelargonium x hortorum ‘Scarlet Elite’, Scarlet Elite geranium, were grown in 4-inch pots from April 17 to June 1, 1992, in a fiberglass greenhouse under 40% shade. Greenhouse temperatures were maintained at 85/68° F max/min. The growing medium was a 1 pine bark:3 peat moss:1 perlite (v:v:v) mixture amended with 7 pounds of dolomitic limestone and 1 pound of Micromax (Grace-Sierra, Milpitas, Calif.) per cubic yard. Plants were irrigated using conventional overhead or subirrigation with ebb and flow troughs. The 2 methods of fertilizer application were: 3.34 g of Osmocote 14-14-14 (Grace-Sierra, Milpitas, Calif.) per pot incorporated at planting or Peter’s Geranium Special 15-15-15 (Grace-Sierra, Milpitas, Calif.) applied at 250 ppm at each watering. Data collected included: shoot dry weight, root dry weight, total N available to plants, total shoot N, total root N, total soil N recovered, and leachate N recovered as NH_4-N and NO_3-N. Treatments were organized in a randomized complete block design with 5 replications of 2 plants per treatment.

Results and Discussion: Plants grown in ebb and flow troughs were larger than those grown under conventional overhead irrigation regardless of fertilizer application method. Plants grown with conventional overhead irrigation had a shoot dry weight of 5.08 g compared to plants grown in ebb and flow troughs with a shoot dry weight of 6.59 g. Type of fertilizer had no influence on shoot or root dry weight, and irrigation method had no influence on root dry weight.

There was more total N available to experimental units fertilized with Osmocote 14-14-14 than with Peter’s Geranium Special. Of the 714.6 mg of N available to the plants grown with Osmocote 14-14-14, 156.6 mg was assimilated in the shoots, 7.7 mg was assimilated in the roots, 416.0 mg remained in the growing medium, and 25.0 mg was lost in leachate (Table 1). Total N recovered from the system fertilizing plants with Osmocote 14-14-14 was 605.3 mg or an N recovery of 84.7%. Of the 628.5 mg of N available to the plants fertilized with Peter’s Geranium Special, 182.8 mg was assimilated in the shoots, 8.5 mg was assimilated in the roots, 233.0 mg remained in the growing medium, and 50.0 mg was lost in the container leachate. Total N recovered from these plants was 628.5 mg leading to an N recovery of 75.5%.

There was no difference in total N available to experimental units for conventional overhead irrigation or ebb and flow troughs. Conventional overhead irrigation had 666.6 mg of N available to plants. Of the total N recovered, 159.5 mg of N was assimilated in the shoots, 7.7 mg was assimilated in the roots, 330.0 mg remained in the soil, and 35.8 was lost in container leachate (Table 1). Total N recovered from plants grown under conventional overhead irrigation was 536.4 mg resulting in an N recovery of 80.5%. Total N available to plants grown in ebb and flow troughs was 676.5 mg. Of that total, 179.9 mg of N was assimilated in the shoots, 8.5 mg was assimilated in the roots, 319.0 mg remained in the soil, and 39.2 mg of N was lost when the remaining solution was discarded. A total of 543.2 mg of N was recovered from the ebb and flow system which lead to an N recovery of 80.3%.

Significance to Industry: The quality of water leaving greenhouse operations has become an important concern for the general public as well as growers. To remain profitable, growers must produce a quality plant while limiting the amount of N that is released into the environment during production. By examining the allocation of N to crops using different irrigation methods and fertilizer types, growers will be better able to adapt production methods to limit N loss and still produce a quality plant. These data indicate irrigation method had no effect on N partitioning within the plant or the N leachate loss, but plants grown in ebb and flow troughs were larger than those grown using conventional overhead irrigation. Use of a controlled release fertilizer reduced the amount of N lost in container leachates while producing a comparable plant. This suggests controlled release fertilizers are more efficient fertilization techniques primarily by reducing N leachate.

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Table 1. Nitrogen partitioning and recovery by 'Scarlet Elite' hybrid geranium.

	Method of Irrigation		Method of Fertilization	
Total N	Conventional	Ebb & Flow	Liquid Feed	CRF[1]
Available	666.6a[2]	676.5a	628.5b	714.6a
Recovered	536.4[3]	543.2	474.3	605.3
Shoots	159.5a	179.9a	182.8a	156.6a
Roots	7.7a	8.5a	8.5a	7.7a
Medium	330.0a	319.0a	233.0b	416.0a
Leachate	35.8a	39.2a	50.0a	25.0b

[1] Controlled release fertilizer.
[2] Means within rows for method of irrigation or method of fertilization followed by the same letter are not significantly different according to Tukey's Studentized Range Test, $p<0.05$.
[3] Total N recovered is the sum of foliar, root, soil, and leachate N.

