# SECTION 1
# DR. BRYSON L. JAMES
# STUDENT COMPETITION

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**Section Editor and Moderator**

# Price Trends of Nursery Stock

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**Nature of Work:** Many changes have occurred in the nursery industry since its creation. However none are more important than the ongoing change in the price of nursery stock. I have completed a limited amount of research in the area and have found that two major events have changed the price of plants consistently over time. The droughts of 1983 and 1988 left many growers without crops to sell.

Five different species were selected at random for the study. *Acer platanoides* 'Crimson King', *Liquidambar styracuflua, Euonymus alata* 'Compacta' and *Pinus strobus*. Price lists from a variety of nurseries were evaluated and those consistently available over a four to seven year period were used.

The nursery that had the most unusual price pattern was Bork Nurseries. From 1981 to 1991 the size and price of plant material seldom stayed the same, both maple and barberry change frequently over time. The only consistency seems to be the larger size maples (Figure 1). Each year the maple caliper size increased. While both 1.5" and 2" trees were grown annually, 2.25" and 2.5" trees were not sold until after 1990. Barberry plants increased in 1988 from 4" plants to 6" plants (Figure 2). After the drought the 6"-9" plants were moved to 10" plants.

One of the price trends that I found to be unusual was that one nursery would increase the price of a plant by as much as 20% while another would decrease it by as much or more in the same year. This happened several times but was never as obvious as with white pines being produced in Tennessee (Figure 3). 1984 was the recovery year for the first drought of the decade. This may explain why the price of 4' white pine trees increased by 28%, while the price of 3' white pines decreased by 21%. More interesting is that one Tennessee nursery dropped the price of their 4' pines by 11%, while the price of the 3' pines didn't change. Prices for white pines after 1987 were unavailable, therefore, I was unable to determine the effects of the second drought on these trees. Prices have dramatically increased since 1984.

Of the five plants that I have evaluated, the maples seem to be the most affected by the drought. The price of most caliper trees plummeted following the drought of 1983 (Figure 4). However, 1.5" and 2" caliper trees remained somewhat constant. Surprisingly, following the drought of 1988, almost all showed little change. The exception being 1.25" caliper trees which stopped being sold after the drought.

The droughts also caused significant changes in the price of Burning Bush. What is interesting though is that the biggest drop in price came in the spring of 1982, one year before the first drought (Figure 5). That year the production of Burning Bush, by several nurseries, was almost non existent. After a steady rise in '83, the prices leveled off following the drought. The only size to show significant change was the 36" plant which dropped approximately $10. The drought of 1988 seemed to be more effective in reducing the price for this species. However this popular plant made a quick recovery, peaking in 1991. Since '91, 36" plants have been steadily increasing, while 12"-30" plants have been steadily decreasing in price.

Of the nurseries used in this study only a few were producing white pines before 1980. As with the Burning Bush, the '83 drought showed little effect on white pine production (Figure 6). Actually the prices showed a steady increase from 1980 to 1988 before being slowed by the drought. The sizes most effected were 2', 3', and 8' pines. All other sizes have shown steady increases in price despite the two droughts.

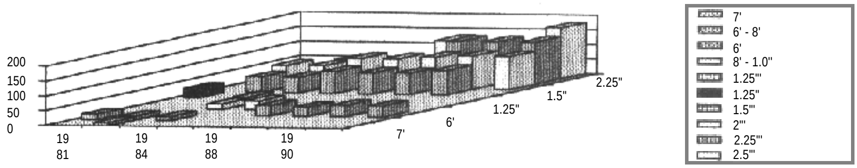
Another plant that has showed an increase in price during the droughts is sweet gum. The price of sweet gums did not decrease during '83 but remained constant for a year (Figure 7). From 1984 to 1988, the prices increased among every size, with the greatest increases coming in larger caliper trees. The sweet gum showed little change immediately after the '88 drought. Instead, the prices slowly declined, reaching a low point in 1990. With the exception of 3.5" & 4" trees the sweet gum has steadily increased in price.

**Results and Discussion:** Based on the information that I have observed the drought of 1988 caused a greater change in price in every plant except maples. Each of the plants studied displayed different price changes, as each market reacted differently to the change in price. Every plant and every plant size showed dramatic price decreases following the dry spell (Figure 8). Although the prices dropped following 1983, the decrease was not as extreme. An interesting point to notice is that the prices overall peaked for the season just after the drought. Although prices have continuously risen since then, they have not yet regained the earlier high price.

**Significance to Industry:** It is inevitable that there will always be continuous change in the nursery industry. With rising inflation and production cost, it is very interesting that the prices were actually higher in 1988 than in 1992.

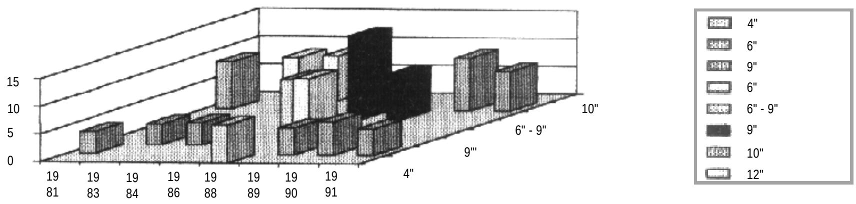
(Figure 1)

Price Change of Maples From Bork Nurseries



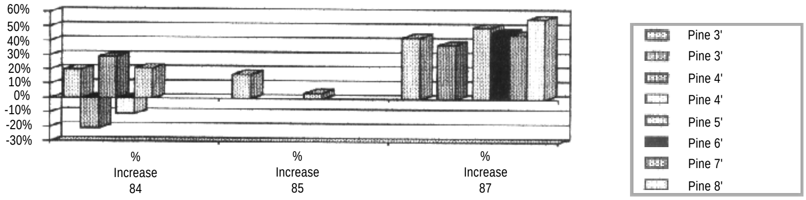

(Figure 2)

Price Change of Barberry Plants From Bork Nurseries



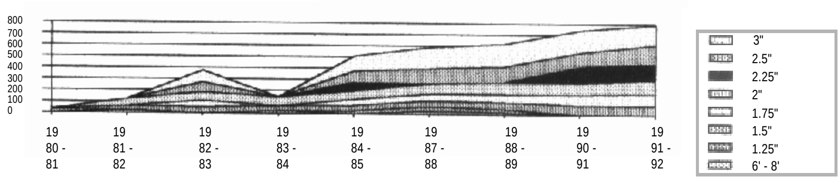

(Figure 3)

Percent Change of Price of White Pines Produced in Tennessee



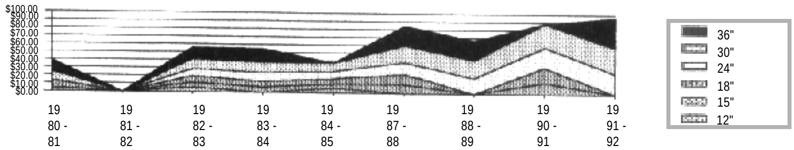

(Figure 4)

Price Change of Crimson King Maple From Several Nurseries



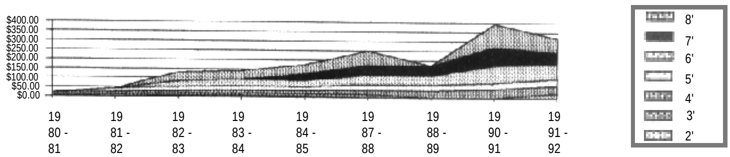
(Figure 5)

Price Change of Burning Bush From Several Nurseries



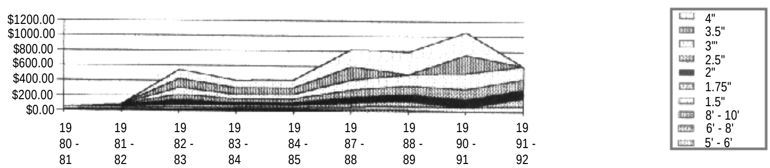

(Figure 6)

Price Change of White Pine From Several Nurseries



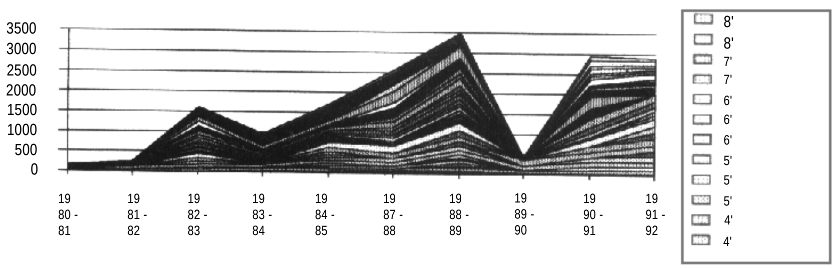

(Figure 7)

Price Change of Sweet Gum From Several Nurseries




(Figure 8)

Price Change of White Pine From Several Nurseries



# Pre-plant Bulb Dips for Height Control of L.A. Hybrid Lilies

**Jason P. Ball and William B. Miller**
**South Carolina**

**Nature Of Work:** New hybrid lilies resulting from interspecific crosses of *Lilium longiflorum* and Asiatic hybrid lilies (the so called "L.A. hybrids") have great potential as a new pot plant for greenhouse producers. L.A. hybrid lilies have been used mainly for cut flower production to this point, but their increased use as a pot crop is dependent on effective height control techniques. Researchers have used plant growth regulators (PGR's) as pre-plant bulb dips and/or soaks with Easter lilies with some success (1), but these dips have not been widely adapted because of the effectiveness of the same chemicals as post-emergence sprays and/or drenches. Since results of PGR bulb dips have not previously been reported on L.A. hybrid lilies, this preliminary study was conducted to test the efficacy of bulb dips of three chemical growth regulators, A-Rest, Sumagic, and Bonzi, for control of L.A. hybrid lily height.

On February 15, 1996, L.A. hybrid lily bulbs (12-14 cm circumference, cultivar 'Royal Fantasy') were treated with three growth regulators: A-Rest (ancymidol) at 33 ppm, Sumagic (uniconazole) at 5, 10 and 20 ppm, and Bonzi (paclobutrazole) at 100 and 200 ppm. Five bulbs were soaked in 600 ml of each solution for 5, 10, or 60 minutes. Control bulbs were soaked in distilled water for the same three time periods. After soaking, bulbs were allowed to sit overnight at room temperature and planted in 6" standard pots in a standard soilless greenhouse mix (Fafard 360) the next day. The bulbs were then placed in the greenhouse and grown with standard cultural practices, with night temperatures of 63F, and days approximately 12F higher. Plant height was determined weekly, and flower date, number of buds, and number of aborted buds were determined at flowering (these data were only collected on plants that emerged and flowered). To determine the relationship of flower size to the number of days until flowers opened, a number of buds of different sizes were tagged, and date of anthesis subsequently recorded. Only control plants were used in this experiment.

**Results and Discussion:** Figure 1 depicts final plant height of each treatment at flowering. All growth regulator bulb soaks reduced height relative to the untreated controls. A-Rest treatments reduced height by more than 50% relative to the controls, and increasing soak time did not change the final height obtained. The percentage of height reduction we saw with 33 ppm A-Rest soaks is somewhat greater than reported earlier with the standard Easter lily cultivars 'Ace' and 'Nellie White' (1). The extent of height control was excessive with the 60 minute Sumagic soaks, where final height was reduced by more than 75% relative to the untreated controls. Plants in the 20 ppm Sumagic soaks were also too short, even with the 5 minute soak. The 5 minute Bonzi soaks at either 100 or 200 ppm gave excellent results, with plants well proportioned in the 6" standard pots.

Relative to the untreated controls, growth regulator bulb dips caused an average flowering delay of five days (Table 1), and, except for the severe 60 minute soak in 20 ppm Sumagic, flowering delay did not appear to be closely related to PGR dose. Growth regulator bulb soaks did not appear to affect the number of flower buds or aborted buds, even on plants that were severely stunted in height (Table 1). Overall, plants averaged 3.6 flowers per plant. The relationship of bud length to number days until bloom is given in Table 2.

**Significance to Industry:** With the reduction in height that was observed with this preliminary experiment, it appears that these lilies can potentially be tailored for production in 6 inch pots with no reduction in flower number or quality. Since only one cultivar has been investigated so far, PGR recommendations cannot be made, but the potential for progress with this crop is exciting. We plan additional trials with more cultivars and lower concentrations of active ingredient to further explore this area.

LA hybrid lilies have other potential as well, since the garden performance of these hybrids is excellent. Nursery producers should consider “green” sales with 5-9 bulbs in large containers (12+ inches diameter). Items such as these would need no growth regulator, and would give the consumer long term value as the buds develop and flower, followed by transplanting into the perennial garden for additional years of enjoyment.

## Literature Cited

1. Larson, R. A., C. B. Thorne, R. R. Milks, Y. M. Isenberg, L. D. Brisson. 1987. Use of ancymidol bulbs dips to control stem elongation of Easter lilies grown in a pine bark medium. J. Amer. Soc. Hort. Sci. 112:773-777.

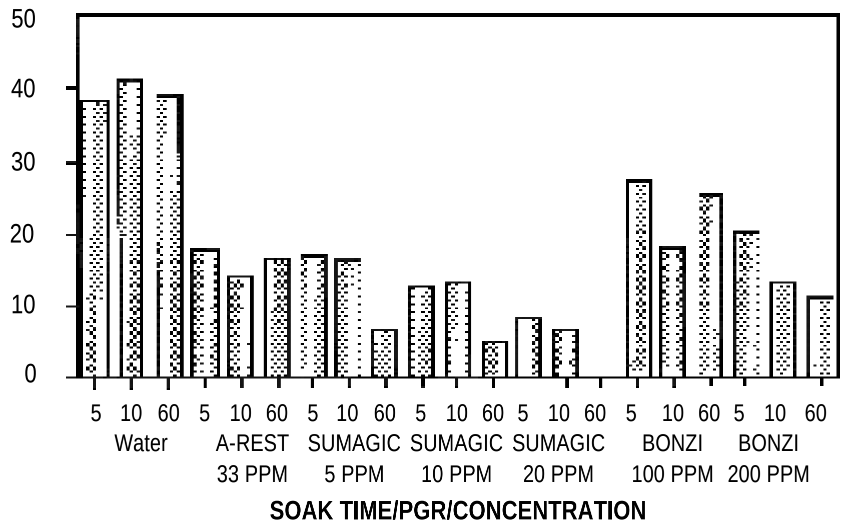
Table 1. Effects of plant growth regulator (PGR), concentration, and length of pre-plant bulb soak on days to flower, number of flowers, and number of aborted flowers for 'Royal Fantasy' L.A. hybrid lily. Numbers are means of 5 plants per treatment.

| PGR | Concentration | Length of bulb soak (min) | Days to flower | Number of flowers | Number of aborted flowers |
|---|---|---|---|---|---|
| Control | — | 5 | 63 | 4.2 | 0.4 |
| | | 10 | 67 | 3.0 | 0.8 |
| | | 60 | 64 | 4.2 | 0.4 |
| A-Rest | 33 ppm | 5 | 72 | 4.2 | 0.4 |
| | | 10 | 71 | 3.6 | 0.4 |
| | | 60 | 71 | 4.8 | 0.4 |
| Sumagic | 5 ppm | 5 | 72 | 4.4 | 0.2 |
| | | 10 | 68 | 3.6 | 0.6 |
| | | 60 | 69 | 3.2 | 0.4 |
| Sumagic | 10 ppm | 5 | 70 | 4.2 | 0.4 |
| | | 10 | 68 | 3.2 | 0.6 |
| | | 60 | 71 | 2.2 | 0.0 |
| Sumagic | 20 ppm | 5 | 72 | 2.4 | 0.4 |
| | | 10 | 70 | 4.4 | 0.0 |
| | | 60 | — | 0 | 0.0 |
| Bonzi | 100 ppm | 5 | 68 | 3.6 | 0.4 |
| | | 10 | 70 | 3.0 | 1.0 |
| | | 60 | 68 | 4.2 | 0.2 |
| Bonzi | 200 ppm | 5 | 69 | 3.2 | 0.6 |
| | | 10 | 72 | 2.8 | 0.6 |
| | | 60 | 71 | 3.2 | 0.8 |

Table 2. Relationship of flower bud length to number of days until flowering for L.A. 'Royal Fantasy' hybrid lily. Night temperatures were 17C (63F), with days approximately 12F higher.

| Length of flower bud (cm) | Number of days to flower | Number of buds observed |
|---|---|---|
| 4 | 10 | 4 |
| 5.5 | 7 | 1 |
| 6 | 5 | 3 |
| 6.5 | 5 | 2 |
| 7 | 5 | 1 |
| 7.5 | 3 | 1 |
| 8 | 3 | 1 |
| 8.5 | 2 | 5 |
| 9 | 2 | 4 |
| 9.5 | 1 | 3 |
| 10 | 1 | 2 |

Fig. 1. Effect of soaking time, concentration and PGR on flowering height of 'Royal Fantasy' L.A. hybrid lilies.



# New Herbaceous Perennial Species Tolerance to Preemergence Herbicides

**Paul M. Ritoch, Russell Smith, Ted Whitwell**
**South Carolina**

**Nature of Work:** A limited number of herbaceous perennial species are included on herbicide labels. Due to an increase in production and sales of many species that provide year long color in the landscape, more herbicide tolerance information is needed to produce and maintain weed free plant material. Additionally, labor costs continue to increase and hand weeding is not a viable option for most nurseries producing quantities of these plants.

Porter (1) conducted a study using herbicides and herbaceous perennials during the early 1990's. His study indicated that "Certain herbaceous flowering perennials were found to be sensitive to Gallery and Snapshot DF. Snapshot TG was found to be less injurious to all species tested."

Other experiments indicate that less injury occurs to certain landscape species when Gallery is applied on a fertilizer carrier as a granular product rather than applied as a spray. Also, there is little information available concerning the tolerance of perennials to the new Regal OO formulation.

Clemson University's research center at Carolina Nurseries was the site for a study to evaluate selected preemergence herbicides on fall potted herbaceous perennials (Table 1). Ten perennial species were potted two weeks prior to the first herbicide applications. Perennial plugs were potted in one-gallon pots in a fertilizer/lime amended media (20% sand and 80% pine bark). Experimental design was a randomized block for each species with 5 single pot replications.

Both sprayable and granular formulations of herbicides were evaluated (Table 2). The sprayable treatments were applied using a $CO_2$ backpack boom sprayer with 8006 flat fan nozzles. Pre-measured granular formulations were distributed with a hand-held shaker. Two (1X and 4X) rates of each herbicide treatment were applied on 10/26/95 and the same pots were retreated with the same rate on 3/21/96. Visual ratings were taken on a scale of 0 = no injury to 100 = complete kill. Weed control data are not included in this presentation because of limited space. Data was subjected to analysis of variance and means were separated by LSD at P = 0.05.

**Results and Discussion:** Species responded differently to the various herbicides during the study (Tables 3 and 4).

Chrysanthemum x superbum 'Snow Lady' was injured by all treatments, while *Gaura lindheimeri* and *Paradancanda norisii* were tolerant to most herbicides. The response after one and two applications varied. *Boltonia asteroides* 'Pink Beauty' exhibited injury symptoms to Rout and OO 60 days after the first application but no injury was observed after the second herbicide application. Gallery spray injured Veronica and Rudbeckia, and both Chrysanthemum species at the two evaluations. Injury to Phlox, Rudbeckia and Tiarella was evident 30 days after the second Gallery application. In general, Gallery sprays caused unacceptable injury to these species.

There was a trend of less injury from the 1X rate of the granular formulation of Gallery (on KMg) compared to the same rate sprayed on the perennials. The other species in the study were tolerant to Gallery. A similar pattern of injury was observed from Snapshot applications with the exception of more severe injury to Hibiscus from Snapshot than from Gallery. Rout and OO produced unacceptable injury to all species except Paradancanda, Guara, Veronica and Boltonia. Early injury was observed on Boltonia with Snapshot 10.0 lb ai/A, Rout 12.0lb ai/A, and both rates of Regal OO. The plants recovered from this injury by the last rating date.