Gas Exchange and Growth of Select Red Maples

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Alabama

Nature of Work: Red maple (*Acer rubrum* L.) is a commonly used landscape tree. In the past, seedling red maples have been planted with expectations of rapid growth, attractive canopy form, and excellent red fall color. Studies have shown great variability among seedlings collected from 70 locations across their native range, extending throughout the eastern United States and Canada(3). Studies on sugar maple have shown that seedlings from the same progeny grown in uniform environments have significant differences in growth and gas exchange(1).

Seedling variability has been the major source of marketability among the 46 named cultivars of red maple. The popularity of cultivars rests in their uniformity with regard to a particular form, unique foliage or fall color selected from seedling variants. Even with certain stability within one cultivar, there remains considerable variation between cultivars in their regional adaptability. Of the 46 named cultivars, none have been released that developed from selections originating from the southern area of their native range(2).

Based on this, our objectives were to evaluate the growth of selected red maples and to characterize the gas exchange capacities for these selections. Cultivars known to perform well in other regions of the United States were included in the study. The selections evaluated were: Autumn Blaze, Autumn Flame, Franksred (Red Sunset), Morgan (Indian Summer, Embers), Northwood, October Glory, Schlesingeri, and seedlings.

All trees were obtained from a single nursery source (Microplant Inc., Fairview, OR.), on their own root systems in 1988 as microplantlets. They were containerized to trade gallons in a 6:1 pinebark sand mix and grown for 6 months under standard nursery practices in the container production area at Auburn University, then shifted to 3 gallon containers for another 12 months. The trees ranged 4-5 feet in height when transplanted in March 1990, at Camp Hill, AL., into a Cecil gravelly sandy loam soil. Selections were planted in a RCBD with 5 blocks of 2 plants per selection per block for a total of 10 trees. Drip irrigation was supplied to each tree based on net evaporation from a class A pan. The trees were planted on a 30 x 35 foot spacing and have been fertilized with 13-13-13 at a rate of one pound per inch of caliper annually.

Height and caliper measurements were taken following the 1990, 1991, and 1992 growing seasons. In June 1992, gas exchange measurements were initiated using a LI-6250 portable photosynthesis system (LI-COR Inc., Lincoln, NE) in a closed mode, allowing the leaf to decrease the CO^2 concentration in a 1 liter chamber over a set period of time.

Results and Discussion: In 1990, after the first growing season in the field, the tallest cultivar was Northwood with a mean height of 7’6" (227 cm) and the smallest cultivar was Schlesingeri at a height of 4’5" (135 cm). Autumn Flame was the tallest cultivar in 1991 with a mean height of 9’4" (285 cm). Schlesingeri was the smallest cultivar in 1991 with a mean height of 6’11" (211 cm). In

1992, Autumn Flame was the tallest cultivar with a mean height of 12'10" (390 cm) and Schlesingeri remained the smallest cultivar, with a mean height of 9'8" (295 cm). In all 3 years the caliper measurements closely followed the height data. After 3 growing seasons, Autumn Flame had the largest height and caliper measurements and Northwood has the smallest.

In the summer of 1992, net photosynthesis (Pn) evaluations began. Measurements were taken throughout the morning to mid-afternoon at an average photon flux density of 1483 $\mu mol/m^2/s$. Northwood consistently had the highest Pn rate at 15.7 $\mu mol/m^2/s$ followed by Schlesingeri with 14.5 $\mu mol/m^2/s$. October Glory had the lowest CO^2 assimilation at 9.7 $\mu mol/m^2/s$, just below Red Sunset at 10.7 $\mu mol/m^2/s$. Stomatal conductance in 1992 was 0.58 cm/s on Morgan, 0.57 cm/s on Northwood, and 0.48 cm/s on Schlesingeri. October Glory and Red Sunset both had stomatal conductances of 0.33 cm/s. The same trend existed for leaf transpiration as stomatal conductance for all cultivars.

In summary, in 1992 the highest Pn rates were observed on the trees that exhibited the least amount of growth in the field. There does not appear to be a positive correlation between Pn and growth for the red maple selections in this test.

Significance to Industry: The proliferation of specie cultivars is an indication of the nursery industry's desire to seek out new and different but not necessarily the best or most universal selections. The development of a model to link growth and gas exchange capacities would aid the originator of a developing cultivar in identifying which climatic zones or microclimates the selection would perform best in without a 20-30 year evaluation period. However, there does not appear to be a positive correlation between growth and gas exchange on the red maple selections evaluated. Field performance to evaluate cultivars remains essential. Based on growth data for 3 years, the best red maple cultivar for the selections considered is Autumn Flame. The Northwood and Schlesingeri cultivars are poor selections for this region of the Southeastern United States.