**Significance to Industry:** There were no herbicides evaluated that were safe on all perennial species tested. Herbicides for perennial production will need to be continually evaluated and prescription herbicide use should be on the usage guide.

**Literature Cited**

1. Porter, W.C. 1996. Isoxaben and isoxaben combinations for weed control in container-grown herbaceous flowering perennials. J. Environ. Hort. 14(1):27-30.

Table 1. Species Used in Study

| |
|---|
| *Boltonia asteroides* 'Pink Beauty' |
| *Chrysanthemum* x *superbum* 'Becky' |
| *Chrysanthemum* x *superbum* 'Snow Lady' |
| *Gaura lindheimeri* |
| *Hibiscus moscheutos* 'Disco Belle Pink' |
| *Paradancanda norisii* |
| *Phlox paniculata* 'Sandra' |
| *Rudbeckia fulgida* 'Goldsturm' |
| *Tiarella* sp. 'Slickrock' |
| *Veronica latifolia* 'Icicle' |

Table 2. Trade Names , Common Names and Rates of Herbicides Used.

| Trade Name | Common Name | Rates lbs ai/ A |
|---|---|---|
| Gallery 75 DF | isoxaben | 1.0 and 4.0 |
| Gallery 0.5 G/KMg | isoxaben coated fertilizer | 1.0 and 4.0 |
| Snapshot 2.5 TG | trifluralin + isoxaben | 2.5 and 10.0 |
| Rout 3.0 G | oxyfluorfen + oryzalin | 3.0 and 12.0 |
| Regal 00 | oxadiazon + oxyfluorfen | 3.0 and 12.0 |

Table 3. Early Injury Following Preemergence Herbicide Application on Selected Herbaceous Perennial

% Injury

| Herb | Rate lb ai | Bol[Z] | ChB | Par | Hib | Phl | Rud | Gau | ChS | Tia | Ver |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gall | 1.0 | 11[Y] | 23 | 3 | 0 | 0 | 8 | 0 | 47 | 5 | 40 |
| Gall | 4.0 | 8 | 50 | 5 | 0 | 18 | 11 | 2 | 93 | 2 | 43 |
| Gall/ Kmg | 1.0 | 2 | 5 | 0 | 0 | 0 | 1 | 6 | 20 | 1 | 13 |
| Gall/ Kmg | 4.0 | 5 | 19 | 2 | 0 | 0 | 3 | 4 | 64 | 7 | 24 |
| Kmg | 4.0 | 8 | 2 | 11 | 0 | 2 | 0 | 3 | 14 | 0 | 4 |
| Snap shot | 2.5 | 6 | 4 | 6 | 0 | 0 | 2 | 4 | 21 | 2 | 12 |
| Snap shot | 10.0 | 17 | 24 | 3 | 0 | 5 | 2 | 2 | 51 | 0 | 12 |
| Rout | 3.0 | 12 | 17 | 8 | 0 | 0 | 13 | 4 | 32 | 4 | 7 |
| Rout | 12.0 | 22 | 34 | 12 | 0 | 2 | 21 | 8 | 94 | 6 | 11 |
| ∞ | 3.00 | 18 | 8 | 7 | 0 | 5 | 8 | 2 | 32 | 5 | 7 |
| ∞ | 12.0 | 30 | 25 | 9 | 0 | 2 | 14 | 8 | 56 | 11 | 9 |
| Untrt | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LSD | | 12[X] | 14 | 8 | 0 | 15 | 6 | 10 | 42 | 6 | 17 |

[Z] - Bol=Boltonia, ChB=Chrysanthemum 'Becky', Par=Pardancanda, Hib=Hibiscus, Phl=Phlox, Rud=Rudbeckia, Gau=Gaura, ChS=Chrysanthemum 'Snow Lady', Tia-Tiarella, Ver=Veronica

[Y]- % injury 0= no injury, 100=crop dead.Rating date 3/14/96 for Hib and ChS, all others 12/4/95

[X] - Least significant difference at P=0.05 for each species.

Table 4. Late Injury Following Preemergence Herbicide Application on Selected Herbaceous Perennials

% Injury

| Herb | Rate lb ai | Bol | ChB [z] | Par | Hib | Phl | Rud | Gau | ChS | Tia | Ver |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gall | 1.0 | 0[Y] | 39 | 0 | 0 | 16 | 20 | 0 | 60 | 57 | 47 |
| Gall | 4.0 | 0 | 77 | 0 | 0 | 25 | 29 | 0 | 96 | 63 | 96 |
| Gall/ Kmg | 1.0 | 0 | 14 | 0 | 20 | 0 | 6 | 0 | 40 | 26 | 21 |
| Gall/ Kmg | 4.0 | 0 | 34 | 0 | 0 | 15 | 20 | 0 | 73 | 59 | 53 |
| Kmg | 4.0 | 0 | 10 | 0 | 20 | 22 | 0 | 0 | 34 | 22 | 8 |
| Snap shot | 2.0 | 0 | 14 | 0 | 43 | 32 | 2 | 0 | 40 | 41 | 25 |
| Snap shot | 10.0 | 0 | 19 | 0 | 70 | 67 | 11 | 0 | 64 | 56 | 30 |
| Rout | 3.0 | 0 | 6 | 0 | 30 | 19 | 25 | 0 | 58 | 68 | 13 |
| Rout | 12.0 | 0 | 65 | 0 | 70 | 62 | 62 | 0 | 97 | 98 | 25 |
| ∞ | 3.00 | 0 | 15 | 0 | 40 | 12 | 14 | 0 | 35 | 82 | 4 |
| ∞ | 12.0 | 0 | 62 | 0 | 93 | 23 | 38 | 0 | 75 | 100 | 4 |
| untrt | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LSD | | 0[X] | 22 | 0 | 39 | 36 | 9 | 0 | 36 | 29 | 24 |

[Z] - Bol=Boltonia, ChB=Chrysanthemum ‘Becky’, Par=Pardancanda, Hib=Hibiscus, Phl=Phlox, Rud=Rudbeckia, Gau=Gaura, ChS=Chrysanthemum ‘Snow Lady’, Tia-Tiarella, Ver=Veronica

[Y]- % injury 0= no injury, 100=crop dead. Rating dates were 4/18/96 or 4/26/96.

[X] - Least significant difference at P=0.05 for each species.

# Different Combinations of Preemergence Herbicides for Weed Control in Container Grown Plants

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**South Carolina**

**Nature of Work**: In the nursery industry, preemergent granular herbicide combinations are the standard, such as Rout (oxyfluorfer + oryzalin) and Snapshot (isoxaben + trifluralin). Herbicide combinations usually increase the spectrum of weeds controlled and may increase the longevity of activity. New combinations are becoming available such as Stakeout + Goal (dithiopyr + oxyflourfer), and Regal's OO which is Ronstar + Goal (oxadiazon + oxyfluorfen). Stakeout has been shown to control ivyleaf morningglory, large crabgrass, and have some control on velvetleaf and barnyard grass (1). Ronstar is effective on several weedy species including Goosegrass, Crabgrass, Velvetleaf, and other annual broadleaves. However, little information is available concerning efficacy with these herbicides in combination with Goal which is said to control groundsel, woodsorrel, and bittercress (2).

This study evaluated herbicide combination effectiveness on four common weeds that cause problems in the nursery industry. The research was conducted at Carolina Nurseries in Moncks Corner, S.C. The weeds tested were groundsel *(Senecio vulgaris)*, creeping woodsorrel *(Oxalis corniculata)*, hairy bittercress *(Cardamine hissuta)*, annual bluegrass *(Poa annua)*. The four landscape plants evaluated were *Clethera alnifolia* 'Hummingbird', *Euonymus japonicus* 'Aureo marginata', *Ilex cornuta* 'Burfordii Nana', *Hydranga paniculata* 'Grandiflora'. All plants were grown in the 1 gallon pots with a fertilizer/lime amended media (80% pine bark, and 20% sand). Individual weeds were seeded on October 26, 1995 in the pots, one per landscape species. Germination started on November 5, 1995 in the untreated controls.

Four herbicides combinations were applied on October 17, 1995 using pre-measured packets in a hand held shaker can. Each herbicide was evaluated at three rates. The rates for the Stakeout/Goal combination were 1.0/2.0, 1.5/3.0, and 2.0/4.0 lb ai/A. Regal OO and Rout were applied at 3.0, 4.5, and 6.0 lb ai/A. The rates for Snapshot TG were 2.5, 3.75, 5.0 lb ai/A. A randomized complete block design was used for each species with 6 single plant replications. Visual ratings were made on a scale of 0 to 100 with 0 = no injury or control and 100 = complete kill or control. Data was subjected to analysis of variance and means were separated by LSD at P = 0.05.

**Results and Discussion:** All rates of Stakeout + Goal gave excellent control (> 92%) of annual bluegrass throughout the 60 day period. Groundsel control was less than 75% at 30 days but by 60 days control improved to greater then 95%. Creeping woodsorrel and bittercress also were controlled effectively with greater than 93% and 97% rating, respectively, by 60 days after treatment. Other studies have shown that Stakeout alone has shown to control broadleaf weeds and grasses with 96% at 2 lb ai/A (3). This combination was more effective on all four weed species than the other herbicide combinations.

Regal's OO was not as effective in reducing annual bluegrass with the highest rate providing only 83% control. Groundsel also was controlled ineffectively with this combination with the highest rate giving 82% control. OO did control (92%) creeping woodsorrel at all rates and bittercress was controlled at the higher rates.

The lower two rates of Rout were ineffective for annual bluegrass and groundsel control. Rout at the highest rate (2x) provided > 98% control for annual bluegrass and > 82% control of groundsel. All rates of Rout were effective for creeping woodsorrel and bittercress with > 89% control.

Annual bluegrass was controlled effectively with only the highest rate (2X) of Snapshot TG. Groundsel control was below 75% at 60 days for the low (1X) rate of Snapshot. The higher rates provided > 88% control of groundsel. Effective creeping woodsorrel control (82%) was found with the 1X and 1.5X Snapshot rates but controlled was not as effective with the 2X rate. Bittercress was controlled effectively (92%) with all rates of Snapshot TG at the 60 day evaluation period.

**Significance to Industry:** The Stakeout/Goal combination was the most effective on all four weed species. Hopefully, Rohm-Haas will rapidly develop this product for use in nurseries and landscapes. The 2X rate of Rout, Regal's OO and Snapshot was effective on all four weed species but care should be taken when using rates higher than the label rates.

## Literature Cited


1. Weston, L.A. and N. Setyowati. 1993. Activity and Selectivity of Dithiopyr (Stake-out) for Control in Woody Ornamentals.Proc. SNA Res. Conf. 38:332-336.

2. Skroch, W.A. Weed Control Suggestions for Christmas Trees, Woody Ornamentals, and Flowers. North Carolina State University, North Carolina Cooperative Extension Service.

3. McNiel, R.E. and L.A. Weston. 1990. Split applications of Herbicides for Weed Control in Woody Nursery Plants. Proc. SNA Res. Conf. 35:255-257.

Table 1. Trade and Common Names of Herbicides in this Study

| Trade Name | Common Name | % Active Ingredients |
|---|---|---|
| Stakeout + Goal | dithiopyr + oxyfluorfen | 0.25 + 2.0 |
| Regal OO | oxadiazon + oxyfluorfen | 2.0 + 2.0 |
| Rout | oxyfluorfen + oryzalin | 2.0 + 1.0 |
| Snapshot TG | isoxaben + trifuralin | 0.5+ 2.0 |

Table 2. Percent Winter Weed Control From Preemergence Herbicide Combination 30 days after treatment/60 days after treatment

| Herbicide | Rate lb. ai/A | % Control Poa[Z] | Senecio[Z] | Oxalis[Z] | Cardamine[Z] |
|---|---|---|---|---|---|
| Stakeout + Goal | 1+ 2 | 95 ab[Y] | 52ab | 97a | 99a |
| Stakeout + Goal | 1.5 + 3.0 | 93ab | 75a | 100a | 100a |
| Stakeout + Goal | 2.0 + 4.0 | 100a | 63a | 100a | 100a |
| Regal OO | 3.0 | 48d | 3cd | 92ab | 70b |
| Regal OO | 4.5 | 54cd | 22cd | 98a | 92a |
| Regal OO | 6.0 | 60cd | 60a | 98a | 94a |
| Rout | 3.0 | 53cd | 32bc | 100a | 97a |
| Rout | 4.5 | 77abc | 28bcd | 95a | 97a |
| Rout | 6.0 | 97ab | 62a | 99a | 89a |
| Snapshot TG | 2.5 | 66cd | 15cd | 91ab | 88a |
| Snapshot TG | 3.75 | 58cd | 13cd | 88ab | 94a |
| Snapshot TG | 5.0 | 73bcd | 27bcs | 82b | 96a |

[Z] = *Poa annua* (annual bluegrass), *Senecio vulgaris* (groundel), *Oxalis corniculata* (creeping woodsorrel), *Cardamine hirsuta* (hairy bittercress).

[Y] = Ratings based on a scale of 0 to 100 with 0 = no control and 100 = complete control. Means within a column followed by different letters are different by LSD at P=0.05.

Table 3. Percent Weed Control From Preemergence Herbicide Combinations 60 days After Treatment.

| | | % Control | | | |
|---|---|---|---|---|---|
| Herbicide | Rate lb. ai/A | Poa[Z] | Senecio[Z] | Oxalis[Z] | Cardamine[Z] |
| Stakeout + Goal | 1+ 2 | 95 a[Y] | 100ab | 93abc | 100a |
| Stakeout + Goal | 1.5 + 3.0 | 96a | 100a | 100a | 100a |
| Stakeout + Goal | 2.0 + 4.0 | 100a | 97a | 100a | 100a |
| Regal OO | 3.0 | 70bc | 33cd | 92abc | 76c |
| Regal OO | 4.5 | 75bc | 66cd | 98ab | 97ab |
| Regal OO | 6.0 | 83ab | 82a | 93abc | 96ab |
| Rout | 3.0 | 64c | 74bcd | 100a | 98ab |
| Rout | 4.5 | 87ab | 64cd | 93abc | 98ab |
| Rout | 6.0 | 98a | 85abc | 100a | 95ab |
| Snapshot TG | 2.5 | 83ab | 73bcd | 86bcd | 92b |
| Snapshot TG | 3.75 | 73bc | 90ab | 83cd | 91b |
| Snapshot TG | 5.0 | 86ab | 88ab | 78d | 95ab |

[Z] = *Poa annua* (annual bluegrass), *Senecio vulgaris* (groundel), *Oxalis corniculata* (creeping woodsorrel), *Cardamine hirsuta* (hairy bittercress).

[Y] = Ratings based on a scale of 0 to 100 with 0 = no control and 100 = complete control. Means within a column followed by different letters are different by LSD at P=0.05.

# Seed Germination of Two Provenances of Atlantic White Cedar as Influenced by Stratification, Temperature, and Light

**Laura G. Jull, Frank A. Blazich, and L. E. Hinesley**
**North Carolina**

**Nature of Work:** Atlantic white cedar [*Chamaecyparis thyoides* (L.) B. S. P.] has a wide distribution occurring in a narrow belt along the northeastern and southeastern coasts of the U. S. extending west along the Gulf Coast (6). Because of several desirable properties, the wood is highly prized and used for a variety of purposes from house siding to outdoor furniture. This evergreen tree also has the potential for wetlands reclamation and as an ornamental and Christmas tree. Understocks from Atlantic white cedar can also be used to graft superior cultivars of other species of Chamaecyparis Spach (9).

Throughout its range, natural stands of Atlantic white cedar are diminishing rapidly. Acreage of white cedar in North Carolina alone has declined by as much as 90% within the last 2 centuries (4). Stands are diminishing due to extensive drainage, agricultural clearing, wildfires, and logging. This destruction has been followed by inadequate regeneration measures and changes to hydrology of the land. Reproduction of Atlantic white cedar is primarily through natural seeding with some sprouting occurring in areas browsed heavily by deer. However, white cedar usually fails to regenerate naturally after logging when no measures are taken to control competing vegetation (8).

Due to extensive reclamation efforts, there is increasing demand for transplants of Atlantic white cedar. However, methods of production, such as sexual propagation, have not been widely utilized due in part to lack of published protocols regarding such practices. Therefore, the objectives of this research were to examine the influence of stratification (moist-prechilling), temperature, and light on seed germination of two provenances of Atlantic white cedar.

Mature cones of two provenances (Wayne Co., N. C. and Escambia Co., Al.) of Atlantic white cedar were collected from open pollinated trees in Fall 1994. Cones were then dried for 2 months, followed by seed extraction, and storage in sealed glass bottles at 4°C (39°F).

In June 1995, seeds were removed from storage and graded initially with the use of an air column (General Seed Blower-Model ER, Seedburo Intl. Equip. Co., Chicago, Ill.). Abnormal, damaged, undersized or discolored seeds and other large debris, not eliminated by the air column, were removed manually. Graded seeds selected for the research were firm with a dark brown color.

Graded seeds were then stratified for 0, 30, 60 or 90 days at 4°C (39°F) in moistened sand. After the designated stratification interval, seeds from each provenance were removed from stratification and sown in covered, 9-cm (3.5 in) glass petri dishes (100 seeds per dish), each dish containing two prewashed (rinsed) germination blotters moistened with tap water. All dishes were placed in black sateen cloth bags and allowed to imbibe overnight at 21°C (70°F). The following day, bags were randomized within three growth chambers [C-chambers (3)] maintained at 25°C (77°F) or at 8/16 hr thermoperiods of 25°/15°C (77°/59°F) or 30°/20°C (86°/68°F). Chamber temperatures varied within ± 0.5°C (0.9°F) of the set point.

Within each temperature regime, seeds were subjected daily to the following photoperiods: total darkness, 1/2, 1, 2, 4, 8, 12, or 24 hr. Regardless of stratification and temperature, photoperiod treatments were administered the same time each day. All photoperiod treatments for the alternating temperatures of 25°/15°C (77°/59°F) or 30°/20°C (86°/68°F), with the exception of total darkness and 24 hr, began with the transition to the high temperature portion of the cycle.

Growth chambers were equipped with cool-white fluorescent lamps that provided a photosynthetic photon flux (400-700 nm) of 27-36 μmol·m-2·s-1 (2.1-2.7 klx) as measured at dish level. All photoperiod treatments, except total darkness and 24 hr, were regulated by removal and placement of the petri dishes in black sateen cloth bags. For the 24 hr photoperiod treatment, the petri dishes remained continuously unbagged in open chamber conditions. Regardless of the photoperiod, temperatures within the petri dishes never exceeded ambient temperature by more than 1°C (2°F). The constant darkness treatment was maintained by keeping the petri dishes in the black cloth bags throughout the experiment and all watering and germination counts were performed in a darkroom utilizing a green safelight. Germination blotters were kept moist with tap water throughout the duration of the experiment. Seeds showing signs of decay were removed immediately from the dishes.

For each provenance, all treatments were replicated four times with a replication consisting of a petri dish containing 100 seeds. Germination counts were recorded every 3 days for 30 days. A seed was considered germinated when radicle emergence was ≥ 1 mm (0.04 in). Percent germination was calculated as a mean of four replications per treatment. Data were subjected to analysis of variance and regression analysis.

**Results and Discussion:** Germination of the Alabama provenance was greater than the North Carolina provenance for all treatments (74% vs. 46%). However, germination of species of Chamaecyparis has been reported to be inherently low, due in part to poor seed quality and also to various degrees of embryo dormancy (10). Variation in seed germination of New Jersey provenances of Atlantic white cedar has been reported to range from a high of 70%-90% (6) to a low of 3%-25% (7).

For each provenance, there were no significant differences between 25°/15°C (77°/59°F) and 30°/20°C (86°/68°F) with regard to total percent germination at all durations of stratification. Regardless of stratification, germination was lowest at 25°C (77°F) for each provenance. This is similar to a report by Hartmann et al. (5) that germination of seeds of warm temperature requiring and cool temperature tolerant species is optimized by using alternating temperatures of 30°/20°C (86°/68°F). Similarly, Bianchetti et al. (1) reported greater germination of stratified seeds of Atlantic white cedar at an alternating temperature of 30°/20°C (86°/68°F) versus constant temperatures of 23°C (73°F) or 26°C (79°F). In some cases, however, there were no significant differences in germination of the North Carolina provenance when stratified for 60 or 90 days and germinated at 30°/20°C (86°/68°F) or 25°C (77°F) (60% vs. 58% and 66% vs. 63%, for days 60 and 90, respectively). Although germination data were recorded for 30 days, germination was essentially complete by day 18 for all treatment combinations.

There was a highly significant quadratic response ($P \leq 0.001$) to stratification for cumulative germination of both provenances, except at day 6 for the North Carolina provenance ($P \leq 0.01$). The North Carolina provenance required 90 days stratification to maximize germination (66%) in contrast to the Alabama provenance which only needed 30 days (80%). Boyle and Kuser (2) stratified seeds of Atlantic white cedar at 4°C (39°F) for 30, 60, or 90 days. They reported no significant differences between 30 and 60 days stratification with germination of 44%. However, their data for the 90 day stratification treatment could not be analyzed statistically because of seed decay.

With regard to light, Little (7) "reported a fair amount of light, probably to provide heat, is desirable for obtaining good seed germination of white-cedar." In the present study, seeds of both provenances of white cedar did not exhibit an obligate light requirement. However, a photoperiod of only 1/2 hr daily increased germination greatly over seeds in darkness (29% vs. 62%). This is in contrast to data reported by Boyle and Kuser (2) where seeds of white cedar from New Jersey provenances germinated under a 16 hr photoperiod (32%) with negligible germination under a 10 hr photoperiod (0.7%). At 25°C (77°F), both provenances exhibited lower germination than at 25°/15°C (77°/59°F) or 30°/20°C (86°/68°F) regardless of photoperiod and stratification. There were no significant differences in germination at 30°/20°C (86°/68°F) or 25°/15°C (77°/59°F) at all photoperiods except at 0 and 1 hr.

**Significance to Industry**: Data herein indicate that the germination requirements of an Alabama versus a North Carolina provenance of Atlantic white cedar are different. Thus, light, temperature, and stratification treatments needed to maximize germination will vary depending on the provenance. Stratification for 30 days utilizing alternating temperatures of 30°/20°C (86°/68°F) or 25°/15°C (77°/59°F) and daily photoperiods as short as 1/2 hr are needed to maximize germination of seeds from Alabama whereas to achieve maximum germination of seeds from North Carolina, stratification of 60 or 90 days is required along with alternating temperatures and a 1/2 hr photoperiod daily. Seed viability of Atlantic white cedar may be low , thus requiring rigorous seed grading prior to sowing. Nurserymen are cautioned not to cover the seeds following sowing since they are relatively small and require light to maximize germination.

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# Shade Level, Wind Speed, and Wind Direction Affect Air Temperatures Inside Model Shade Structures

**Svoboda V. Vladimirova, Dennis B. McConnell and Ray A. Bucklin**
**Florida**

**Nature of Work:** Shade cloth is widely used in the nursery industry to reduce solar radiation to levels that promote optimal plant growth (Yates,1989). Over the past decade, a limited amount of research has focused on modifications of environmental conditions inside shade structures. Temperature data under shade cloth (Colombo and Cameron,1988; Willits,1992) and interactions between shade cover and air movement in greenhouse environments (Willits,1992) have shown shade cloth may affect temperature as well as light levels. Preliminary research in Florida has shown air temperatures under 80% shade fabric may exceed air temperatures under 50% shade. This study investigated the effects of four shade levels using black woven polypropylene shade cloth on air temperatures in model shade structures. Effects of wind speed and direction on air temperature were also studied. The objectives were twofold: a) to determine the effects of shade level, wind speed and wind direction on air temperature inside small shade structures, and b) to determine the variability of air temperatures inside small shade structures covered with shade cloth with different light transmission properties. The investigation was conducted at the Environmental Horticulture Greenhouse complex, University of Florida. Twenty four arch-shaped shade structures (6.0ft (1.85m) x 2.6ft (0.8m) x 2.6ft (0.8m) - length x width x height) were placed with their longitudinal axis oriented north-south. Shade structures consisted of polyvinyl (PVC) pipe frame covered with commercial shade fabric with three shade factors: 47%, 63% and 80%. In addition, 63% and 80% shade fabrics were combined to obtain a shade factor of 91%. Each shade treatment was replicated six times. Light intensity and air temperature were monitored in twelve randomly selected units, with three replicates for each shade treatment. Light intensity levels were measured using PAR sensors and air temperatures were measured using copper-constantan thermocouples (AWG No.20). A cup anemometer and a wind direction indicator were used for measuring wind speed and wind direction. A datalogger recorded readings for all environmental sensors on an hourly basis. As a part of the study, water-measuring cups were placed in the shade structures to determine the amount of water from natural precipitation and an overhead sprinkler system under different shade fabrics.

**Results and discussion:** A total of 30, 24-hourly observations were made during August, 1994, and 480 observations (20 days, 24 a day) recorded August 8 to August 27 were analyzed. A complete desription of statistical methodology has been previously published (Vladimirova, 1996). The model included shade level, wind speed, wind direction, and hour as independent variables. Wind direction was grouped in four levels. Wind speed was divided in three groups: from 0 to 11.2 mph (5 m/s) - MILD, from 11.3 mph (5.1 m/s) to 22.4 mph (10 m/s) - MODERATE, and above 22.4 mph (10 m/s) - STRONG. HOUR had 13 groups (6 A.M.-6 P.M.). Air temperatures and temperature differentials calculated by the least squares means procedure were analyzed (Table 1).

The two way interaction terms included in the model - WS*SHADE, WD*SHADE, and WS*WD, as well as higher order interactions were not significant at the 0.05 level. Least significant means for HOUR were all significantly different at the 0.001 probability level except at 6 A.M. and 7 A.M. which did not differ.

Table 1. Least significant temperature means generated by SAS for the independent variables SHADE, WIND SPEED and WIND DIRECTION for a 20 day period (August 8 to August 27, 1994). The time periods: 6 A.M.- 6 P.M. was used for analysis of air temperature, and 10 A.M.- 3 P.M. - for temperature difference above ambient.

| | | DEPENDENT VARIABLE | |
|---|---|---|---|
| INDEPENDENT VARIABLE | LEVELS | AIR TEMPERATURE F°(°C) | TEMPERATURE DIFFERENCE ABOVE AMBIENT F° (°C) |
| SHADE | 47% | 80.1 (26.7) a* | 2.3 (1.31) a |
| | 63% | 82.0 (27.8) a[V] | 3.0 (1.65) a |
| | 80% | 82.6 (28.1) b | 3.2 (1.85) a |
| | 91% | 82.0 (27.8) a | 2.2 (1.22) a |
| WIND SPEED | MILD | 82.2 (27.9) a | 1.8 (0.99) a |
| | MODERATE | 81.0 (27.2) b | 2.2 (1.25) ab |
| | STRONG | 83.3 (28.5) c | 2.4 (1.36) b |
| WIND DIR | NS(SN*) | 82.8 (28.2) b[d] | 2.3 (1.31) ab |
| | EW(WE) | 82.2 (27.9) a | 2.9 (1.59) a |
| | SENW(NWSE) | 82.2 (27.9) a | 1.7 (0.95) c |
| | SWNE(NESW) | 81.3 (27.4) c | 2.5 (1.39) b |

* Within each variable level (SHADE, WIND SPEED etc.) means followed by the same letter are not significantly different at the 0.05 level.

[V] Means separation were made by Tukeyís procedure.

[d] Winds from both directions (e.g. north-south and south-north were analyzed).

Air temperatures inside the shade structures were affected by shade levels (Table 1). Eighty percent shade had higher temperatures compared to other shade levels, which did not differ statistically. The difference between 80% (hottest) and 47% (coolest) shade averaged 2.5°F (1.4°C). The data also revealed that air temperatures exceeded 104°F (40°C) 16 times under 80% shade, 8 times under 91% shade, 3 times under 63% shade, and 1 time under 47% shade.

Solar radiation affected temperature differentials inside shade structures more than wind speed, wind direction or shade levels. Temperature recordings for August 10, a typical August day, showed specific daily events that would be masked by weekly or monthly means (Fig. 1). Air temperature rose rapidly from 8 A.M. to noon, peaked at 2 P.M. and decreased during late afternoon. Highest air temperatures under all shade levels occurred between noon and 2 P.M. Ambient air temperature (0% shade) was lower than air temperatures within all shade structures. Air temperatures in 91% shade from noon-2 P.M. were 1.8 - 3.6°F (1-2°C) lower than air temperatures in 47%, 63% and 80% shade. Light intensity data outside the structures, showed maximum light levels between 455-500 W/m2. On August 15, air temperatures, inside and outside the shade structures did not exceed 77°F (25°C) and remained constant in all shade structures with the exception of 47% shade which fluctuated slightly (Fig. 2). Light intensity data outside the shade structures showed maximum light levels between 200-260 W/m2. Large changes in incident radiation have profound effects on temperatures under shade. The reduced solar radiation minimized air temperature differentials between shade structures and ambient temperatures.

Wind speed affected temperature differentials between shade levels and ambient temperature (Figs. 3-4). When winds were mild, predominantly diagonal and perpendicular to the shade structures (August 17 - Fig. 3), temperature differentials between shade and ambient were positive. This situation occurred from 10 A.M. until 3 P.M., when an afternoon thunderstorm began. Temperature differentials between the four shade levels were greatest on August 13th at 2 P.M. when 80% shade was 10.8°F (6°C) above ambient, 63% - 7.2°F (4°C) above ambient, 91% - 5.4°F (3°C) above ambient, and 47% - 3.6°F (2°C) above ambient. An interesting trend was observed following an afternoon thunderstorm on August 17th. When wind speed was mild, temperature differentials went from +3.2°F (1.8°C), +3.6°F (2°C), +5.4°F (3°C) and +7.2°F (4°C) for 47%, 91%, 63% and 80% shade, respectively, at 3 P.M. to almost -5.4°F (3°C) at 4 P.M. By 5 P.M., 80% and 91% shade temperatures were essentially equal to ambient, while 47% and 63% shade remained below ambient. On August 17th, when winds were moderate (Fig. 4), the same afternoon event had a less pronounced effect on temperature differentials. At 4 P.M. all shade levels had temperature differences of -0.9°F (0.5°C) to -1.8°F (1°C). Temperatures increased in all shade structures and were above ambient at 6 P.M., with 91% shade having the highest differential of +2.7°F (1.5°C). These variations in temperature differentials can best be explained in terms of radiant hear transfer. Shade fabric absorbs solar radiation and re-emits it as infrared radiation, elevating temperatures. This explanation is substantiated by nighttime air temperatures, whose nonsignificantly different mean values were 75°F (23.9°C) in 80%, 75.4°F (24°C) in 63%, 75.4°F (24.1°C) in 47% and 75.6°F (24.2°C) in 91% shade. Thus heat transfer was greatest in 80% shade.

Winds with speeds exceeding 22.4 mph (10m/s) were usually recorded when ambient temperatures were high. Although wind speeds were occasionally high in the early morning hours, wind speeds in excess of 22 mph (10m/s) occurred predominantly in the afternoon, usually prior to a thunderstorm. Consequently, correlations between wind speeds and air temperatures reflect Florida summer weather patterns, rather than linked effects, i.e. when winds are strong, temperatures will be highest. Air temperature differentials from ambient were significantly influenced by wind speed. Analysis of the time between 10 A.M. and 3 P.M. (Table 1), indicated the smallest deviations from ambient temperature occurred during mild wind speed (0-11.2 mph - MILD). Temperature differentials between the three wind speed groups were less than 1.8°F (1°C). Wind direction also had an effect on air temperatures. It was anticipated that air temperatures would be highest when winds were perpendicular and/or diagonal to the long axis of the shade structures (EW, SE, SW, NE, NW) and lowest when winds were axial (NS). The open design of the shade structures, would permit north-south (axial) winds to pass freely through the structure and negate shade cloth effects on air temperatures. Winds from other directions (east-west, etc.), were expected to result in higher temperature differences where the shading factor was high (80% and 91%). The same winds were expected to produce lower temperature differences in shade structures with 47% and 63% shade. Contrary to expectations, north or south winds were associated with highest air temperatures. Winds from SENW were associated with the lowest temperature differential (+1.7°F (0.95°C)). Again, heat transfer may offer an explanation. Shade fabric would be coolest when winds were perpendicular or diagonal and hottest when winds were axial.

The percent of water allowed through the shade fabric was related to the percent of physical blockage provided by the material. The expected amounts of irrigation allowed through the different shade cloths were as follows: 47% shade cloth - 53% of the water, 63% shade cloth - 37% of the water, 80% shade cloth - 20% of the water, and 91% - 9% of the water. The amount of water collected from an outside measuring cup was considered 100%. With the exception of 80% shade, which permitted 13% in excess of the expected 20%, and 47% shade - 4% excess, the percent of water allowed through was as expected.

**Significance to the industry:** Our findings agree with Bucklinís (1987) interpretation that shade cloth with higher shade factors (in this study 80% shade) restricts the airflow and produces higher air temperatures. Based on our results and contrary to the believed cooling factor of shade cloth above 50%, we recommend that activities conducted in these structures be scheduled for early morning hours. If hoop shadehouses are used, cooler air temperatures are to be expected if the orientation of the structure is perpendicular to the prevailing winds. In addition, growers should be aware that a hoop shadehouse providing shade levels above 50%, allows less natural precipitation to reach the crops compared to similar structures covered with less than 50% shade.

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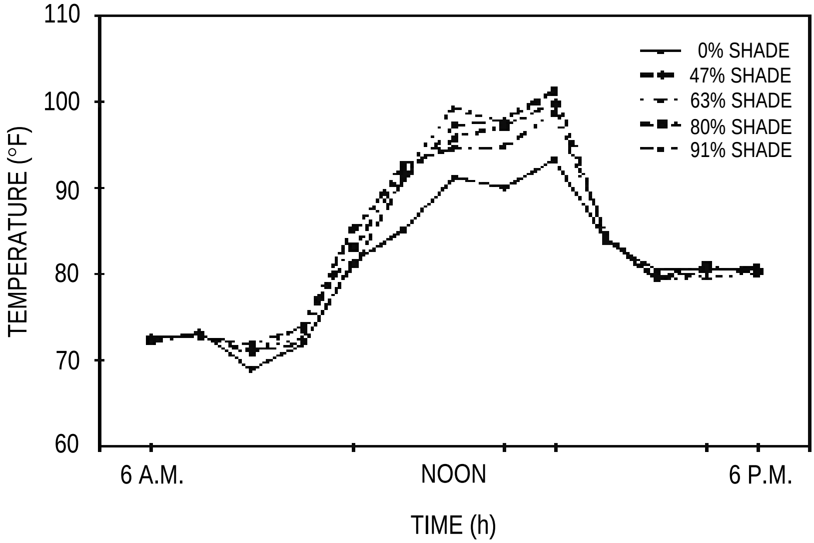


Figure 1 - Air temperature inside shade structures for August 10, 1994. 0% shade represents ambient air temperature.

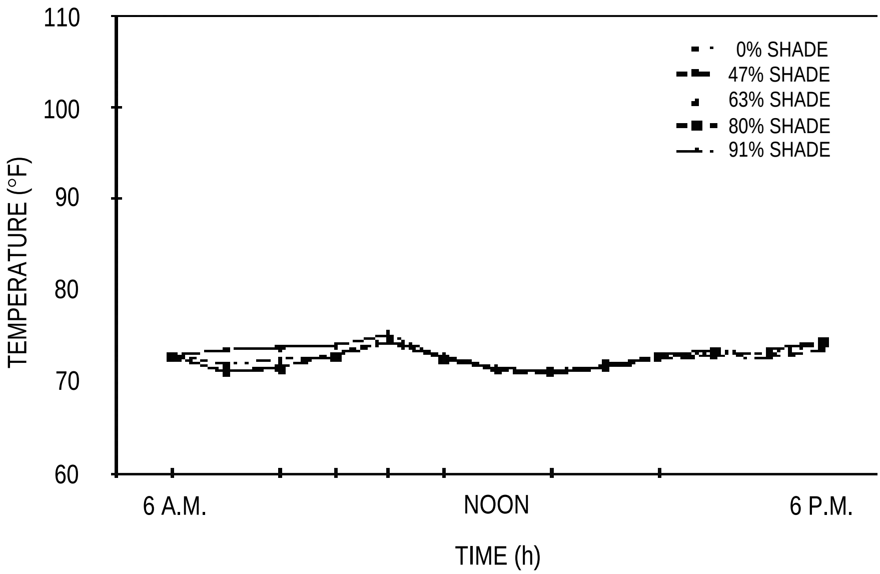


Figure 2 - Air temperature inside shade structures for August 15, 1994. 0% shade represents air temperature.

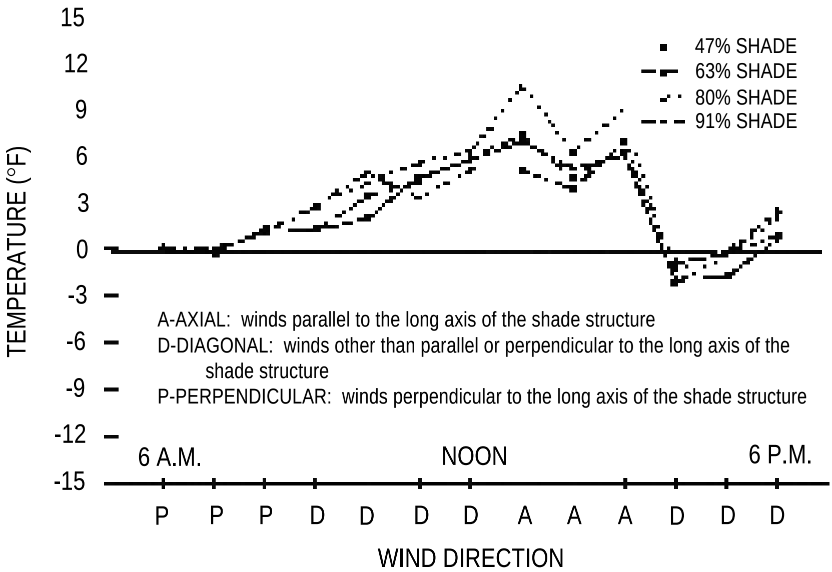


Figure 3 - Differences between air temperatures under four shade levels and ambient (O-line). August 17th, 1994 - wind speed predominantly mild. X-axis represents wind direction at that particular hour.

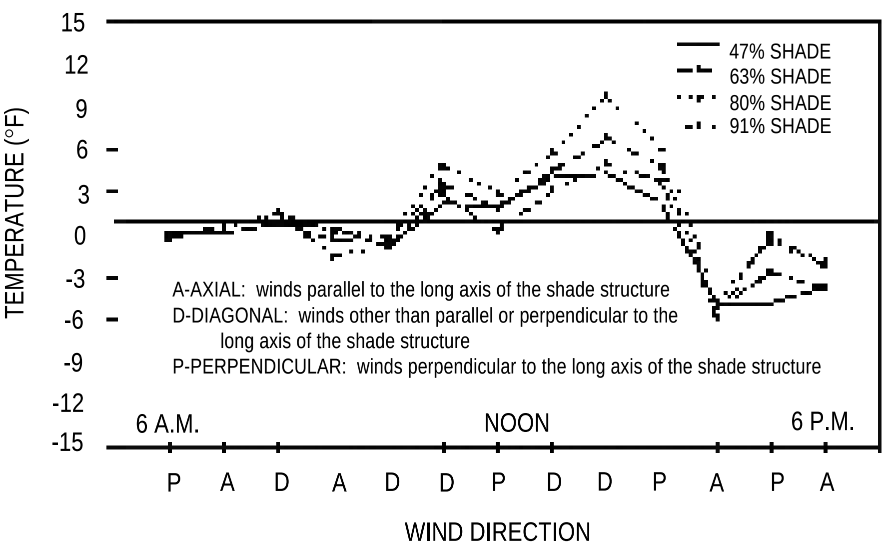


Figure 4 - Differences between air temperatures under four shade levels and ambient (O-line). August 13th, 1994 - wind speed predominantly moderate. X-axis represents wind direction at that particular hour.