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Bioassay of Toxic Metabolites From Fungi Associated with Dogwood Anthracnose

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South Carolina

Nature of Work: Dogwood anthracnose is a severe disease of flowering dogwood, *Cornus florida,* and Pacific dogwood, C. *nuttatlii,* caused by the fungus, *Discula destructiva.* Presently, control in nurseries and landscapes is inadequate and there are no feasible controls for this disease in the forest. Resistant, commercially available cultivars of these species do not exist. Evidence suggests that fungal toxins are involved in the injury to dogwood tissues during infection and colonization. Necrosis in leaves with few visible hyphae strongly support the hypothesis that a toxic metabolite may be active in lesion formation during pathogenesis (6). Characteristic symptoms of infection including: failure of blighted leaves to abscise and heavy epicormic branching suggest loss of apical dominance which also indicates that *D. destructiva* may be producing one or more toxins with plant growth regulator (PGR) activity (Wedge, unpublished). Ventkatasubbaiah and Chilton (5) have isolated and chemically characterized several toxins from *D. destructiva* culture filtrates, but the physiological effects of these substances have not been determined.

The purpose of this research was to develop a reliable and quantitative bioassay system to study and characterize the effects of culture filtrates containing possible phytotoxins from various *Discula* isolates. Radish *(Raphanus sativus)* was chosen as the preliminary test species since it was the standard bioassay species used in previous allelopathy studies (3). An allelopathic screening method described by Duke (2) and Patterson (3) was used to confirm the presence of toxic metabolites in the culture filtrates of *D. destructiva* grown in potato-dextrose broth (PDB). Modifying the above method, an *in vitro* bioassay was developed to investigate and compare the relative toxicity of metabolites of different isolates. Isolates of *D. destructiva* and type II *Discula,* were grown under identical conditions. Serial dilutions of culture filtrates from *Discula* were added to Murashige-Skoog media on which radish seeds were germinated *in vitro.* Bioassays were maintained at 77° F (25°±1C) under mixed fluorescent lamps with light levels at 47±2 umoles and a 12 hour photoperiod.

Results and Discussion: Root and shoot growth were significantly ($p<0.01$) inhibited by high doses of culture filtrate for each isolate tested when compared with the controls (Figures 1, 2). An analytical method of Strebig et al. (4) was used to estimate and compare the dosage response curves for the isolates and relate these findings to *in vitro* phytotoxicity. Different degrees of inhibition were observed among the isolates with isolate 99 (type II *Discula),* demonstrating the least toxicity while isolate 181 was the most toxic. Closely related isolates 100a and 100b showed overlapping regression lines demonstrating the reliability of this technique. Inhibition of primary root and shoot elongation occurred at high dosages while stimulation occurred at low dosages with all isolates. Concomitantly, inhibition of secondary lateral roots occurred throughout the dosage range tested. Inhibition of lateral root growth and root hairs was also evident. Our preliminary studies and those of others support the hypothesis that *D. destructiva* produces a phytotoxin(s) which has plant growth regulatory activity that may deleteriously affect root and shoot growth of dogwood. One of the most common approaches to developing a system for selecting disease resistance in tissue culture has been to use pathogen toxins as the selection agent. Cultured cells can be exposed easily and uniformly to toxins by dispersing the cells in or on toxin-containing media. Toxin resistance expressed in regenerated plants has correlated well with significant increases in the levels of disease resistance in the plants (1).

Significance to Industry: This research is the foundation work for the development of an *in vitro* resistance detection scheme utilizing pathogenic fungal toxins. The development of resistant cultivars is of paramount importance. Dogwood anthracnose has virtually destroyed the populations of *C. florida* in certain mountain areas in the eastern United States and has had a direct impact on the ornamental industry because some states have established quarantines and many nurseries no longer produce and market dogwood. The continuing loss of registration of chemical fungicides, the increase in ecological awareness of consumers, and the severity of dogwood anthracnose require the development of new and innovative approaches to disease control. The development of resistant dogwood germplasm will directly affect the nursery industry by supplying resistant clonal material for propagation and hybridization programs.