# Production Method and Irrigation Affect Post-Planting Root Morphology of *Quercus virginiana*.

**Michael D. Marshall and Edward F. Gilman**
**Florida**

**Nature of work:** Landscape trees are commonly produced in containers, or are field-grown and balled and burlapped (B&B) when harvested. Limited research has been done comparing root systems of these two production methods after transplanting. Blessing and Dana (2) found that after sixteen weeks, field-grown (FG) *Juniperus chinensis* L. had significantly more new root dry weight than container-grown (CG), whereas there was no difference in shoot growth. In a similar experiment, there were no differences in root number or root dry weight between CG and FG *Thuja occidentalis* L., 40 days after transplanting (4). Using three species, Harris and Gilman (9) found that ten weeks after transplanting FG trees had greater root extension than CG trees. Laiche et. al. (10) showed that, five years after transplanting, height, caliper, and number of roots were not different between production methods for pecan [*Carya illinoensis* (Wang) K. Koch].

Rooting depth is largely influenced by cultural and environmental conditions (1). Research has shown that 99% of tree roots are found in the top 90 cm (35.4 in) of soil (3). Laiche et. al. (10) showed that roots of FG trees grew to a depth of 97 cm (38.2 in), significantly deeper than CG trees at 85 cm (33.5 in). The root system of FG pecan trees had good root distribution, while CG trees had a denser root mass of circling, thicker roots. A deep root system could be beneficial in dry or well-drained soil, since the deeper soil layers dry out slower than surface layers (6), thereby making more water available to the plant. Deep roots are important for tree support and water absorption (5). Deep root systems could become a disadvantage in poorly drained or compacted sites where deep roots would not receive enough oxygen (7).

In May 1992, ten container-grown (CG) and ten field-grown (FG) live oak (*Quercus virginiana*) trees were transplanted into sandy soil and established with frequent or periodic irrigation. The plot was laid out in a randomized block design of ten blocks, each containing one tree from each production method. Mean trunk diameter, 15 cm (6 in) from the soil, was 8.9 cm (3.5 in) and 9.9 cm (3.9 in), for CG and FG trees respectively. All 20 trees received 76 liters (20 gal) of irrigation daily for two weeks after planting, after which trees received either frequent or periodic irrigation. On the frequent irrigation schedule, five trees from each production method received irrigation daily weeks 3-22, then every other day from weeks 23-27. No irrigation was applied to these trees after week 27. Five trees from each production method, on the periodic irrigation schedule, were watered every other day from weeks 3-6, every third day from weeks 7-13, then weekly through week 18. Irrigation was discontinued after week 18 on periodically irrigated trees. Trees were grown for three years after transplanting, and were fertilized three times a year at a rate of 3 lbs. (1.4 kg) of nitrogen / 1000 $ft^2$ / year.

In June 1995, all 20 trees were cut off at ground level. Mean trunk diameter was 15.1 cm (6 in) and 17.3 cm (6.8 in) for CG and FG, respectively. Root systems were dug with a mechanical tree spade, which harvested a conical root ball measuring 1.5 m (60 in) wide by 1.0 m (40 in) deep. Root balls were turned upside down to allow for easy access to the roots. They were divided into four depth classes: soil surface to 25 cm (9.8 in) deep, 25-50 cm (9.8-19.7 in) deep, 50-75 cm (19.7-29.5 in) deep, and 75-100 cm (29.5-39.3 in) deep. Roots were grouped by root diameter into seven classes: 3-5 mm, > 5-10 mm, > 10-15 mm, > 15-20 mm, > 20-25 mm, > 25-30 mm, and > 30 mm. Roots ≥ 3 mm (0.12 in) that intersected the perimeter of each root ball were counted and cut 3 cm (1.2 in) back from the perimeter. Using the cut portion of the root, a clean cross-section was traced onto vellum paper from which the root cross-sectional area was calculated with a Delta T area meter (Decagon Instruments, Pullman, WA).

**Results and Discussion:** Production method and soil depth each had a significant effect on root area, as did the interaction between the two. FG trees had greater root cross-sectional area than CG trees in the 0-25 cm and 75-100 cm soil depths. The 50% greater total root area of FG trees was accounted for in the 0-25 cm and 75-100 cm soil depth. Laiche et. al. (10) also found that FG trees had deeper root systems than CG.

The three way interaction, production method x irrigation x soil depth, was significant only because at the 25-50 cm soil depth root cross-sectional area for FG trees receiving frequent irrigation was less than FG trees periodically irrigated. This represents the only significant irrigation effect on root cross-sectional area. Gilman et. al. (8), using *Ilex cornuta* ‘Burfordii Nana’, showed a similar pattern of increased rooting deeper in the soil profile with infrequent irrigation.

More than two-thirds (69.3%) of the total root cross-sectional area over all treatments came from roots 5-20 mm in diameter. The only significant differences in root cross-sectional area between FG and CG trees were in these same size classes, accounting for the significant production method x root diameter interaction. Root cross-sectional area in these classes was greater than in the other diameter classes only in the 0-25 cm soil depth, accounting for the soil depth x root diameter interaction. There was a more uniform distribution of root cross-sectional area among root diameters deeper in the soil.

FG trees generated a greater number of roots than CG trees three years after transplanting. There was an interesting production method x irrigation interaction. Although FG trees under frequent or periodic irrigation had similar root numbers, CG trees had less roots with periodic irrigation than with frequent irrigation. Apparently the plant compensated for reduced root number by increasing root size, causing, overall root cross-sectional area to remain the same. Laiche et. al. (10) found that after five years there was no difference in root number between CG and FG pecan trees.

**Significance to Industry:** Trees that were root pruned, fertilized, and irrigated in a field-grown nursery produced greater root cross-sectional area and root number, three years after transplanting, than container grown trees. This might help FG trees establish more successfully in some landscape environments. FG trees also developed more roots deeper in the soil profile which could help them survive and grow in dry or well-drained landscape soils. CG trees developed less root cross-sectional area in the top 25 cm of soil than FG trees which could make them more suited for planting near sidewalks. Sensitivity of CG trees to dry conditions immediately after transplanting might be responsible for reduced root number. Therefore, regular irrigation after transplanting might be more important on CG plants than well prepared FG plants.

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# Sequential BA Applications Enhance Offset Formation in Hosta

**James M. Garner, Gary J. Keever, D. Joseph Eakes, and J. Raymond Kessler**
**Alabama**

**Nature of Work:** Vegetative buds of hosta grow from rhizomes, and the rhizomic apex appears to suppress outgrowth of axillary and rhizomic buds by apical dominance. Previous studies have demonstrated that application of the synthetic cytokinin BA induces the outgrowth of axillary and rhizomic buds in hosta (Keever, 1994), and offsets formed from BA-induced buds can be removed from the mother plant soon after elongation and rooted under intermittent mist (Keever et al., 1995). Propagators of hosta may wish to utilize hosta stock plants as a source for BA-stimulated offset cuttings, and harvest cuttings several times over a given season. The objective of this study was to determine the effects of multiple BA applications and subsequent repeated removal of BA-induced offsets on stock plant yield. On February 20, 1995, dormant, bare-root divisions of hosta cultivars 'Francis Williams' and 'Francee' were potted in 1-gallon containers in an amended pine bark /sand medium (6:1 by volume). Plants were grown under 47% shade and irrigated by overhead rotary nozzles twice daily for 30 minutes per application. On July 7, 1995, 50 single-eye (no offsets) plants of each cultivar were selected for uniformity, 40 of which received BA treatment. At 30 day intervals, the number of treated plants was reduced by 10, and BA was reapplied to the remaining plants. This resulted in 5 treatments consisting of 0, 1, 2, 3, or 4 BA applications with 10 single-plant replicates per treatment of each cultivar. At each application, plants were treated with 3000 ppm BA, with Buffer-X at 0.2% added to the BA solution as a surfactant prior to foliar application. Application at 2 qts./ 100 $ft.^2$ or approximately 0.18 fl. oz./ plant was made with a $CO_2$ sprayer fitted with a cone nozzle at 25 lbs./ $in.^2$.

At 30, 60, 90, and 120 days after initial treatment (DAT), visible offset count and a growth index [(height + width at widest point+ width 90° to first width)/3] were determined for each plant. Offsets present were removed from each plant, and offset stage of development, based on leaf number, was determined for each offset. Data were analyzed by analysis of variance using the SAS General Linear Model procedure, and single degree of freedom contrasts were used to make specific planned comparisons.

**Results and Discussion:** Application of BA stimulated offset formation in hosta, which agrees with previous research (1, 2). However, repeated BA application was necessary for a continued response in offset production (Table 1). At 60, 90, and 120 DAT, offset numbers for plants of both cultivars, which had not been retreated, were similar to those of untreated controls. In all treatments except 'Francee' at 60 DAT, retreatment with BA produced greater numbers of offsets than either untreated controls or plants retreated, regardless of the number of applications received. Removal of offsets prior to reapplication of BA did not prevent offset formation following subsequent BA application. Total yield of offsets with 0, 1, 2, 3 or 4 BA applications was 9.8, 9.5, 13.9, 17.4, or 22.0 ('Francee') and 0, 6.3, 8.6, 14.0, or 18.2 ('Francis Williams') over the 120-day study. Total offset yields indicate the potential benefits of repeated BA application, particularly with cultivars such as 'Francis Williams' which do not readily form offsets. Offset stage of development and growth index were generally not affected by BA treatment (data not shown).

**Significance to Industry:** Hostas are conventionally propagated by annual division of the crown or by tissue culture, both of which have limitations. A practical system for the rapid multiplication of hosta which employs BA application to stimulate the outgrowth of offsets could be of benefit to growers by allowing them to propagate hosta cultivars, including cultivars which do not readily form offsets, efficiently and economically. These findings are a significant step in the development of such a system.

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Table 1. Offset number at 30, 60, 90 and 120 days after initial treatment (DAT) in two hosta cultivars treated with 0,1,2,3 or 4 applications of 3000 ppm BA.

| | Offset number | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Application number | | | | | Application number | | | | |
| DAT[z] | 0 | 1 | 2 | 3 | 4 | 0 | 1 | 2 | 3 | 4 |
| | "Francee" | | | | | "Francis Williams" | | | | |
| 30 | 3.7 | 4.5 | - | - | - | 0.0 | 3.9 | - | - | - |
| 60 | 4.9 | 3.6 | 5.9 | - | - | 0.0 | 2.4 | 3.7 | - | - |
| 90 | 1.2 | 1.4 | 3.5 | 6.0 | - | 0.0 | 0.0 | 1.0 | 5.4 | - |
| 120 | 0.0 | 0.0 | 0.0 | 1.0 | 5.6 | 0.0 | 0.0 | 0.0 | 1.0 | 5.2 |

[z]DAT = days after treatment

Significant Contrast:

| DAT | Application number |
|---|---|
| 30 | 0 v. 1 |
| 60 | 0v. 2, 1 v. 2 ('Francis Williams'only) |
| 90 | 0 v. 3, 1 v. 3, 2 v. 3 |
| 120 | 0 v. 4, 1 v. 4, 2 v. 4, 3 v. 4 |

# Movement of Chlorpyrifos and Thiophanate-Methyl in Runoff Water from a Container Nursery

**Jeanne Briggs, Ted Whitwell and Melissa B. Riley**
**South Carolina**

**Nature of Work:** The containerized plant nursery industry utilizes management practices which encourage the movement of pesticides in runoff water. Pesticides are applied in large quantities to control insects and pathogens which could render plants unmarketable. Spray applied pesticides cover foliage, pots, and ground covers (Gilliam *et al*., 1992) and are available for transport from application site in the runoff water generated by overhead irrigation. Herbicides were previously detected in runoff water and retention basins at plant nurseries in South Carolina (Camper *et al*., 1994; Keese *et al*., 1994; Riley *et al*., 1994).

Grassed filter strips and waterways contiguous to agricultural fields reduce the amounts of pesticides, sediments, and nutrients transported in runoff water (Magette *et al*., 1989; Dillaha *et al*., 1989). The mechanism of remediation is primarily a reduction in volume and transport capacity of runoff water, thus allowing for enhanced infiltration. Vascular aquatic macrophytes, such as the common cattail, *Typha latifolia* , have been an efficacious component of domestic and industrial wastewater treatment for decades. The objectives of this research were to investigate the movement in runoff water of chlorpyrifos (organophosphate insecticide), and thiophanate-methyl (systemic fungicide), at a container nursery, and to evaluate the ability of vegetated waterways to reduce pesticide loads in runoff water.

The study was conducted at a wholesale containerized plant production facility in northwestern South Carolina. The nursery has a large (1.5 ha), isolated growing area which slopes uniformly and unidirectionally so runoff waters may be easily channeled. The area was under production during the research holding different species of 10 L containerized landscape plants, and the ground cover was semi-permeable polypropylene landscape fabric over a layer of black plastic. Runoff water from half of the growing area was channeled into an existing clay/gravel waterway (91.5 x 1.8 m), and the remainder of the runoff water was directed into a bermudagrass (*Cynodon dactylon x C. transvaalensis*) waterway (91.5 x 1.8 m). Effluent from the grass waterway was further filtered through a planting of common cattails (91.5 x 1.8 m). Weirs were installed at the end of each waterway to allow for runoff volume determination.

Water samples were collected after pesticide applications during the summer of 1995. Dursban 50W (50% chlorpyrifos), and Cleary's 3336 (50% thiophanate-methyl) were applied at the rate of 1.2 kg $ha^{-1}$ product with an air blast mist sprayer. A two hour irrigation event immediately followed the application simulating 1/2 inch of precipitation. Runoff samples were collected at 20 minute intervals after inception of runoff from each waterway. Samples were taken on the day of application (DOA), and 1, 2, 4 and 8 days after application (DAA). The experiment was conducted twice.

Samples were transported on ice and stored at 4°C until extracted for analysis. The pH of water samples was adjusted to 2.2 - 2.3, and duplicate 150 ml aliquots were filtered through Whatman #5 qualitative paper, and extracted onto $C_{18}$ solid phase extraction columns (Riley *et al*., 1994), and eluted with 2 ml acetone. Analysis was by high pressure liquid chromatography using a $C_{18}$ reverse phase column. The solvent system was an acetonitrile: water gradient, and the diode array detector was set at 206 nm. Percent recoveries were 103 and 88, and limits of detection were 26 and 45 µg/ml, for thiophanate-methyl and chlorpyrifos, respectively.

Data were subjected to statistical analysis using ANOVA, and Duncan's Multiple Range test at $P = 0.05$ to separate means. Amounts reported as none detected (ND) were calculated at the limit of detection.

**Results and Discussion:** Thiophanate-methyl, was detected on the DOA in all waterways and on the day after application in the clay/gravel channel only. The highest concentration, 5.10 µg/ml, was detected from the clay/gravel treatment on the DOA at 0 minutes of runoff. The highest concentration from the grass and cattail waterways on the DOA were 1.47 and 0.76 µg/ml, respectively. Significant differences were noted between the waterway treatments for times 0, 20, and 100 minutes on the DOA. Concentrations were higher from the clay/gravel waterway for the early runoff, and greater from the grass and cattail treatments for the 100 minute samples. The vegetated waterways reduced initial losses of thiophanate-methyl. Concentrations on 1 DAA from the clay/gravel channel ranged from 0.08 to 0.15 µg/ml.

Of the total amount of thiophanate-methyl applied, 13% was detected in the clay/gravel runoff, 11% in the grass effluent, and 7% from the cattail treatment (Table 1). Thiophanate-methyl amounts on the DOA were reduced 15% by the grass treatment as compared to the clay/gravel waterway, and 48% for both vegetated channels. There was a 39% reduction in thiophanate-methyl in runoff water leaving the cattail waterway compared to levels entering from the grass treatment. Thiophanate-methyl is moderately soluble in water (26.6 mg/L at 20° C) and some loss might be anticipated if irrigation or rainfall closely follow application.

Chlorpyrifos was detected in only three samples from the first replication. Concentrations of 0.22, 0.09 and 0.20 µg/ml were noted in the first two samples of runoff on the DOA for the reference waterway, and the 100 minute DOA sample of the grass treatment. The grass waterway appears to retard the movement of chlorpyrifos from site. No chlorpyrifos was detected in the effluent from the cattail waterway. A major method of dissipation for chlorpyrifos is volatilization, and climatic conditions were conducive to high rates of volatility throughout these studies, and, therefore, minimal residues of the compound may be expected. Of the total amount of chlorpyrifos applied, < 0.01% was recouped from any treatment (Table 1).

First-flush analysis indicates the relationship between pesticide load and runoff volume. A slope of 1 indicates a proportionality between pesticide transport and runoff amounts. A slope greater than one was found for thiophanate-methyl recovered from the clay/gravel waterway (Figure 1). In the first 40% of runoff, 70% of thiophanate-methyl had moved through the system. Thiophanate-methyl loss from the grass waterway was significantly different from the clay/gravel treatment, and more closely approached a direct proportionality to runoff volume. First flush analysis of chlorpyrifos losses was not conducted because amounts were detected in only one replication of the experiment.

**Significance to Industry:** Measurable amounts of pesticides are transported in runoff water after application at container plant nurseries. Amounts lost are dependent upon the physical and chemical properties of the pesticide and climatic and environmental conditions. Losses may be reduced by channeling runoff water through vegetated waterways comprised of grasses or vascular aquatic plants. Runoff may also be lowered by delaying irrigation events following pesticide application and by reducing irrigation volumes.

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Table 1. Total pesticides (g) lost and percentage of total applied for waterway treatments. Means followed by the same letter are not significantly different at $P = 0.05$.

| | Thiophanate-methyl | | | Chlorpyrifos | |
|---|---|---|---|---|---|
| Waterway Treatment | Grams DOA[1] | Grams 1DAA[2] | % Applied | Grams DOA | % Applied |
| Clay/Gravel | 44a | 3 | 13% | 0.5a | <.01% |
| Grass | 37b | ND[3] | 11% | 2.5a | <.01% |
| Cattails | 21c | ND | 7% | ND | <.01% |

[1] Day of application.
[2] Days after application.
[3] None detected.

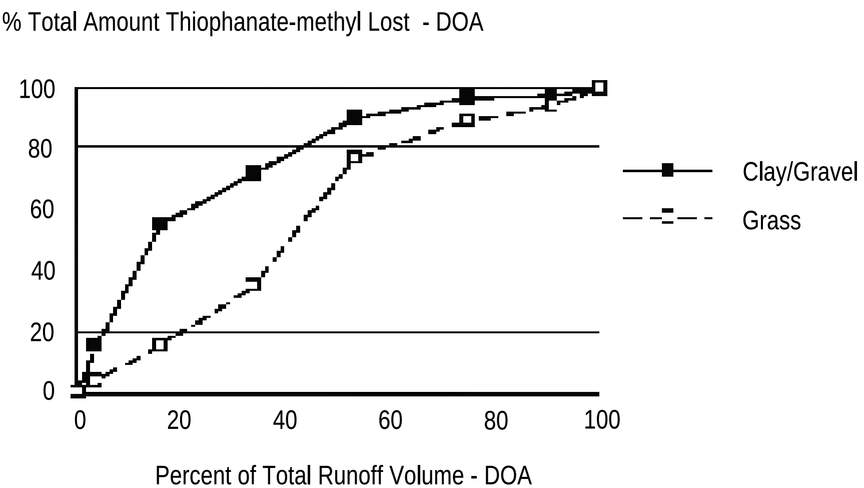


Figure 1. First-flush analysis for thiophanate-methyl from the grass and clay/gravel waterways. The percent of total pesticide loss on the day of application (DOA) is graphed for percent of total runoff volume. Treatment means followed by the same letter are not significantly different at $P = 0.05$.

# Recycled Newspaper Use in the Landscape

**D.R. Smith, C.H. Gilliam, J.H. Edwards, D.J. Eakes and J.D. Williams**
**Alabama**

**Nature of work:** Waste disposal continues to be a problem across the U.S. due to diminishing landfill space. USEPA mandated a national goal for a 25% reduction in landfill disposal which was effective in 1995 and total reduction of 75% by the year 2000. Approximately 40% of the municipal solid waste stream consists of paper and paper products and an additional 18% is comprised of yard waste(1). Recycling of these products could greatly impact landfill longevity. One area receiving some attention is the use of recycled newspaper in landscape areas (2). The purpose of our research was to determine if recycled paper has potential for use as a landscape mulch.

Two studies were conducted to evaluate two recycled paper products, recycled paper pellets and recycled paper crumble. The newsprint was ground using a hammer mill equipped with a series of 3 screens, the smallest approximately .03 in. in size. This material was compressed using pelletizing equipment to form recycled paper pellets approximately 1/4 in. in diameter and 1 1/4 in. in length. Pellets were put through a granulator with variable pressure plates to obtain the recycled paper crumble. It is noncomposted and has a C:N ratio of 150:1. Plants tested in the first study included *Ageratum houstonianum* 'Blue Puff', *Pelargonium x hortorum* 'Ringo', *Tagates erecta* 'Voyager' and *Salvia splendens* 'Burgandy'. Plots 3'x7' were prepared by amending each with 2-3 in. pinebark, fertilized with 13-13-13 slow release fertilizer applied at .26 $lbN/ft^2$, tilled and planted on May 10, 1995. Prior to mulch application the plots were overseeded with 25 spurge seed. Treatments were the two paper products each applied at a depth of 0.5 in., 1 in. or 2 in., pinebark applied at 3 in., pinebark (3in.) plus Geotextile weedmat, Ronstar applied at 4lb/aia and a non-treated control. Data collected included: percent weed control at 30 and 60 days after treatment (DAT), and dry weights at 60 DAT when the study was terminated.

A second experiment was conducted to determine if the addition of P would eliminate suspected Al toxicity in the first study. Mulch from the first study was removed and the beds were prepared using the same procedure as the first experiment. Three annual species were planted on September 7, 1995: *Ageratum houstonianium* 'Blue Puff', *Tagetes erecta* 'Discovery' and *Pelargonium x hortorum* 'Voyager'. Mulch treatments included either pellets or crumble to which P was added at a rate of 0, 3.75 or 7.5 ppm in the form of triple super phosphate. Each paper product was applied at a depth of 1 in. Other treatments included pinebark at a depth of 3 in., pinebark (3in.) plus weedmat, Ronstar applied at 4lb/aia and the non-treated control. Data collected at 45 DAT were shoot dry weight and root volume displacement.

**Results and discussion:** Percent weed control at 30 and 60 DAT in the first test showed both products provided effective control with the exception of the pellets at 0.5 in. depth. Recycled crumble at a depth of 0.5 in. provided 95% and 92% control at 30 and 60 DAT while pellets at the same depth provided only 79% and 72% respectively. At 60 DAT, crumble at 1 in. and 2 in. depth resulted in 99.5% and 100% control while the pellets at the same depths resulted in 75% and 97%. Severe stunting occurred in Ageratum with a stunted root system being the primary symptom. Ageratum proved to be the most sensitive while Marigold was the least affected. With Ageratum the control plants exhibited the best growth with a shoot dry weight of 54.8g/plant while the pellets and crumble at a depth of 2 in. had the least growth with shoot dry weight of 9.8g and 4.1g respectively.

The second experiment demonstrated that the addition of P eliminated the problem of decreased growth resulting from the Al toxicity. As the P level increased the growth was similar to and exceeded that of the control with the crumble at 3.75 ppm producing a significantly better plant with a shoot dry weight of 19.0g vs 6.25g with no addition of P (Table 1). When no P was added to the newspaper products the growth of the Ageratums was half that of the control plants. The addition of P did not effect the growth of the marigolds.

**Significance to the industry:** These two recycled newspaper products have considerable potential for use as a landscape mulch. As they absorb moisture they expand and bond together forming a mat which provides an effective non-chemical method of weed control which conserves moisture, saving both labor and natural resources. Use of recycled products addresses a national environmental concern by providing an alternative method for disposal of a post consumer by-product, thus enhancing the environmental image of the nursery and landscape industry.

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Table 1. The influence of newspaper on shoot and root growth of bedding plant species 45 days after transplant.

| | | | Ageratum | | Marigold | |
|---|---|---|---|---|---|---|
| Treatment | Mulch depth | P ppm[1] | Root Displacement ml/plant | Shoot dry weight g/plant | Root Displacement ml/plant | Shoot dry weight g/plant |
| Crumble | 1 in. | 0 | 14.5 | 6.2 | 50.3 | 36.4 |
| Crumble | 1 in. | 3.75 | 25.3 | 19.0 | 47.2 | 36.6 |
| Crumble | 1 in. | 7.5 | 15.1 | 12.8 | 39.6 | 32.2 |
| Pellet | 1 in. | 0 | 10.7 | 5.4 | 60.9 | 37.7 |
| Pellet | 1 in. | 7.5 | 20.8 | 10.9 | 47.8 | 34.4 |
| Ronstar | 4 lb/aia | - | 12.1 | 10.7 | 41.5 | 47.7 |
| Pinebark + mat | 3 in. | - | 25.3 | 10.3 | 49.8 | 32.7 |
| Pinebark | 3 in. | - | 20.2 | 8.8 | 62.2 | 36.4 |
| Control | - | - | 20.0 | 12.5 | 50.9 | 39.2 |
| LSD 0.05 | | | 10.7 | 2.9 | 19.3 | 7.2 |

[1]P source was triple super phosphate; ppm based on pounds of recycled paper per plot.

# Natural Resistance to Japanese Beetle Among *Malus* Taxa: Role of Endogenous Foliar Phenolics

**Amy F. Fulcher, Thomas G. Ranney, James D. Burton, James F. Walgenbach, and Eleanor P. Maness**
**North Carolina**

**Nature of Work**: Japanese beetles (JB), *Popillia japonica* Newman, are destructive, highly polyphagus herbivores that show a general preference for plants in the Rosaceae family. Although *Malus* taxa are often found to be susceptible to JB there are substantial differences in resistance among *Malus* species and cultivars. (1). The objectives of this study were to compare natural resistance to JB among *Malus* taxa and to evaluate the role of phenolics in host plant resistance. Choice and no-choice feeding assays were performed on 10 taxa grown in a randomized complete block design at the Mountain Horticultural Crops Research Station in Fletcher, NC.

For no-choice feeding trials the beetles were placed in a growth chamber with constant light (PAR 75-80 umol$\cdot$m$^{-2}\cdot$s$^{-1}$) at 25°C (77°F) and starved for 24 hr. The following morning 3 branches of a given replicate, of each taxa, were collected and kept with the cut stem in water. Leaves for chemical analysis were frozen at -80°C (-112°F), freeze dried, and then stored at -80°C (-112°F) until needed. The leaves for the feeding study were removed, leaf area was measured ( FIN DIAS System #2, Decagon Devices, Inc.), and leaves were set into a petri dish with the petiole in a water filled vial. One female beetle was placed in each petri dish and each dish was set randomly in the growth chamber. After 24 hr the beetles were removed, leaf area was remeasured, and fecal matter was collected and dried for 24 hr at 70°C (158°F). Three separate assays (subsamples) were conducted on each of three replicates (trees) for each taxa.

The choice feeding study was conducted on field grown trees and utilized the natural beetle population. Defoliation ratings were done by two independent observers on August 14, 1995. Observers estimated percentage defoliation based on an 11 point, pretransformed rating scale and data were averaged among observers.

Total phenolics determinations were made using the Folin-Ciocalteu method, adapted from Julkunen-Tiitto (3). Two hundred mg (0.01 oz) of freeze dried leaf tissue was dissolved in 10 ml (0.02 pt) acetone in a centrifuge tube. While extracting, the tissue was shaken in an ice bath for 30 min, then centrifuged for 20 min. A 25ul (0.000053 pt) aliquot was taken and diluted with water to 2 ml (0.004 pt) in a 10 ml (0.02 pt) volumetric flask. One ml (0.002 pt) of Folin - Ciocalteu phenol reagent was added to each flask and shaken. Five ml (0.01 pt ) of 20% sodium carbonate was added and the mixture was raised to 10 ml (0.02 pt) with water. The flasks were shaken thoroughly. After 60 min the absorptivity of the mixture was read at 765 nm ( Lambda 6 UV/VIS spectrophotometer, Perkin Elmer ). The spectrophotometer was zeroed against air. A standard curve was prepared using concentrations of gallic acid ranging from 0 to 2000 ug/L.

**Results and Discussion:** Leaf area consumption under no-choice conditions ranged from 1.0 $cm^2$ to 7.6 $cm^2$ (Table 1). Under this intense feeding pressure *M.* 'Golden Raindrops', *M. baccata* 'Jackii', and *M.* Harvest Gold™ were highly resistant with less than 2 $cm^2$ leaf area consumption. Six other taxa were intermediate and *M.* 'Radiant' was statistically the most susceptible with 7.6 $cm^2$ leaf area consumption. Mean fecal weight provided an additional measure of feeding intensity and ranged from 4.70 to 17.4 mg (Table 1). Beetles feeding on *M. baccata* 'Jackii' produced the lowest with their mean fecal weight not being statistically different from zero.

Feeding intensity among *Malus* taxa in the choice test varied from 0 to 73 percent defoliation (Table1 ). Eight *Malus* taxa had an average feeding defoliation of 10% or less. *Malus* 'Red Splendor' was intermediate with 26% defoliation and *M*. 'Radiant' was the most susceptible with defoliation of 73%. In general results from no-choice and choice assays provided similar rankings for susceptibility with the exception of 'Baskatong' which was relatively more susceptible to feeding under no-choice conditions.

Total phenolic levels in these plants ranged from 7.4 to 17.3% dry weight of leaf tissue and was not correlated with resistance (Table1 ). Although total phenolic content can sometimes influence insect feeding, the presence and concentration of specific phenolic constituents can be more important than total phenolic content. *Malus* taxa contain several phenolics such as phloridzin, phloretin, quercitin, kaempferol, and catechin (4,5). Research has shown chemical constituents such as phloridzin, and its hydrolysis product phloretin, are highly effective at deterring JB feeding when present in artificial diets (2). Conversely, quercitin was found to be a phagostimulant (2). Variations in phenolic constituents among these plants would explain what otherwise seem to be inconsistencies in total phenolic levels and feeding relationships. Due to the high percentage of total phenolics in leaf tissue and their individual documented relationship with resistance there is a need for additional studies on the isolation and identification of the exact compound or compounds responsible for resistance and their mode of action.

**Significance to Industry:** Japanese beetles are one of the most damaging insect pests on rosaceous trees. This research documented a broad range of natural resistance to feeding by adult Japanese beetles among taxa of M*alus.* Greater use of pest resistant plants will reduce the need for chemical controls, reduce production and maintenance costs, and aid in the development of more sustainable landscapes. In addition, identification of resistant genotypes provides the basic information needed for breeding new plants that are deliberately designed to have greater pest resistance.

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Table 1. Resistance to Japanese beetle as measured by leaf area consumption, fecal weight, field defoliation, and total phenolics among crabapples (*Malus* spp.).

| | | No choice test | | Choice test | |
|---|---|---|---|---|---|
| Taxon | Cultivar/ Tradename | Leaf area consumed ($cm^2$) | Fecal wt (mg) | % Field defol. | Total phenolics (%) |
| 'Golden Raindrops' | 'Golden Raindrops' | 0.99 | 8.5 | 1 | 16.6 |
| M. baccata 'Jackii' | M. baccata 'Jackii' | 1.07 | 4.7 | 0 | 8.6 |
| 'Hargozam' | Harvest Gold™ | 1.83 | 10.7 | 1 | 14.8 |
| 'Branzam' | Brandywine™ | 3.29 | 10.6 | 1 | 11.4 |
| M. floribunda | M. floribunda | 3.61 | 15.9 | 0 | 16.4 |
| 'Naragansett' | 'Naragansett' | 3.63 | 11.7 | 3 | 15.1 |
| 'Robinson' | 'Robinson' | 4.19 | 15.0 | 2 | 17.3 |
| 'Red Splendor' | 'Red Splendor' | 4.84 | 16.6 | 26 | 7.4 |
| 'Baskatong' | 'Baskatong' | 5.05 | 17.4 | 9 | 7.6 |
| 'Radiant' | 'Radiant' | 7.62 | 14.7 | 73 | 8.7 |
| $LSD_{0.05}$ | | 2.01 | 4.8 | 10 | 2.2 |

# Germination and Seedling Emergence in Pawpaw [*Asimina triloba* (L.) Dunal]

**C.L.H. Finneseth, D.R. Layne and R.L. Geneve**
**Kentucky**

**Nature of Work:** Pawpaw [*Asimina triloba* (L.) Dunal] is a temperate, deciduous, understory tree native to most of the eastern United States. In addition to bearing the largest fruit indigenous to North America this tree has a lush, tropical appearance, but is hardy to zone 5 (-13°F). Pawpaw is gaining popularity among homeowners because of the pleasing floral and foliage displays plus production of edible fruit. Flowers are pendulous and green when expanding in early March, but soon turn an attractive, reddish-maroon color. As flowers are developing, leaves are also expanding (5). When fully expanded, the dark green leaves can be from eight to 12 inches long. These droopy, non-waxy leaves turn from deep green to gold in the autumn producing an excellent display of color similar to *Ginkgo biloba.* Smooth, gray bark on straight trunks and branches create a pleasing pyramidal tree shape when grown in full sun, which also provides winter interest. Though a native understory tree, the pawpaw can bear a large amount of fruit in full sun conditions. Yields of 70 to 75 pounds per tree have been reported (1). The green oblong fruit can be borne singly or in clusters of up to nine fruits and can measure 2-6 inches in length. The fruit skin turns yellow and then brown when ripe in early fall. Pawpaw is also the exclusive larval host for the zebra swallowtail butterfly (Eurytides marcellus), making it an ideal specimen plant in butterfly gardens.

Presently, most pawpaw trees supplied to the nursery industry are produced by growers who cannot keep up with consumer demand (2). Many of the trees sold commercially are a genetically diverse group produced from seed. Selected cultivars can be chip-budded to seedling understocks. In retail trade, a container-grown grafted pawpaw can sell for as much as $26.50 compared with the same size grafted apple tree for approximately $3. Even unnamed seedlings sell at a retail price of almost $20 each (3).

Although pawpaw is gaining popularity as both a landscape specimen and a fruit tree, little scientific information is available regarding cultivation of the plant. Since the production of pawpaw is dependent on seed propagation - for seedlings and rootstocks - the industry can benefit greatly from information describing germination and emergence. In response to this need, studies were designed to describe important developmental stages and seedling characteristics during germination and emergence.

As a temperate member of the tropical Annonaceae or Custard Apple family, pawpaw seeds possess a rudimentary embryo embedded in a large amount of endosperm. The ruminate endosperm contains the energy reserves for the immature, dormant embryo. Seeds require a period of stratification at 40°F for between 60 and 100 days (5). Seeds apparently cannot withstand drying and should be stratified soon after removal from the fruit. Stratified seed can remain viable for several years.

**Results and Discussion:** In non-stratified seed, the embryonic axis measured 1.05 mm. Stratified seeds were planted in vermiculite and exposed to 70°F in a growth chamber. Embryo elongation began prior to radicle protrusion through the seed coat. The radicle emerged at 12 days after planting and was approximately 3.4 mm in length, with simultaneous development of the cotyledons to a length of 3.0 mm. Neither hypocotyl nor epicotyl was distinguishable at this time. The first above ground indication of germination (emergence of the hypocotyl hook) occurred at 27 days after the seeds were sown. When the hypocotyl penetrated the soil surface, the average lengths for the radicle, hypocotyl and cotyledons were 31, 10 and 9 mm, respectively. The shoot meristem began to elongate at 45 days and after 50 days, the seed coat containing residual endosperm and the cotyledons had abscised. At the termination of the study (70 days after sowing), the lengths of the seedling components were 215, 59 and 39 mm for the radicle, hypocotyl and epicotyl, respectively.

As embryo length increased, dry weight determinations showed a dramatic reallocation of reserves from the storage tissue to the developing seedling parts (Table 1). Seed fresh weight remained constant until hypocotyl emergence; however, the respective dry weight proportions changed significantly as the embryo grew. At radicle protrusion (12 days), endosperm comprised the largest proportion of dry weight (99.1%). When the hypocotyl emerged (27 days), the embryo was 13.5% and endosperm 86.5% of the dry weight. As the epicotyl began to elongate (45 days), embryo and endosperm percentages were 69.9 and 30.1, respectively. At the termination of the study (70 days), seedling dry weight measurements were 69.7%, 13.4% and 16.9% for the radicle, hypocotyl and epicotyl, respectively.

Seedling emergence can be hastened by 10 days if seeds are exposed to bottom-heating after sowing. A constant soil temperature of 90°F is recommended during seed germination and early seedling development (4). Seed should be planted about 1" below the soil surface in a deep container due to the rapidly developing taproot. Rootrainer™ (Spencer-Lemaire, Alberta, Edmonton, Canada) containers are excellent for starting seedlings. A fertilizer application of 250 ppm of 20-20-20 fertilizer with trace elements, supplied twice per week to the point of runoff, is adequate to ensure good growth. When seedlings have approximately 12 expanded leaves, transplanting to larger containers (2 gallon) is necessary. Fertilizer formulation may remain the same, but the concentration should be increased to 500 ppm after moving seedlings to larger containers. Copper compounds incorporated in a latex paint (Spin Out™, Griffen Corp., Houston, TX, USA) coating the inside of containers have been effective in controlling root circling in either size containers (4). With bottom heat and fertilizer applications, pawpaw seedlings grown in the greenhouse can produce more than four feet of top growth in one season. Once reaching this size, trees are large enough to field transplant and have a large enough caliper for grafting or budding. Chip-budding seems to be the most successful method of clonal propagation and works best when actively growing seedlings are at least the diameter of a pencil.

**Significance to Industry:** As it has gained interest as a native plant, an exotic plant, an edible landscape plant and a specimen tree for specialty gardens (i.e., butterfly gardens), pawpaw is an ideal plant for nurserymen and consumers. Pawpaws are relatively simple to grow and can be a potentially profitable crop that is easy to incorporate within a temperate nursery production system. Nurseries able to supply high quality, container-grown seedlings and grafted cultivars will be in position to earn significant revenue as public awareness and demand for pawpaw continues to develop in the United States and abroad (3).

Table 1. Dry weight partitioning to embryo and endosperm during germination and early seedling development in Pawpaw.

| | Initialz (day 0) | Radicle Protrusion (day 12) | Hypocotyl Emergence (day 27) | Epicotyl Elongation (day 45) |
|---|---|---|---|---|
| Embryo | 0.19 (0.3)y | 0.65 (0.9) | 8.35 (13.5) | 41.8 (69.9 |
| Endosperm | 71.9 (99.7) | 70.0 (99.1) | 53.7 (86.5) | 18.0 (30.1) |

[z] Initial dry weights were taken from seed after a stratification period of 12 months at 40°F

[y] mg of dry matter (% of total dry weight)

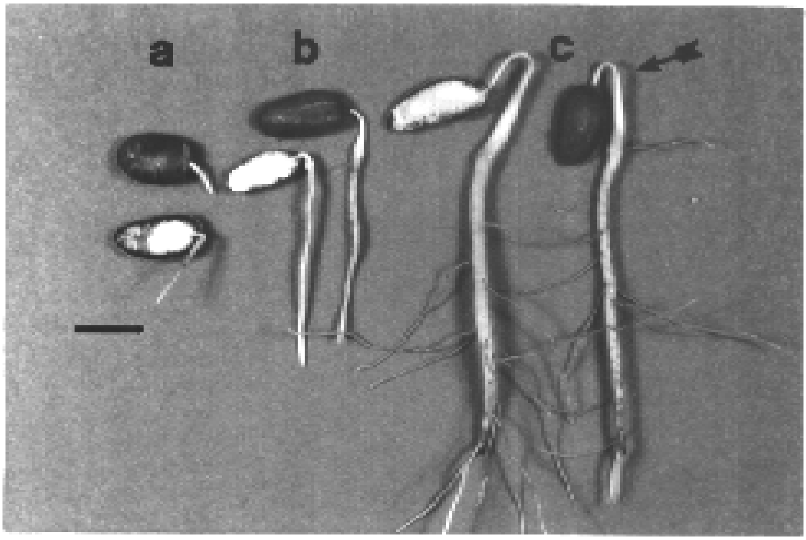


Figure 1. Stages of development in germinating Pawpaw seed. a) Simultaneous development of radicle and cotyledons. Cotyledons are 1/2 the length of the seed. b) Visible hypocotyl with radicle elongation and cotyledons expanding to 3/4 of seed length. c) Continued development of radicle with secondary root formation, fully expanded cotyledons extending the entire length of the seed, epicotyl elongation begins. Arrow shows hypocotyl hook which emerges through soil surface. Reference bar equals 2.5 cm.