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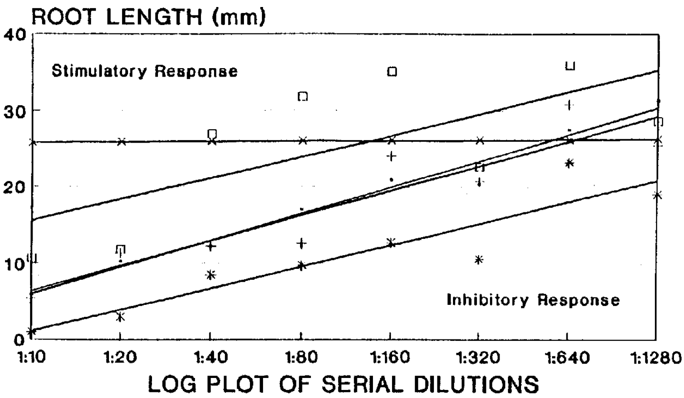
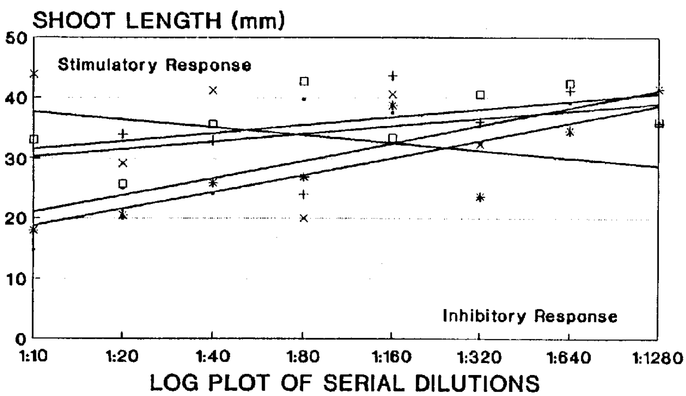


— 100b —+— 100a —*— 181 —□— 99 —×— Control

100a:$R^2=0.44$, $p<0.01$; 100b:$R^2=0.54$, $p<0.01$; 181:$R^2=0.47$, $p<0.01$; 99:$R^2=0.34$, $p<0.01$

Figure 1. In vitro root responses of radish seedlings to serial dilutions of culture filtrates containing phytotoxins from isolates of *Discula destructiva* and type II *Discula.*



— 100b —+— 100a —*— 181 —□— 99 —×— Control

100a:$R^2=0.59$, $p<0.01$; 100b:$R^2=0.48$, $p<0.01$; 181:$R^2=0.81$, $p<0.01$; 99:$R^2=0.31$, $p<0.01$

Figure 2. In vitro shoot responses of radish seedlings to serial dilutions of culture filtrates containing phytotoxins from isolates of *Discula destructiva* and type II *Discula.*

Isoxaben Movement and Dissipation in Container Nursery Runoff and Containment Pond Water

Chris Wilson, Ted Whitwell, and Melissa Riley
South Carolina

Nature of Work: Granular preemergent herbicide formulations are preferred by the nursery industry because of their ease of application. These materials are broadcast applied over the top of container crops and then irrigation is applied for herhicide activation. Treated areas may receive 200 inches of water each year from irrigation and rain. Depending on plant architecture and pot spacing, much of the applied herbicide lands on the surface surrounding the target pots. This herbicide is available to move offsite in the runoff water into containment ponds. Reapplication of this containment water to valuable container crops may result in plant damage.

Mahnken, et al. detected simazine and metolachlor in surface runoff water from a container ornamental production site (5) . In a series of studies. Keese et al. detected oryzalin, oxyfluorfen, and pendimethalin residues in a container nursery containment pond water and sediments (3, 4). The objective of this study was to determine the quantities of isoxaben from Snapshot TG (DowElanco) lost in irrigation runoff water and to monitor its dissipation in containment pond water.

Materials and Methods: A 5 acre (2 hectare) nursery container production area containing a diversity of plant species was treated with Snapshot TG (0.5% isoxaben + 2.0% Trifluralin) at 100 lbs. product/acre in August 1992 and May 1993. The area drains into a 1.25 acre (0.5 hectare) containment pond through a single storm drain. Overhead irrigation (0.5 inches) was applied following herbicide application. Water samples were collected flom the runoff water before it entered the collection pond at 0.25, 0.5, 1.5, 2.5, and 3.5 hrs after runoff water began to enter the pond on the day of treatment, and at 2 and 5 days after treatment (DAT). Samples were also collected in the pond at the runoff entry-point and at the point of the containment pond where water exits before treatment, after the first runoff event, and then at 2, 5, 7, 14, 21, 29, and 60 DAT. Measurements of runoff depth within the discharge pipe, pipe diameter, and slope of the pipe were used to determine runoff water volume entering the pond during the sampling periods.

All samples were collected in silanized glass jars and stored on ice for transport to the laboratory and stored at 7.2 F (4 C) until extractions were performed. Water samples (200 mls) were pH adjusted to 2.2-2.3 and filtered through Whatman #5 qualitative filter paper. The herbicides were then extracted using solid phase C_{18} columns (500 mg) and eluted with acetone (2 mls). Herbicide concentrations were then quantified using a Varion 5060 HPLC with a C_{18} reverse-phase column, UV detection at 206 nm, and a mobile phase gradient of 65:35 acetonitrile:water to 100% acetonitrile in 25 minutes. Isoxaben retention time was 7.2 minutes and the detection limit was 1 ppb (ng/ml).