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# Extracts of Locust and Willow Influence Mung Bean Rooting

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**Nature of Work:** Research conducted by Kawase (1964, 1970, 1971 1981) showed that willow (*Salix alba*) stems contained water diffusible substances that could positively influence the rooting of mung bean cuttings (*Vigna radiata*), with or without IBA. The theory is that plants contain their own rooting substances and rooting inhibitors (Chong, 1983). Chong showed that other plants also contained water diffusible rooting promoters as well as rooting inhibitors. Some compounds act like rooting cofactors in positive synergy with IBA (Kawase, 1981). This study was conducted to determine the effects of water diffusible extracts of black locust (*Robinia pseudoacacia*) in comparison with willow (*Salix erythroflexus*) extracts to stimulate rooting of mung bean cuttings.
Mung beans were sown in nursery flats and grown for seven days under fluorescent light in a controlled environment growth room. Mung bean cuttings 4 inches long were harvested. A single cutting was immediately placed in a test tube contining 16 ml of autoclaved deionized water. Stem tips six inches long were collected from locust and willow. Leaves were stripped from half the stems. One treatment consisted of placing one leafless willow stem in a test tube with a mung bean cutting. The second treatment used a willow stem with leaves. The third treatment used a leafless black locust stem. The fourth treatment was the rachis of a black locust leaf from which the leaflets had been removed. The control treatment received no additional material in the test tube beyond the mung bean cutting and water. There were ten replications of each treatment, with the test tubes arranged in a randomized complete block in racks. The racks were placed under fluorescent lights in the growth room. After six days, roots were counted on each mung bean cutting. Data were analyzed statistically using SAS and significance differences accepted at the 5% level.

**Results and Discussion:** Mung bean cuttings in the test tubes with the locust rachis produced more roots (mean 13.0, SD 8.3) than any other treatment. The treatment using the willow stem with leaves produced a mean of 6.6 roots per cutting but did not differ from the remaining treatments (5, 4, 3, 1) or the control (5, 2). These results indicate that a substance diffused out of the black locust rachis that promoted rooting of the mung bean cutting, producing twice as many roots as the other treatments. This work is the first to show that extracts from black locust can influence rooting, and confirms that plants other than willow can release water diffusible substances that influence the rooting of other plant cuttings. We do not know why the willow extract failed to produce additional roots, but perhaps it is because we used a different species from previous research. Further work is underway to determine the effect of these treatments in the presence or absence of IBA. Additional work is planned using various types of locust extracts followed by conventional IBA treatment on difficult to root woody plants, such as *Chionanthus* species.

**Significance to Industry:** Results of this research are preliminary, but they indicate that water extracts of black locust could be a technique worth trying to aid in the cutting propagation of difficult-to-root plants.

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# Container Production of Under-Utilized Small Trees Using Kenaf and Coconut Coir Pith

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**Texas**

**Nature of the Work:** Pine bark is a commonly used component of soilless media because of its wide availability, uniformity, and resistance to decomposition. Nursery professionals in regions of the SW USA, where there is little timber industry, are placed at an economic disadvantage because of the added expense of shipping pine bark long distances. Sphagnum peat moss is another component that is often used in soilless media to improve water and nutrient holding capacities. Some concerns have been raised by wetland ecologist that the current rate of peat harvest in lowland bogs is not sustainable (1). The industry has recognized the need to study alternative components to replace pine bark and peat with more renewable sources for use in container media. Both pine bark and peat are excellent growth media for container production and any substitute for them must meet or exceed their standard and be readily available at a competitive price.

Ground stem core of kenaf (*Hibiscus cannabinus* L.), a light-weight biomass crop grown in several Gulf Coast States including Louisiana, Mississippi, and Texas has been used successfully as a replacement for pine bark in production media for greenhouse and tropical nursery crops (4). The availability of pine bark fluctuates according to the timber market, while kenaf is an annual renewable crop that could stabilize the availability and price of container media.

Coconut coir pith is the short fibrous material remaining after the long fibers (coir) are extracted from the mesocarp pith of the coconut fruit (*Cocos nucifera* L.) and used in manufacturing. Coir pith consists primarily of 0.2 -2.0 mm particle and is predominantly lignin and cellulose with a high C:N ratio (3). Coconut coir has many of the qualities of peat including high water holding capacity, good drainage, absence of weeds and pathogens, and acceptable pH, cation exchange capacity (CEC), and electrical conductivity (EC) (2).

The objectives of these experiments were to 1) contrast growth responses of under-utilized small trees to that of a small tree commonly produced in containers and 2) to determine species' growth responses and characterize alternative media combinations containing kenaf and coconut coir pith to those associated with conventional pine bark sand media at three fertilization rates.

The four media combinations consisted of 3 pine bark:1 sand (vol. : vol.), 3 pine bark:1 coconut coir, 3 kenaf:1 sphagnum peat, and 3 kenaf:1 coconut coir. Each media was amended with 1.5 lb./yd.$^3$ (0.88 kg.m$^{-3}$) of the micronutrient source Micromax® (Grace-Sierra Horticultural Products, Milpitas, CA), 7 lb./yd.$^3$ (4.15 kg.m$^{-3}$) dolomitic limestone, and 3 lb./yd.$^3$ (1.78 kg.m$^{-3}$) gypsum. They were then amended with Sierrablen 18-6-12 (Grace-Sierra) at a rate of 6 lb./yd.$^3$ (3.55 kg.m$^{-3}$), 12 lb./yd.$^3$ (7.12 kg.m$^{-3}$) or 18 lb./yd.$^3$ (10.68 kg.m$^{-3}$).

Seed from 4 selected species, *Chilopsis linearis* Cav., *Acacia wrightii* Benth., *Rhus lanceolata* L., and *Fraxinus velutina* Torr. ( commercial control) were sown in 2 in. (5 cm) propagation cups containing a 3:1 0.75 in. (19 cm) screened pine bark:sphagnum peat propagation mix amended as above with dolomitic limestone, micro-nutrients, and slow release fertilizer [12 lb./yd.$^3$ (7.12 kg.m$^{-3}$)] on March 21, 1995. The most uniform seedlings were then transplanted on May 10 into #1 (2.5 liter) black plastic nursery containers, treated with 100g $Cu(OH)_2$ / liter carrier (Spinout®, Griffin Corp., Houston, TX), containing the various media. All containers were placed outdoors on gravel covered with black woven weed barrier in full sun and watered, as needed, using 9 gph spray stakes with acid injected water (pH 6.5) containing 50 mg N/liter (ppm) from 24-8-16 water soluble fertilizer (Peters, Scotts Co., Marysville, OH). Trees were pruned to remove lower limbs and establish a central leader. On August 10, 1995, all trees were transplanted to #3 (15 liter) black plastic pots containing the same media as before. Measurements for height and caliper were taken 240 days from the time the plants were placed in the one gallon containers.

Sixty containers (15 per media / fertilization combination) without plants were filled with the above media, placed in the production area, and monitored at 30 day intervals to determine pH, EC, and media shrinkage. Leachate samples were extracted by pouring 200 ml of distilled water over the media surface and collecting the resulting leachate for analysis of pH and EC. Shrinkage was determined by measuring the reduction in height of the media surface from the container rim.

**Results and Discussion:** Growth Response Study: There was no significant difference due to media effects on the height of three of the four species tested. The A. wrightii, R. lanceolata, and F. velutina ( control) all showed similar height responses in each of the four media combinations (Table 1). The kenaf:coir media resulted in a slight reduction in height of C. linearis compared to bark : coir and kenaf : peat media (Table 1), but no treatments differed significantly ($P \leq 0.05$) from the bark:sand media. Caliper development for the A. wrightii and R. lanceolata was not different in the 4 media types (Table 2). Caliper growth for F. velutina was greater in bark media combinations than in kenaf media (Table 2). A similar trend was observed for caliper growth of C. linearis (Table 2). Effects of increased fertilizer in this study resulted only in a slight caliper increase for A. wrightii and a height decrease in R. lanceolata (data not presented).

Media characteristics: The range of pH for all media were acceptable, from 6.34 to 6.49 (Table 3). Electrical conductivity (EC) was greatest in kenaf based media (Table 3), while bark:coir media EC was similar to that of bark : sand (Table 3). Both bark media exhibited little shrinkage (Fig. 1). However, both kenaf based media exhibited substantial shrinkage, 40% for kenaf:coir and 43% for kenaf:peat.

**Significance to Industry:** The use of kenaf and coconut coir as media components resulted in acceptable plant growth. Height and caliper differences attributable to media type were not likely of commercial significance. While the pH range of all media were within acceptable levels, the EC readings for kenaf media were high. Both kenaf media exhibited extreme shrinkage that would not be conducive to container production of long term crops. Shrinkage of approximately 40% of the original volume was noted for these media over the season (240 days). This shrinkage resulted in mechanical instability of the rootball within the containers and excessive blow-over during winds.

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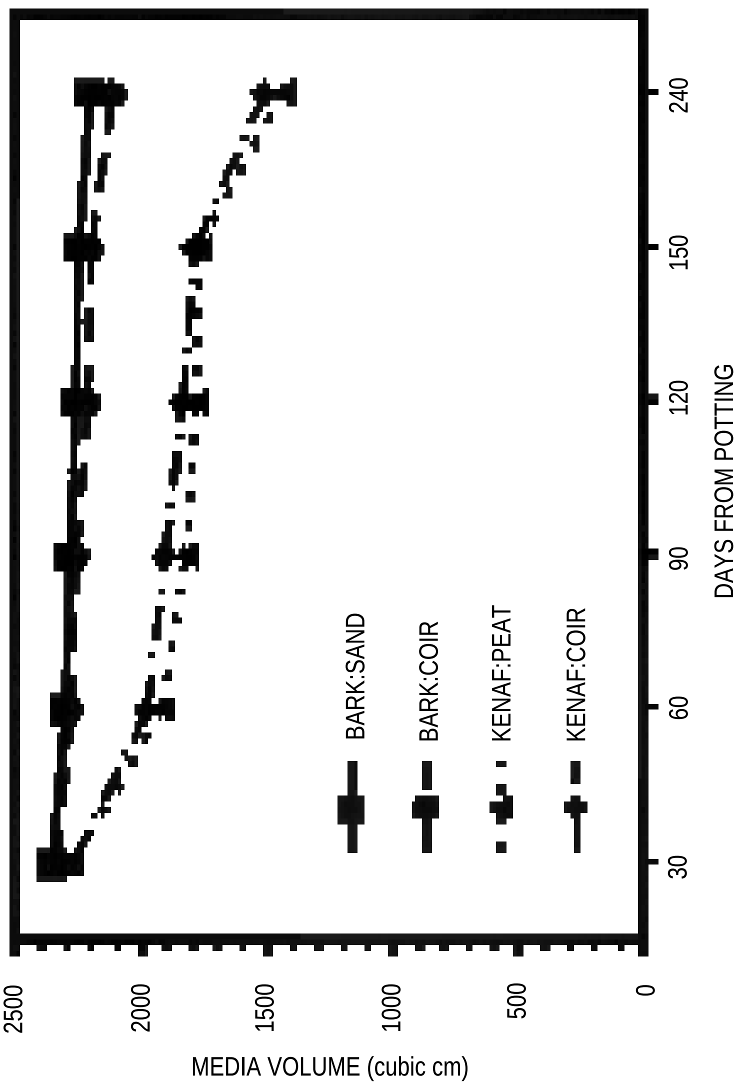


Figure 1. Effects of media type on volume of rooting substrate over time in #1 (2.5 liter) containers during outdoor container nursery production in College Station, Texas, n = 15.

Table 1. Main effects of media combinations on height (cm) of four small tree species grown for 240 days in 3 gallon containers.

| | *Chilopsis* | *Acacia* | *Fraxinus* | *Rhus* |
|---|---|---|---|---|
| Bark:Sand | 134 [z] ab | 114 a | 166 a | 80 a |
| Bark:Coir | 144 a | 127 a | 173 a | 82 a |
| Kenaf:Peat | 145 a | 110 a | 161 a | 78 a |
| Kenaf:Coir | 126 b | 119 a | 164 a | 75 a |

[z] Means within a column followed by the same letter are not significantly ( $P < 0.05$) different, n = 45.

Table 2. Main effects of media combinations on caliper (mm) of four small tree species grown for 240 days in 3 gallon containers.

| | *Chilopsis* | *Acacia* | *Fraxinus* | *Rhus* |
|---|---|---|---|---|
| Bark:Sand | 13.5 [z] ab | 7.0 a | 17.7 a | 9.7 a |
| Bark:Coir | 13.6 a | 6.8 a | 18.4 a | 9.7 a |
| Kenaf:Peat | 12.9 bc | 7.3 a | 15.7 b | 10.4 a |
| Kenaf:Coir | 12.5 c | 6.5 a | 14.7 c | 9.6 a |

[z] Means within a column followed by the same letter are not significantly ( $P < 0.05$) different, n = 45.Table 3. Main effect of media on pH and EC of leachate of four media taken at 30 day intervals for 240 days.

Table 3. Main effect of media on pH and EC of leachate of four media taken at 30 day intervals for 240 days.

| Media | pH | EC |
|---|---|---|
| Bark:Sand | 6.41 [z] ab | 0.87 [z] c |
| Bark:Coir | 6.49 a | 0.93 bc |
| Kenaf:Peat | 6.34 b | 1.20 a |
| Kenaf:Coir | 6.46 a | 1.14 ab |

[z] Means within a column followed by the same letter are not significantly ( $P < 0.05$) different, n = 45.

# Changes in Root Length and Diameter in Plants Grown in Copper Treated Containers

**Myra Stafford, Robert L. Geneve, and Robert E. McNiel**
**Kentucky**

**Nature of Work:** Copper products have been successfully used to control root growth and development in container grown woody landscape plants for several years. Nurseries apply a solution of copper and latex paint to inner surfaces of containers for increased root control enabling improved field establishment and performance of woody landscape plants (Struve, 1993). Copper products control roots by eliminating circling in containers, forcing roots to branch to the center of the container (Arnold and Struve, 1989). The resulting root system is more compact and evenly distributed throughout the container. Increased shoot growth and development after transplanting has also been reported in several plant species produced in copper-treated containers (Arnold and Struve, 1989). The objective of this study is to determine how copper treatment modifies total root length and root diameter of plants grown in containers.

A fine-rooted species, redbud (*Cercis canadensis*), and a greenhouse species utilized for rapid growth, marigold (*Tagetes patula* 'Little Devil') were grown in 12 cm containers. Container walls were untreated or treated with Spin Out™ (Griffen Corp., Valdosta, GA, USA) a form of cupric hydroxide in latex paint. Marigold seeds were sown directly into containers and redbud were sown into Metro Mix 360 (Scott's) in large flats (60 cm x 30 cm x 10 cm), and transplanted to containers once seedlings reached two inches. Overhead irrigation was applied as needed with Peter's 15-5-15 fertilizer in solution at 200 ppm. Plants were grown under standard greenhouse conditions.

Evaluation of root systems was achieved with the aid of MacRhizo™ (Regent, Inc.), a computer imaging and analysis program. Root length and root diameter classes were obtained from a random 2.5 cm x 2.5 cm x 6.5 cm section of the root system. Marigold plants were evaluated after 38 days, once 4-5 flower buds were visible and beginning to open. Redbud were evaluated after 114 days, once treatment effects were observed in the root system.

**Results and Discussion:** Copper treatment effectively increased total root length in the sampled wedge of redbud and marigold by 28% and 11%, respectively. There was a significant increase in root length in the smallest diameter root class, which ranged from 0.0 to 0.5 mm for both species. Copper treated redbud plants showed a 30% increase in roots in this class, while there was an 18% increase in amount of marigold roots in this class. In the 0.5 to 1.0 mm class, the copper treatments again resulted in significantly larger proportions of roots with 26% and 13% for redbud and marigold, respectively.

The observed shoots of redbud and marigold were larger when subjected to copper treatments. In redbud, the leaf area increased by 14%, from 793.7 $cm^2$ to 925.3 $cm^2$, additionally shoot dry weight increased by 18%. In marigold the results were less dramatic with only 5% and 11% increases in leaf area and shoot dry weight, but again the plants treated with copper maintained larger shoots. These results suggest increased shoot development occurs as a result of better root development. A root system comprised of a greater proportion of small diameter roots results in increased water and nutrient uptake (Atkinson, 1980).

**Significance to the Nursery Industry:** The use of copper products to modify total root length and diameter resulted in a 28% and 11% increase in total root length and a 29% and 16% increase in amount of small roots (0.0 to 1.0 mm ) occurring in redbud and marigold, respectively. Shoots of both species were larger with the addition of copper to the container walls. Utilization of copper treated containers by nurserymen effects root distribution within containers resulting in a more successful transplant for the consumer.

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Table 1. Leaf area, shoot and root dry weight, and root length per root class of redbud and marigold 'Little Devil' plants grown in 12 cm containers treated and untreated with copper hydroxide.

| Species | Trtmt | Leaf area ($cm^2$) | Shoot dry wt (g) | Root dry wt (g) | Root length per root class 0-0.5mm | 0.5-1mm | >1mm |
|---|---|---|---|---|---|---|---|
| Redbud | | | | | | | |
| | Control | 793.7 | 7.3 | 2.4 | 2.69.29 | 108.63 | 63.49 |
| | Copper | 925.3 | 9.0 | 2.5 | 388.44 | 146.78 | 79.30 |
| Marigold | | | | | | | |
| | Control | 490.15 | 2.5 | 0.8 | 348.30 | 312.99 | 259.53 |
| | Copper | 517.99 | 2.8 | 0.8 | 426.32 | 361.02 | 246.94 |

# Stock Plant Soluble Carbohydrate and Nitrogen Status Affect Rooting of Stem Cuttings of Loblolly Pine

**D. Bradley Rowe, Frank A. Blazich, and Farrell C. Wise**
**North Carolina**

**Nature of Work:** Carbohydrate and nitrogen content are two measures of stock plant physiological status which influence subsequent adventitious rooting of stem cuttings. Nitrogen deficiency (not stress) within the stock plant generally promotes root formation in cuttings, presumably due to restricted metabolism of stock plant carbohydrates (3). A low nitrogen status relative to available carbohydrates (high C/N ratio) results in a tendency for stored carbohydrates and current photosynthate to be directed into adventitious root formation. Hyun and Hong (2) reported that clones of pitch pine (*Pinus rigida* Mill.) which rooted easily had higher C/N ratios than clones which were difficult-to-root.

Although precise endogenous and exogenous relations between nitrogen and adventitious rooting have not been established, carbohydrate to nitrogen ratios can be manipulated by varying nitrogen fertilization provided to the stock plants. Henry et al. (1) reported optimal growth of eastern redcedar (*Juniperus virginiana* L.) when stock plants were provided weekly with 180 ppm N. However, optimal rooting occurred at only 20 ppm N. Therefore, our objective was to determine if selected levels of applied nitrogen supplied to hedged stock plants of loblolly pine (*Pinus taeda* L.) would influence adventitious rooting with respect to the carbohydrate and nitrogen content of the cuttings taken from those stock plants.