Results and Discussion: The data for the 1992 and 1993 irrigated runoff events were combined since there was little variation between the 2 studies. However, the data for isoxaben dissipation within the pond at the entrance and exit points is presented separately by year due to variation between the 2 studies.

Runoff studies indicate that 7.4% of the applied isoxaben was lost in the irrigation runoff water during the first runoff event. Nearly 3.0% of the applied isoxaben was lost during the second runoff event 2 DAT and 0.9% was lost during the runoff event 5 DAT. This data is similar to that reported by Caro and Taylor in an agricultural lield study where the majority of soil-incolporated dieldrin was lost during a single early runoff event (2). Later events combined did not exceed the amount lost duling the first runoff event.

A total of approximately 38 grams of isoxaben was detected during the first 1.5 hours of runoff following herbicide application. The majority (30 grams) of isoxaben lost during this event was detected at the 1.5 hr sampling period during the first event (figure 1). Minimum quantities of 2.9 and 0.26 grams were lost at the 0.25 and 3.5 hr. sampling periods. Maximum losses closely correspond to runoff rates with maximum losses occurring when maximum runoff occurred (Figure 1). These data agree with those reported by Bovey et al. in which maximum losses of picloram in a treated grassland watershed occurred following a heavy rainfall with high runoff rates soon after treatment (1).

Isoxaben concentrations in the containment pond were much lower in 1993 when compared with 1992. This difference could be due to seasonal valiations. Duling both years, no isoxaben was detected in the pond before treatment. Initial concentrations at the runoff entrance point within the pond after treatment were approximately 26 and 87 ppb (ng/ml) for 1992 and 1993, respectively. Concentrations decreased to less than 5 ppb (ng/ml) 21 DAT for both years (Figure 2).

A similar trend was observed at the site where water exits the pond. Initial concentrations were 33 and 13 ppb (ng/ml) immediately following the t'irst runoff events in 1992 and 1993, respectively. The maximum level reached in the 1992 study was 33 ppb (ng/ml). A maximum of 34 ppb was reached 2 DAT in the 1993 study. The detected levels of isoxahen at the exit site were below 5 ppb (ng/ml) 21 DAT as was observed with the runoff entrance site.

Significance to Industry: The environmental fate of isoxaben is very important to the nursery industry due to its widespread use. This study shows that isoxaben moves from the application site in runoff water shortly after application and that it does not accumulate in the containment pond. By holding containment water for a period of time depending on the pond size and amount of isoxaben applied, growers can reduce the risk of damage to their container crops with isoxaben contaminated irrigation water.

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Acknowledgment: Special thanks to DowElanco for funding this research. Trade names and companies are mentioned with the understanding that no discrimination is intended nor endorsement implied.

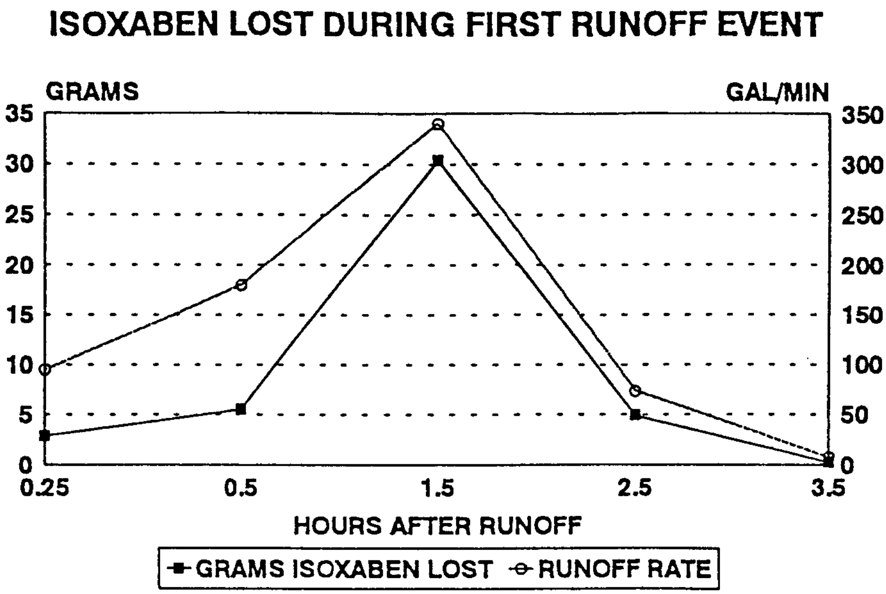

Figure 1.