Hedged stock plants cultured in 3-gal pots were arranged in a randomized complete block with 4 blocks each containing four full-sib families (controlled pollinations where both parents were known) designated B, G, R, and W and six nitrogen treatments (including a peat : vermiculite : perlite control). Trees for the five N treatments were grown in a medium of 6 perlite : 4 sand (v/v) while controls were grown in a medium of 2 peat : 2 coarse vermiculite : 1 perlite (v/v) amended with 2.1, 0.24, and 1.0 $kg \cdot m^{-3}$ (3.6, 0.4, and 1.7 $lb \cdot yd^{-3}$) Osmocote 18-6-12, Micromax, and dolomitic lime, respectively. The six N treatments consisted of the peat culture control and five levels of N (10, 25, 40, 55, and 70 ppm N) supplied daily as $NH_4NO_3$ through an automated irrigation system. All other mineral nutrients were supplied at optimal levels.

During May 1995 (spring softwood), July 1995 (summer softwood), and January 1996 (hardwood), 9 cm (3.5 in) long terminal stem cuttings were taken from the hedged stock plants for tissue analysis and rooting experiments. These dates also coincided with rehedging of stock plants to maintain juvenility. Tissue collected for carbohydrate and mineral nutrient analysis were freeze dried, extracted in 80% ethanol, and centrifuged through microfilter columns packed with anion and cation exchange resins and polyvinylpolypyrrolidone (PVPP) to remove phenolic compounds. Samples were then analyzed for glucose, fructose, sucrose, raffinose, and the sugar alcohols, myo-inisitol and pinitol, utilizing high performance liquid chromatography. In addition, tissue samples were analyzed with a CHN elemental analyzer to determine total C and N and by plasma emission spectrometry to determine P, K, Ca, S, Mg, Mn, Fe, Zn, B, and Cu. Cuttings to be utilized for rooting experiments were inserted into flats containing a medium of 1 perlite : 1 coarse vermiculite (v/v) and placed in a greenhouse under intermittent mist. They were not treated with auxin. After 12 weeks, cuttings were evaluated for percent rooting and means were subjected to analysis of variance procedures and regression analysis.

**Results and Discussion:** There were significant differences among seasons, families, and nitrogen treatments, as well as a family x nitrogen interaction in regards to rooting percentages. When averaged over families and N treatments, significantly greater rooting percentages occurred for spring softwood cuttings (59.5%) than summer softwood (34.7%) or winter hardwood cuttings (40.5%). Likewise, differences were evident in the percentage of total soluble carbohydrates (TSC) and percent N concentrations of the cutting tissue. Winter values of TSC were twice levels present in spring or summer (32.7% vs. 16.5% and 15.7%). In contrast, average N concentrations were lower in winter (1.29% vs. 1.79% and 1.69%).

When averaged over seasons, families B, G, and W exhibited a quadratic response with maximum rooting of 61.1% at 70 ppm applied N, 54.4% at 55 ppm N, and 63.0% at 40 ppm N, respectively (Fig. 1). Overall, family R was the poorest rooting family, however, rooting increased linearly with higher applied N suggesting that further increases in applied N may improve rooting. Families G and W were the best rooting families at the lower applied N levels, whereas family B was extremely poor (8.3% at 10 ppm N). However, family B was the best rooting family at the highest applied N level (61.1% at 70 ppm N). These results emphasize that differences in rooting response may be genetic, even within the same species.

Levels of applied N showed similar linear and quadratic responses for TSC (Fig. 1B). Families B and W contained the highest levels of TSC and were both good rooting families, whereas family R contained the lowest TSC levels and was the poorest rooting family. Family G was an exception. Although it was generally a good rooter, it contained low TSC levels, which suggests that it may be more efficient in metabolizing carbohydrates. Contrary, to our hypothesis, TSC : N ratio was not related to rooting. Even so, determining this ratio would be too time consuming and costly to be practical for a grower. A more reasonable test would be tissue N concentration. For all families studied, tissue N concentration increased linearly with increasing N fertilization (data not presented). Optimal rooting occurred at concentrations ranging from 1.8% to 2.0% N for spring and summer softwood cuttings and at approximately 1.5% N for winter hardwood cuttings.

Of the other mineral nutrients, boron had the greatest impact on rooting. There were no significant differences among families or applied N levels, but a B deficiency in the spring control treatment (8.7 ppm B) compared to the other 5 N treatments (21.7 ppm B), appeared to reduce rooting dramatically. Rooting percentages were 0.83% in spring, but increased to 61.1% for winter cuttings when tissue levels were restored to 15.9 ppm B. This occurred despite the fact that spring controls produced the greatest number of shoots, contained high TSC levels, and exhibited no visible deficiency symptoms (data not presented). Even though 8.7 ppm B is adequate for plant growth, it appears that higher amounts may be required for adventitious rooting. Thus, further stimulation of rooting also may be possible by manipulating stock plant B concentrations.

**Significance to Industry:** The time of year in which cuttings are taken from stock plants (actually the growth stage), mineral nutrient fertility of stock plants, and genetic variation all have a major influence on adventitious rooting of loblolly pine. Spring softwood cuttings rooted in the highest percentages, followed by winter hardwood, and summer softwood cuttings. Although, N fertilization of stock plants can be used to optimize rooting success, specific regimes will need to be determined for each species and even for families or clones within a species. In addition, low B concentrations which were not detrimental for plant growth may have severely inhibited adventitious root formation.

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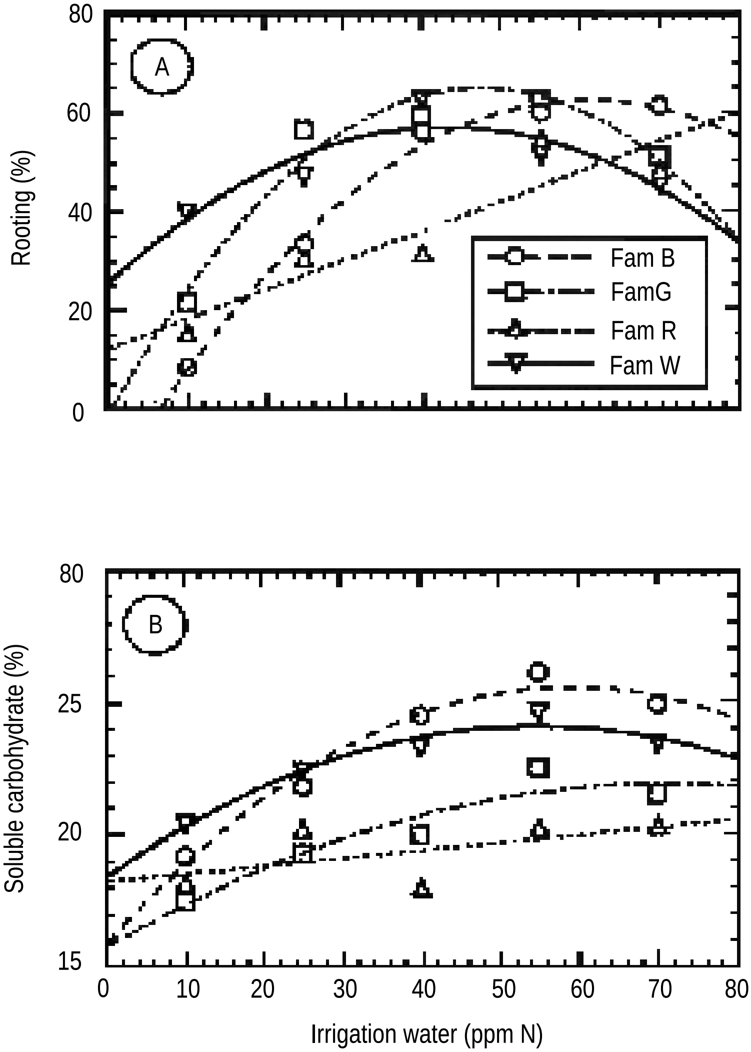


Figure 1. Effect of stock plant nitrogen fertilization on (A) rooting and (B) soluble carbohydrate content of stem cuttings of loblolly pine taken from four families (Fam. B, G, R, or W) of hedged stock plants. In (A), each symbol is based on 72 observations. In (B), each symbol is based on 12 observations. Data are averaged over seasons.

# Use of Sulfentrazone (F6285) for Weed Management in Field-Grown Ornamentals

**Kimberly B. Collins, Leslie A. Weston, and Robert E. McNiel**
**Kentucky**

**Nature of Work:** The nursery industry currently has few options for effective season-long weed control, because relatively few soil persistent broad spectrum herbicides are registered for use in ornamentals. An herbicide that provides season-long weed control would be extremely beneficial because it would enable nurserymen to produce high quality ornamentals with minimal weed interference. Sulfentrazone (F6285), a newly developed herbicide from the FMC Corporation, has shown promising results for weed control in field trials with ornamentals. Additional trials are needed to further evaluate the potential for registration of sulfentrazone in a wide variety of ornamentals.

Sulfentrazone provides selective control of yellow nutsedge and morningglory spp., as well as broadleaf and annual grass weeds (Weston et al., 1995). Sulfentrazone controls weeds by inhibiting protoporphyrinogen oxidase in the chlorophyll biosynthetic pathway. This process causes a phytodynamic toxicant (protoporphyrin IX) to build up, which leads to membrane disruption. Plants absorb sulfentrazone from both the roots and shoots, and they turn necrotic and die shortly after exposure to light. Postemergence application resulting in foliar contact of weeds with sulfentrazone can cause rapid desiccation and necrosis in affected weeds, particularly smaller ones (Theodoridis et al., 1992, Van Saun et al., 1991). Sulfentrazone, like other soil applied herbicides, requires soil moisture/rainfall for activation. However, pre-plant incorporation improves its activity under dry soil conditions. Efficacy of sulfentrazone is also influenced by soil texture and organic matter content. Greater activity is found in light, sandy soils than in medium to heavy soils with high organic matter content (Van Saun et al., 1991).

Research was conducted to evaluate sulfentrazone and combinations of sulfentrazone plus labeled products applied at different rates in ornamentals (manufacturers are shown in Table 1). The plots were sprayed in June, and the 17 treatments are shown in Table 2.

During the spring of 1994, plots measuring 1800 $ft^2$ were planted with ten tree and shrub species, using 3 plants of each species per plot. Each treatment was replicated 3 times. The treatments included the following plant materials: Daylily, *Liriope muscari, Euonymus alata* 'Compacta', *Abies concolor, Viburnum trilobum* 'Hahs', *Syringa vulgaris, Cercis canadensis, Crataegus viridis* 'Winter King', *Fraxinus americana* 'Skyline', and *Quercus rubra*. Application was made with a $CO_2$ pressurized backpack sprayer calibrated to 26 gallons per acre using 8004 nozzles and 30 lbs psi at the boom. Herbicide efficacy was evaluated at 4 weeks after application, with 0 representing no control and 100 representing complete control.

**Results and Discussion:** Weed control ratings are reported in Table 2. The major weeds encountered in this experiment included annual grasses, johnsongrass, yellow nutsedge, morningglory spp., honeyvine milkweed, and velvetleaf. Johnsongrass occurred mainly in clumps (rhizome johnsongrass) and was sporadic throughout the study. Although some treatments exhibited no johnsongrass, its absence may be due to plot location and not herbicide treatment. Therefore, limited consideration will be given to the ratings for johnsongrass. The best overall control was provided by sulfentrazone (0.375 lb ai/A) plus Pennant (3.0 pt ai/A), with a 90% overall weed control rating. With the exception of johnsongrass, this treatment gave superior control (>90%) of nearly all of the major weeds in this study, and 88% control of honeyvine milkweed. Sulfentrazone at 0.125 lb ai/A provided the poorest overall control (32%), with less than 60% control of morningglory spp., honeyvine milkweed, and johnsongrass. Sulfentrazone at higher rates provided moderate control (>80%).

Limited phytotoxicity was observed with sulfentrazone and sulfentrazone combinations (data not presented). Liriope and day lily were the most sensitive, exhibiting chlorosis and bleaching of the foliage. The highest levels of phytotoxicity in these species were caused by sulfentrazone at 0.5 lb ai/A and sulfentrazone (0.375 lb ai/A) plus Pennant (3.0 pt ai/A). *Syringa vulgaris* exhibited slight herbicide damage due to foliar contact, which was similar among all sulfentrazone treatments.

**Significance to Industry:** An herbicide which provides season long control, minimal offsite movement or leaching and low toxicity to ornamentals and annuals would be extremely beneficial to the nursery industry. It would better enable nurserymen to produce high quality nursery stock with an environmentally sound product. Sulfentrazone, an FMC product, has shown promising results in field trials by controlling serious weeds that are often difficult to control with products currently labeled for nursery crops. Additional trials are needed to further evaluate sulfentrazone and its efficacy and phytotoxicity to ornamentals in the nursery and landscape.

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Table 1. Herbicide Manufacturers

| HERBICIDE | CHEMICAL | MANUFACTURER |
|---|---|---|
| Sulfentrazone 80WP | sulfentrazone | FMC |
| Gallery 75DF | isoxaben | DowElanco |
| Pennant | metolachlor | Ciba |
| Treflan | trifluralin | DowElanco |

Table 2. Four week weed control rating

| TREATMENT | RATE (lb ai/A) | Annual Grass | Yellow Nutsedge | Morning Glory | Honeyvine Milkweed | Velvet Leaf | OVER ALL |
|---|---|---|---|---|---|---|---|
| 1. Sulfentrazone 80WP | 0.125 | 88.33a | 100.00a | 53.33b | 56.67b | 100.00a | 31.67c |
| 2. Sulfentrazone 80WP | 0.250 | 95.00a | 100.00a | 89.33a | 62.33ab | 98.33a | 80.00ab |
| 3. Sulfentrazone 80WP | 0.375 | 96.33a | 100.00a | 91.67a | 76.00ab | 95.00a | 84.33a |
| 4. Sulfentrazone 80WP | 0.5 | 91.00a | 100.00a | 87.33ab | 80.00ab | 96.67a | 86.33 |
| 5. Gallery 75DF | 0.5 | 60.00b | 97.67ab | 53.33b | 80.00ab | 66.67a | 55.00bc |
| 6. Sulfentrazone 80WP | 0.250<br>0.5 | 84.33a | 98.33ab | 86.00ab | 83.33ab | 100.00a | 78.33ab |
| 7. Sulfentrazone 80WP+Gallery 75DF | 0.375<br>0.5 | 86.67 | 100.00a | 91.00a | 56.67 | 100.00a | 78.33ab |
| 8. Pennant 7.8L | 3.0 | 93.33a | 100.00a | 53.33b | 78.33ab | 66.67a | 55.67bc |
| 9. Sulfentrazone 80WP + Pennant 7.8L | 0.125<br>3.0 | 93.33a | 100.00a | 86.67ab | 63.33ab | 99.33a | 76.67ab |
| 10. Sulfentrazone 80WP + Pennant 7.8L | 0.250<br>3.0 | 95.67a | 100.00a | 81.67ab | 65.00ab | 96.00a | 72.33ab |
| 11. Sulfentrazone 80WP + Pennant 7.8L | 0.375<br>3.0 | 95.00a | 99.00a | 90.33a | 88.33a | 100.00a | 90.00a |
| 12. Treflan 4EC | 2.0 | 91.67a | 93.33b | 68.33ab | 81.67ab | 98.33a | 77.67ab |
| 13. Treflan 4EC | 4.0 | 89.00a | 95.00ab | 89.33ab | 85.00ab | 100.00a | 83.33a |
| 14. Sulfentrazone 80WP + Treflan 4EC | 0.125<br>2.0 | 90.00a | 99.00a | 81.67ab | 70.00ab | 70.00a | 80.67ab |
| 15. Sulfentrazone 80WP + Treflan 4EC | 0.250<br>2.0 | 92.67a | 99.00a | 85.00ab | 85.00ab | 100.00a | 70.00ab |
| 16. Sulfentrazone 80WP + Treflan 4EC | 0.375<br>2.0 | 91.00a | 100.00a | 66.67ab | 60.00ab | 100.00a | 81.33ab |
| 17. Untreated check | — | 0.00c | 0.00c | 0.00c | 0.00c | 0.00b | 0.00d |
| SIGNIFICANCE | | <.001 | <.001 | <.001 | ** | <.001 | <.001 |
| LSD 0.05 | — | 20.59 | 5.55 | 35.11 | 31.42 | 35.29 | 27.49 |

* Morningglory species include: ivyleaf morningglory and bigroot morningglory

# Evaluation of Herbicide Adsorption and Release Properties of Five Herbicide-Coated Fertilizers

**Kevin R. Keel, Charles H. Gilliam, Glenn R. Wehtje, Tim L. Grey, Gary J. Keever and Donald J. Eakes**
**Alabama**

**Nature of work:** In nursery crop production herbicides are typically broadcast over the top of the containers with a cyclone spreader. A major problem with this type of broadcast application of granular pre-emergence herbicides in container nursery crops is non-target herbicide loss (2). Due to environmental concerns, the container nursery industry has been encouraged to reduce the amount of pesticides used in production. Several approaches have been evaluated to reduce herbicide loss from container grown nursery crops. One technique evaluated in more recent work involved coating several controlled-release fertilizers with oxadiazon and evaluating for weed control. This technique used about 80% less herbicide than traditional broadcast applications (1). Weed control differed with oxadiazon-coated controlled release fertilizers, suggesting that characteristics of the fertilizer carrier influence herbicide activity. The objective of this study was to study oxadiazon release rates from oxadiazon-coated fertilizers and to evaluate factors affecting release.

Five commonly used control release fertilizers were evaluated: Meister 24N-4$P_2O_5$-7$K_2O$ (Helena Chemical Co., Memphis Tenn); Nursery Special 12N-6$P_2O_5$-6$K_2O$ (Pursell Ind. Sylacauga Ala); Polyon 24N-4$P_2O_5$-12$K_2$ (Pursell Ind.); Osmocote 17N-7$P_2O_5$-12$K_2O$ (Scotts Co. Marysville, Ohio); Nutricote 20N-7$P_2O_5$-10$K_2O$ (Chisso-Asahi Fertilizer Co. LTD, Tokyo Japan:Florikan E.S.A. Corp. Sarasoto FL); glass beads 4mm in diameter (0.16 in) served as a similar-sized nonadsorbent control. Fertilizers were coated with commercially-formulated oxadiazon (Ronstar 50WP) and $^{14}C$-oxadiazon to facilitate detection. The effective concentration of herbicide to fertilizer was 0.3 mg ai/g. This is equivalent to 4.4 kg ai/ha (4.0 lb ai/a) the typical use rate for oxadiazon based on treated surface area. Herbicide-coated fertilizers, [20 g (0.04 lb)] were placed into separatory funnels and 20 ml (0.6 oz) of water was added to each funnel with a syringe. This volume of water after 30 minutes was allowed to drain into 125 ml (3.75 oz) flask for 10 minutes. Volume of leachate recovered was measured and 1-ml subsamples were assayed for $^{14}C$ using liquid scintillation spectrometry (LSS) (3). This procedure was repeated daily for 14 days. The amount of oxadiazon recovered in each leaching was determined by multiplying the amount of radioactivity in the 1-ml subsample by the total volume of leachate collected. Fertilizer surface area was determined by passing 50 g (.11 lb) of each fertilizer through a nested series of 9 screens with a progression of precise-sized openings which ranged from 11.1 mm to 0.31 mm. Fertilizer surface texture was examined using scanning electron microscopy at 300x magnification for leached and nonleached random samples of Polyon and Osmocote. These two fertilizers were selected since the oxadiazon release patterns were markedly different.