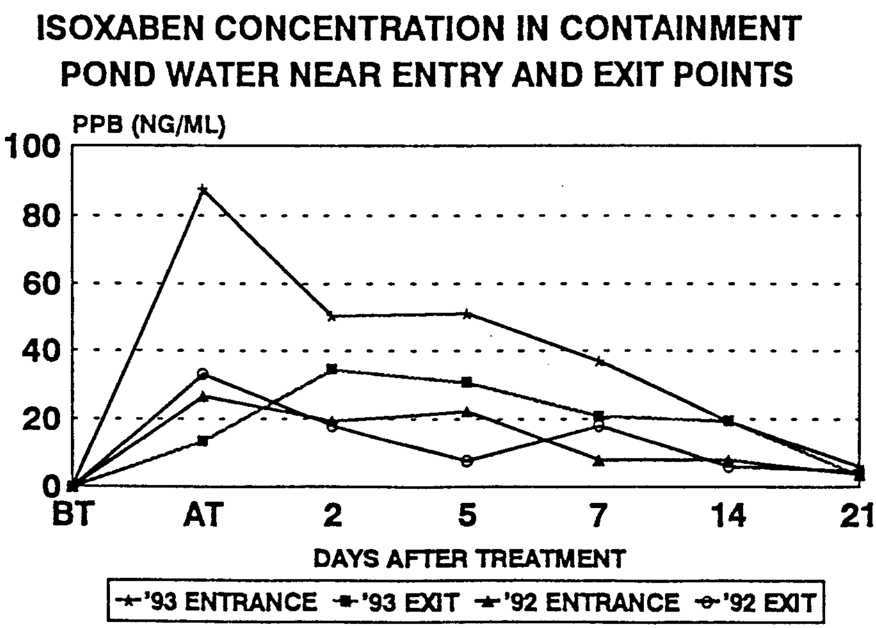

Figure 2.

Timing of Pruning Affects Cold Hardiness of Field-Grown Crape Myrtles

C.L. Haynes, O.M. Lindstrom, and M.A. Dirr
Georgia

Nature of Work: *Lagerstroemia* 'Natchez' (crape myrtle) is a widely grown shrub or small tree in the southeastern United States. Crape myrtle is often pruned in late summer or fall to remove spent inflorescences and promote new flowers. However, several researchers (2,6) have suggested delaying pruning to insure development of maximum cold hardiness.

In previous experiments, pruning in late summer through early winter decreased the cold hardiness of crape myrtle plants grown in containers under lath-house (55% shade) conditions (3). However, researchers have also reported that shading affects the cold hardiness of fruit crops (1, 4). In addition, containerized plants often are less hardy and/or acclimate differently than field-grown plants (5). Therefore, the objective of this study was to determine the effect of pruning date on the cold hardiness of field-grown Natchez crape myrtle.

Rooted cuttings of Natchez crape myrtle were transplanted and maintained at the Georgia Experiment Station in Griffin, GA. A total of 593 rooted cuttings were planted in a completely randomized design approximately 3 ft (90 cm) apart. In October, November, December, January, and February, 159, 158, 107, 56, and 54 plants were pruned, respectively. Four inch (10cm) terminal stem segments were removed at each pruning date and laboratory tested for cold hardiness as described by Haynes et al. (1991). Repeated sampling of previously pruned plants was avoided.

Results and Discussion: Similar to the previous study (3), October through December pruning reduced the cold hardiness of Natchez crape myrtle on all dates tested compared to the unpruned controls (Table 1). However, in February the cold hardiness of the January pruned sample was not different from the unpruned control. Where differences were detected a maximum of 5-6°F (3°C) in cold hardiness estimates existed between pruned treatments and unpruned controls. Natchez crape myrtle acclimated late in fall since only the unfrozen checks survived in the October sampling. In addition the maximum cold hardiness estimates were 7°F (-14°C) in 1989-1990 (3) and 5°F (-15°C) in 1990-1991 for lath-house grown plants and field-grown plants respectively.

Although light level can be a limiting factor in the cold resistance of some plants (1, 4) no differences were detected with crape myrtle. Conditions that alter light exposure on plants may affect carbohydrate production and accumulation which may influence a plant's cold hardiness (5). Flore et al. (1983) reported no differences in cold hardiness estimations between 100 and 36% of full sun on peach wood or buds.

Significance to Industry: Late summer to mid winter pruning of crape myrtle is discouraged for both field-grown and container-grown plants. Pruning at this time may encourage new growth and/or predispose plants to winter injury. Natchez crape myrtle should be pruned in late winter.

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Table 1. The effect of pruning date on the lowest survival temperature of field-grown Natchez crape myrtles.

	Sample Month				
Prune month	October	November	December °F (°C)	January	February
October	ck[z]	21 (-6) a	16 (-9) a	16 (-9) a	10 (-12) a
November		16 (-g)[y] b	16 (-9) a	16 (-9) a	10 (-12) a
December			10 (-12)[x] b	16 (-9) a	10 (-12) a
January				10 (-12) b	5 (-15) b
February					5 (-15) b

[z] Only unfrozen checks survived.
[y] Unpruned controls are represented by the numbers at the bottom of each column.
[x] Mean separation within columns by Duncan's Multiple Range Test, 0.05% level.

Permit, a New Herbicide for Nutsedge Control in Ornamentals

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Nature of Work: Yellow and purple nutsedge are considered as two of the world's worst weeds (1). In Georgia, yellow and purple nutsedges are the most troublesome and among the most common weeds in nursery container ornamentals (2). Currently postemergence herbicide options for nutsedge control in ornamentals are limited (3). The objective of our research was to evaluate the efficacy of four new herbicides for nutsedge control in ornamental crops. The herbicides evaluated were Permit (Monsanto), Pursuit, Image, and Cadre (American Cyanamid). The weed species used were yellow and purple nutsedges (Cyperus esculentus L. and C. rotundus L.). The ornamentals used included: azalea (Rhododendron x 'Macrantha Orange', liriope (Liriope muscari Bailey), photinia (Photinia x fraseri Lindl.), juniper (Juniperus conferta), and several bedding plant species.

The study utilized a randomized complete block design with 4 to 6 replications, two rates, and controls. All spray mixtures included a nonionic surfactant at 0.25% (v/v). Pursuit treatments included 32% nitrogen at 1 quart/acre. Plant materials were potted in ground pine bark amended with nutrients and pH adjusted between 5 and 7. Nutsedge plants were treated when the plant height averaged between 4 to 6 inches. All ornamentals were treated after the roots were determined to be well established in the containers. The herbicide applications were made over-the-top in a spray chamber, using a flat-fan 8004 nozzle, calibrated for an output of 20 gallons per acre. The treated plants and controls were returned to a controlled environment greenhouse and watered daily beginning no sooner than 12 hours after treatment. Weed control and ornamental tolerance ratings were taken at 2 weeks after treatment (WAT) and were taken every two weeks as needed. Percent nutsedge growth reduction was calculated at 4 WAT by subtracting the percent top growth weight from 100 using the difference in top growth weight between each plant and the mean of the contol. Tolerance ratings for the ornamentals included either whole plant or new growth measurements and a qualitative evaluation. Ornamental growth reductions were calculated by subtracting the percent of top growth from 100 using the difference in length of new growth between each plant and the mean of the contol.

Results and Discussion: Excellent purple nutsedge control (> 90%) resulted from Permit and Pursuit at both rates, and Cadre at the higher rate of 0.062 lbs/A when applied early postemergence (Table 1). Image provided 73% control of purple nutsedge at the 0.50 lbs/A rate. Permit also provided 74 and 79% control of yellow nutsedge at 0.008 and 0.016 lbs/A, respectively. Pursuit and Image provided 86 and 72% yellow nutsedge control, respectively, at the higher use rates of 0.5 lbs/A.

Tolerance of container-grown ornamentals varied with herbicides (Table 2). No visual injury on azalea was observed with Permit. However, azalea new shoot growth reduction was observed in the first 8 WAT following Permit application. Permit treated azaleas had outgrown growth reductions by 12 WAT. Growth of the azalea cultivar 'Macrantha Orange' was severely stunted (62-95%) after treatment with Pursuit, Image, or Cadre. The visual injury on azalea from these three herbicides included either a lack of new shoot growth or delay in new shoot growth accompanied by a loss of apical dominance, malformations of new leaves, and irregular flowering patterns. Recovery from Pursuit, Image, or Cadre was not seen by 20 WAT. The photinia were tolerant of all herbicide treatments except both rates of Pursuit and Cadre at the 0.062 lbs/A rate. The Cadre treated photinia recovered by 8 WAT but the Pursuit treated photinia remained stunted and exhibited a loss of apical dominance throughout the 12-week study. All treatments reduced the growth of juniper 15 to 37% during the first 8 WAT. However, the treated juniper recovered by 14 WAT except for the Cadre treatments. No significant visual damage or growth reduction was measured on Liriope muscari from any treatment at 4 WAT.

Injury to bedding plants was minimal in Permit treated species as shown by Tables 3 and 4. Most bedding plant species tested were tolerant of Permit even at the highest use rate. Only geraniums, green-leaved begonias, red petunias, and ageratum received unacceptable injury (visual injury exceeding 30%) from Permit. Pursuit induced unacceptable injury (visual injury exceeding 30%) on all bedding plant species except celosia and french marigolds.

Significance to Industry: Permit has demonstrated a superior ability to control both species of nutsedge and retain a considerable amount of ornamental tolerance. If registered for use in turf and ornamentals, Permit would become an indispensable tool for nutsedge control in nursery crop production and in landscape maintenance.

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Table 1. Nutsedge Control from Permit, Pursuit, Image, and Cadre.

		Yellow Nutsedge		Purple Nutsedge	
Treatment	Rate	Height 28 DAT[a]	Weight 28 DAT	Height 28 DAT	Weight 28 DAT
	(lbs/acre)	(% reduction)			
Check	----	0	0	0	0
Permit	0.008	49	74	45	92
Permit	0.016	57	79	32	96
Pursuit	0.25	33	34	72	95
Pursuit	0.50	65	86	58	96
Image	0.38	43	56	29	53
Image	0.50	58	72	44	73
Cadre	0.0315	11	12	3	52
Cadre	0.062	35	53	35	92
	LSD (0.05)	13	24	37	20

[a] DAT = Days After Treatment

Table 2. Ornamental Tolerance to Permit, Pursuit, Image, and Cadre as Percent Reduction Compared to the Control.

Treatment	Rate	Azalea 'Macrantha Orange' 4 WAT[a]	8 WAT	12 WAT	Photinia x Fraseri 4 WAT	8 WAT	12 WAT	Juniper 'Conferta Shore' 4 WAT	8 WAT	12 WAT	14 WAT	Liriope muscari 4 WAT
	(lbs/acre)	(% reduction)										
Check	----	0	0	0	0	0	0	0	0	0	0	0
Permit	0.008	44	20	0	5	0	0	22	19	5	7	0
Permit	0.016	24	3	0	9	0	2	15	19	19	17	10
Pursuit	0.25	83	92	91	26	32	49	35	37	20	16	0
Pursuit	0.50	85	93	94	33	37	50	17	25	14	9	0
Image	0.38	81	94	95	3	0	6	29	32	17	15	3
Image	0.50	70	79	89	0	0	0	28	32	23	18	9
Cadre	0.0315	57	65	62	12	0	1	24	31	23	24	12
Cadre	0.062	72	75	78	23	4	16	27	33	24	21	1
	LSD (0.05)	22	31	41	12	17	17	15	14	16	17	NS

[a] WAT = Weeks After Treatment

Table 3. Bedding Plant Tolerance to Permit and Pursuit as Percent Reduction Compared to the Control.

Treatment	Rate	Fr.[a] Mar.	Af. Mar.	Wt. Pet.	Rd. Pet.	Ld. Pet.	Ager.	Cel.	Vin.	B.L. Beg.	G.L. Beg.	Pl. Sal.	Rd. Sal.	Ger.
	(lbs/acre)	(% reduction)												
Check	----	0	0	0	0	0	0	0	0	0	0	0	0	0
Permit	0.008	0	0	0	25	23	0	0	0	0	37	0	9	41
Permit	0.016	0	0	5	14	8	10	0	30	6	41	0	31	46
Pursuit	0.25	10	37	15	49	29	0	26	61	6	70	0	3	36
Pursuit	0.50	7	33	0	41	16	8	4	35	56	85	4	34	71
	LSD (0.05)	NS	NS	NS	49	25	NS	NS	23	39	28	NS	24	48

Table 4. Bedding Plants Visual Injury.

Treatment	Rate	Fr.[a] Mar.	Af. Mar.	Wt. Pet.	Rd. Pet.	Ld. Pet.	Ager.	Cel.	Vin.	B.L. Beg.	G.L. Beg.	Pl. Sal.	Rd. Sal.	Ger.
	(lbs/acre)	(% Injury)												
Check	----	18	0	3	10	0	3	0	0	5	0	0	0	3
Permit	0.008	0	5	18	50	3	38	3	3	0	35	5	5	68
Permit	0.016	23	8	5	20	3	53	3	13	8	33	3	3	45
Pursuit	0.25	18	85	43	88	73	40	20	75	65	88	85	78	88
Pursuit	0.50	28	80	45	73	65	58	13	70	85	95	88	78	93
	LSD (0.05)	22	15	27	41	13	21	9	19	24	22	8	16	44

[a] Abbreviations: Fr. Mar. - French Marigolds (Tagetes patula 'Dwarf Orange'), Af. Mar. - African Marigolds (Tagetes erecta 'Discovery Orange'), Wt.Pet. - White Petunias (Petunia x hybrida), Rd. Pet. - Red Petunias ('Red Madness'), Ld. Pet. - Lavender Petunias ('Orchid Madness'), Ager. - Ageratum (Ageratum houstonianum 'Hawaii Blue'), Cel. - Celosia (Celosia plumosus 'Red"), Vin. - Vinca (Catharanthus roseus 'Peppermint Cooler'), B.L. Beg. - Bronze-leaved Begonias (Begonia semperflorens), G.L. Beg.- Green-leaved Begonias, Pl. Sal. - Purple Salvia (Salvia splendens 'Empire Purple'), Rd. Sal. - Red Salvia ('Red Hot Sally'), Ger. - Geranium (Pelargonium x hortorum 'Elite Scarlet').