**Results and Discussion:** During the first three leaching events, Meister, Osmocote and Nutricote released 70% to 80% of the oxadiazon, while Polyon released only 56% (Fig. 1). On day one, $^{14}C$-oxadiazon released from glass beads and Nutricote exceeded 50% of the total oxadiazon recovered during the study. Polyon released the least amount (22%) of the 5 fertilizers on day one. After day five the oxadiazon coated Polyon consistently had the highest level of oxadiazon released. In previous work (1) with herbicide-coated fertilizers, oxadiazon-coated Polyon was more effective in controlling weeds than any other oxadiazon-coated fertilizer. Polyon surface area was 23% greater than the fertilizer with the next largest surface area. The greater surface area of Polyon may contribute to the pseudo slow release properties and improved weed control (1). The surface of Polyon under went visually apparent surface erosion over the 14 leaching events unlike any of the other fertilizers surface which appeared similar before and after the 14 leaching events as exemplified by osmocote.

**Significance to Industry:** This study demonstrates that oxadiazon-coated Polyon releases herbicide more slowly in the first few leaching events than several other control release oxadiazon-coated fertilizers, possibly due to a higher total particle size. Superior weed control obtained with oxadiazon-coated Polyon maybe attributed to its ability to release more oxadiazon over a longer period of time. These data may positively impact the successful development or modification of new technology designed to reduce nontarget herbicide loss while maintaining effective weed control in container grown production areas.

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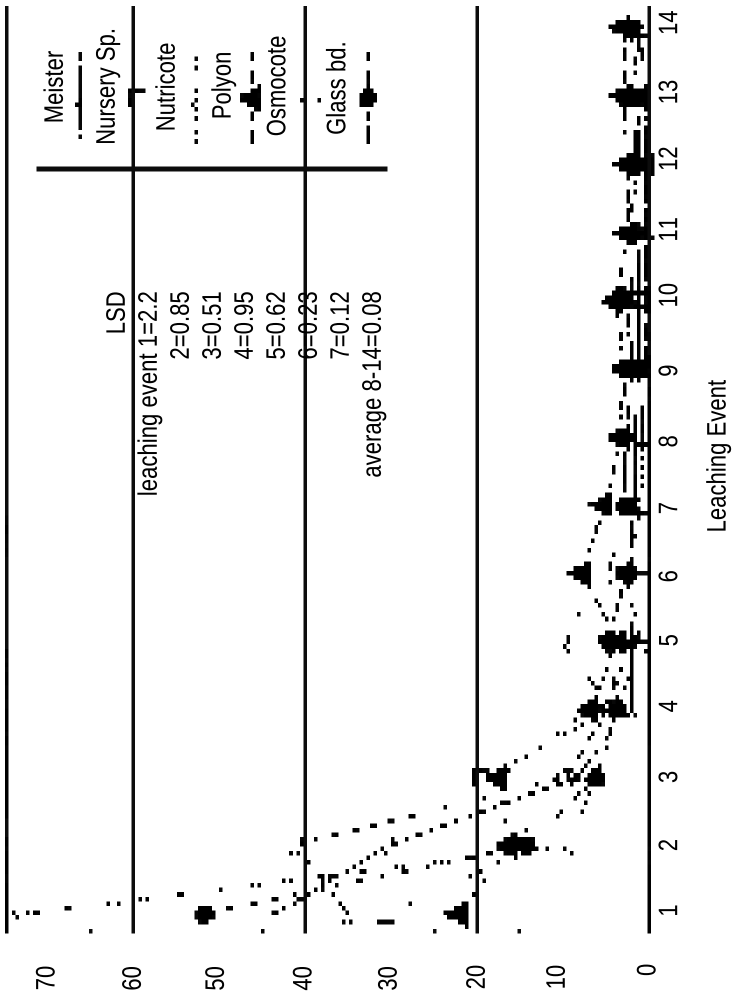
Figure 1. Daily % of total amount of oxadiazon recovered over the 14 leaching events.



# Flowering Dogwood Performance in a Central Alabama Field Study

**R.B. Hardin, D.J. Eakes, C.H. Gilliam, and G.J. Keever**
**Alabama**

**Nature of Work:** Flowering dogwood (*Cornus florida* L.), first cultivated in 1731 (1), has approximately 60 cultivars based on a checklist published by Santamour and McArdle in 1985 (3). It is one of the most popular trees in the United States. Although flowering dogwood is suggested to be planted in partial shade, full sun is acceptable (1). There have been studies of flowering dogwood in full sun in Michigan and Tennessee. The study in Michigan compared seedlings from 18 states for fall color and seedlings from 15 states for cold hardiness, flowering, and the presence of stem cankers (2). The study in Tennessee compared cultivars for disease resistance and desirable characteristics including average number of blooms per tree and average bract length (4). Because of the need for more information concerning differences among flowering dogwood cultivars in growth and bract size for this geographic region, Auburn University and the Alabama Agricultural Experiment Station are evaluating 23 cultivars and 1 forma of flowering dogwood for height and stem diameter increase, and average bract size.

Bare-root liners, 2-3 ft. (0.61-0.91 m) tall, were planted in March, 1993 in Auburn, Alabama. The study is a randomized complete block design with 6 replications and 2 trees per replication. The soil type is a Marvyn loamy sand and the trees were planted on 20 ft. (6.1 m) centers along a row with 25 ft. (7.6 m) between the rows. A 24-in. (61 cm) tractor mounted auger was used to dig planting hole depths of 24 in. (61 cm). The dogwoods are in full sun and are irrigated with two drip emitters per tree on an as needed basis. The trees are top dressed annually at a rate of 1.5 lb. (681 g) per in. (2.54 cm) of stem diameter, measured at 6 in. (15.24 cm) above the soil line. Bract size was calculated using the mean of 3 measurements for each tree. Structures were measured from the tip of one bract across the flower to the tip of the opposite bract.

**Results and Discussion:** The selections were divided into 3 groups for analyses: 1)white bracted with green foliage, 2)red or pink bracted with green foliage, and 3)variegated foliage. Among the white bracted cultivars with green foliage, 'Welch Bay Beauty' had the greatest increase in height and stem diameter from 1994 to 1995 and 'Autumn Gold' the least along with 'Wonderberry' (Table 1). Of the red and pink bracted cultivars with green foliage, 'Stokes' Pink' and 'Welch's Junior Miss' had the greatest increase in height, while 'Cherokee Brave' the least. 'Stokes' Pink' had a greater stem diameter increase than any other red or pink bracted selection and was 32% greater than the next best selection, 'Welch's Junior Miss'. 'Cherokee Chief' had the smallest stem diameter increase from 1994 to 1995. There were no height differences among the cultivars with variegated foliage. However, 'First Lady' had a greater increase in stem diameter than any other variegated selection.

'Cloud 9' had the greatest average bract size among the white bracted flowering dogwood cultivars with green foliage and 'Ozark Spring' the smallest (Table 1). Among the red or pink bracted selections, 'Red Beauty' and 'Cherokee Chief' had the greatest average bract size and 'Stokes' Pink', 'Welch's Junior Miss', and 'Purple Glory' the least. There were no bract size differences among the cultivars with variegated foliage.

**Significance to Industry:** Based on one year's data, 'Welch Bay Beauty' is the fastest growing white bracted cultivar with green foliage. This is a double bracted selection and had smaller bracts than several other selections. 'Cloud 9' had similar growth increases to 'Welch Bay Beauty' and the largest bracts. Of the red and pink bracted cultivars with green foliage, 'Stokes' Pink' and 'Welch's Junior Miss' showed the greatest increases in growth, but smallest bracts. 'Red Beauty' and 'Cherokee Chief' had the greatest bract size, with moderate growth, of the red and pink bracted selections. 'First Lady' is the most desirable selection with variegated foliage for growth increase, while the cultivars are similar with respect to bract size.

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Table 1. Height and stem diameter increase (1994 to 1995) and average bract size (spring 1996) of selected flowering dogwoods.

| Selection | Height (in.) | Stem diameter (in.) | Average bract size (in.) |
|---|---|---|---|
| White bracted with green foliage | | | |
| 'Autumn Gold' | 6.33c[1] | 0.20c | -[2] |
| Barton' | 17.88ab | 0.53b | 2.369cd |
| 'Cherokee Princess' | 14.54abc | 0.52b | 3.071ab |
| 'Cloud 9' | 17.89ab | 0.70ab | 3.442a |
| 'Fragrant Cloud' | 18.36ab | 0.58b | 3.031ab |
| 'Ozark Spring' | 17.30ab | 0.69ab | 2.101d |
| 'Plena' | 10.87bc | 0.62ab | 3.117ab |
| 'Springtime' | 13.31abc | 0.53b | 2.749bc |
| 'Weaver' | 19.66ab | 0.64ab | 2.300cd |
| 'Welch Bay Beauty' | 22.23a | 0.85a | 2.736bc |
| 'Wonderberry' | 13.95abc | 0.25c | 2.378cd |
| 'World's Fair' | 20.72ab | 0.63ab | 2.756bc |
| Red and pink bracted with green foliage | | | |
| 'Cherokee Brave' | 10.25b | 0.54bc | 2.434bc |
| 'Cherokee Chief' | 11.60ab | 0.40c | 2.622ab |
| 'Pink Beauty' | 15.44ab | 0.54bc | 2.287bc |
| 'Purple Glory' | 13.77ab | 0.46bc | 2.205c |
| 'Red Beauty' | 12.87ab | 0.51bc | 2.866a |
| f. *rubra* | 13.21ab | 0.45bc | 2.319bc |
| 'Stokes' Pink' | 18.69a | 0.97a | 2.047c |
| 'Welch's Junior Miss' | 18.07a | 0.66b | 2.057c |
| Variegated foliage | | | |
| 'Cherokee Daybreak' | 4.55a | 0.21b | 2.283a |
| 'First Lady' | 10.05a | 0.45a | 2.738a |
| 'Rainbow' | 8.57a | 0.25b | 2.154a |
| 'Sunset' | 10.43a | 0.25b | 2.677a |

[1] Mean separation in columns for each bract and foliar color group by Duncan's Multiple Range Test, alpha = 0.05.

[2] No bracts produced.

# The Role of Cyanide in Host Plant Resistance to Japanese Beetle

**Cynthia A. Patton, Thomas G. Ranney, James D. Burton, and James F. Walgenbach**
**North Carolina**

**Nature of Work:** The genus *Prunus* is highly diverse and includes many important nursery crops. Although a variety of insect pests feed on *Prunus* species, Japanese beetles (*Popillia japonica* Newman) are damaging foliar feeders that often require chemical control. Some *Prunus* taxa are known to contain cyanogenic glycosides that may play a role in host plant resistance to insect pests. Cyanide potential has been found to be an important factor in deterring the oblique-banded leaf roller (*Choristoneura rosaceana*) in peach and for *Locust migratoria* on sorghum (Kaethler, et al. 1982; Woodhead and Bernays, 1978). Identification and development of taxa with natural pest resistance would minimize the need for pesticide usage and aid in the development of more sustainable landscapes. The objectives of this study were to evaluate the role of cyanide in host plant resistance to Japanese beetle and to quantify variations in cyanide potential among *Prunus* taxa.

Foliage of twenty-seven taxa, representing a naturally occurring range of cyanide potential, were screened for resistance to Japanese beetle under no-choice feeding conditions. Ten replications of single leaves from each taxa were maintained in a fully hydrated state. One female Japanese beetle which had been starved for twenty-four hours was allowed to feed on a leaf for twenty-four hours in a continuously lighted growth chamber at 25C. Fecal material was dried and cyanide potential was determined with an enzymatic assay of lyophilized leaf tissue collected concurrently with leaf tissue collected for feeding trials. The experiment was arranged as a randomized complete block design. In addition to the above feeding study, a dose:response trial was performed with the compound prunasin, the cyanogenic glucoside that occurs in the leaf tissue of *Prunus* species. The artificial diet consisted of agar, cellulose, sucrose, water and prunasin at 0, 1, 5, 10, 20, and 40 mM concentrations. Single starved beetles were allowed to feed on the media for twenty-four hours. This experiment was arranged as a completely randomized design with n=10.

**Results and Discussion:** As foliar cyanide potential increased, feeding intensity of adult Japanese beetle showed a significant sigmoidal decrease (Fig. 1). Taxa with cyanide potentials equaling 2.48 mM/kg fresh weight (FW) and above inhibited feeding to levels not significantly different from zero (Table 1). In general, taxa with cyanide potentials less than 2.48 mM/kg FW were fed on more intensely and in a more random fashion. This data indicates that an apparent threshold level of approximately 2.5 mM/kg FW is needed to effectively deter feeding. An exception to these trends was *P. mahaleb*. This taxon exhibited a low level of cyanide potential but was highly resistant (mean FDW=0.3 mg). The resistance of *P. mahaleb* to feeding of Japanese beetle is therefore due to a mechanism other than cyanide potential. One possibility is the presence of coumarin compounds that have been found in *P. mahaleb* (Santamour and Riedel, 1994).

As the dose of prunasin increased in an artificial diet, feeding intensity also decreased (Fig. 2), with a response similar to that found for endogenous cyanide potential. These data substantiate the hypothesis that cyanogenic glycosides play a role in the deterrence of insect feeding. The effective dose of prunasin which reduced feeding by 50% ($ED_{50}$) was 4.9 mM. This concentration was higher than the concentration found to reduce feeding by the same amount in leaf tissue. The greater efficacy in the plant may be due to the localization of cyanogenic glycosides near the leaf surface or the presence of catabolizing enzymes in the plant capable of releasing larger amounts of hydrogen cyanide.

The selection and development of taxa with enhanced cyanide potential may yield more pest resistant plants. Further work is warranted to screen additional taxa for cyanide potential in order to identify plants which could be used in selection and improvement programs.

**Significance to Industry:** Alternatives to chemical control of insect pests are becoming increasingly desirable. Selecting more naturally pest resistant plants such as *P. padus, P. laurocerasus, P. virginiana, P.* x *yedoensis, and P. besseyi* for use in the landscape will lessen the need for chemical control measures. In addition, the identification of compounds responsible for antixenosis, such as cyanogenic glycosides, will aid in the development of more pest resistant plants through breeding and molecular techniques.

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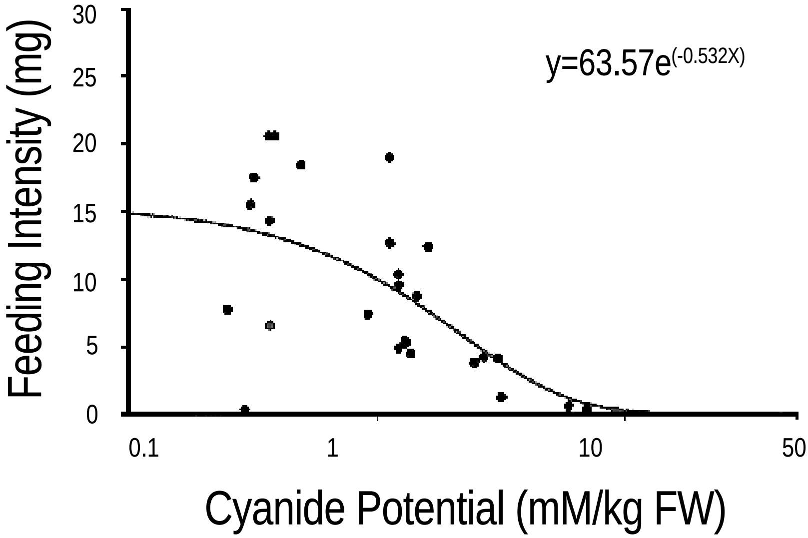


Figure 1. Relationship between feeding intensity (fecal dry weight) and cyanide potential measured in leaf tissue of 27 *Prunus* taxa. Each symbol represents the mean for a given taxa of *Prunus*, n=10.

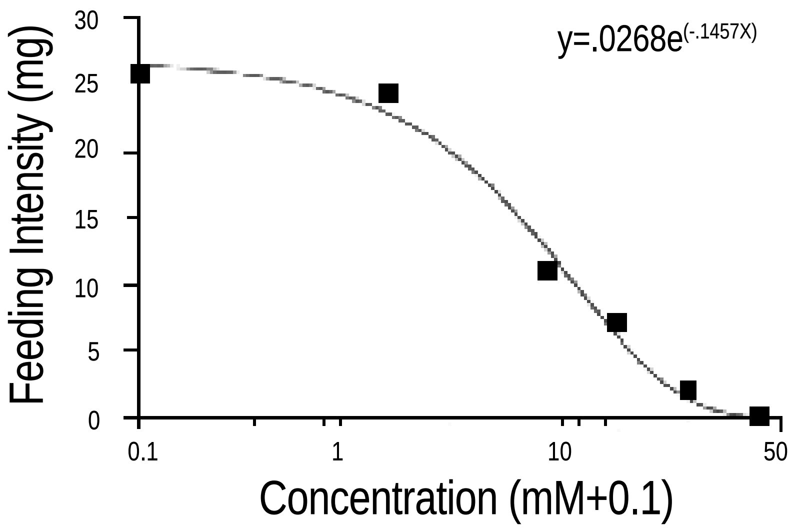


Figure 1. Feeding intensity (fecal dry weight) as a function of prunasin content in an artificial diet. Each symbol represents a mean, n=10.

Table 1. Feeding intensity (fecal dry weight) of Japanese beetles and foliar cyanide potential for 27 taxa of *Prunus*.

| Taxa | Feeding Intensity (mg) | Cyanide Potential mM/kg FW |
|---|---|---|
| P. padus | 0.00 | 9.24 |
| P. laurocerasus | 0.20 | 7.02 |
| P. mahaleb | 0.30 | 0.29 |
| P. serotina | 0.50 | 5.94 |
| P. virginiana | 1.10 | 3.18 |
| P. x yedoensis | 3.70 | 2.48 |
| P. americana | 4.00 | 3.07 |
| P. besseyi | 4.10 | 2.69 |
| P. pennsylvanica | 4.40 | 1.37 |
| P. persica 'Redhaven' | 4.80 | 1.23 |
| P. persica 'Saharanpur' | 5.20 | 1.30 |
| P. persica 'Ta Tao #6' | 5.30 | 1.30 |
| P. artmeniaca | 6.50 | 0.37 |
| P. serrulata | 7.30 | 0.92 |
| P. mume | 7.70 | 0.25 |
| P. cerasifera | 8.60 | 1.46 |
| P. persica '134401' | 9.40 | 1.24 |
| P. persica 'Quetta' | 10.20 | 1.23 |
| P. subhirtella | 12.20 | 1.62 |
| P. x cistena | 12.50 | 1.14 |
| P. domestica | 14.20 | 0.37 |
| P. cerasus 'North Star" | 15.40 | 0.31 |
| P. avium | 17.40 | 0.32 |
| P. salicina | 18.30 | 0.50 |
| P. dulcis | 18.80 | 1.14 |
| P. sargentii | 20.40 | 0.39 |
| P. tomentosa | 20.40 | 0.37 |
| $LSD_{0.05}$ | 4.30 | 0.52 |

# Container Hole Position Affects Growth of Four Wetland Species

**P.A. Merritt, D.J. Eakes, C.H. Gilliam, and G.J. Keever**
**Alabama**

**Nature of Work:** Bilderback et al. (1993) consider wetland and aquatic plants to have at least two market possibilities: (1) wetland mitigation and restoration, and (2) aquascaping in both residential and commercial properties. Nursery owners have an opportunity to take advantage of these growing markets by contract production of wetland and aquatic plants. However, there is little information available on wetland and aquatic plant production.

Our objective was to determine the effects of container hole position on growth and production of four wetland species. The concept of raised holes on containers is currently marketed as Environmentally Friendly Containers (EFC), which have drainage holes about one inch from the bottom. In our experiment we compared various positions of raised drainage holes, to see if a larger water reservoir would be beneficial to the growth of wetland plants.

On May 23, 1995, four wetland species, *Canna flaccida* Salisb. (canna), *Iris versicolor* L. (iris), *Spartina alterniflora* Loisel (smooth cordgrass) and *Juncus effusus* L. (soft rush) were planted into trade gallon containers of Metro Mix 500. The five container types used were: no holes, four holes located at the bottom of the container, four holes half way [3.2 inches(8 cm)] up the side wall of the container, four holes three quarters of the way [4.7 inches (12 cm)] up the side wall of the container, and pot in pot which consisted of a trade gallon growing pot with four holes at the bottom placed inside a full gallon socket pot lined with poly. All plants were fertilized with two Sierra (16-8-12 + minors) tablets(2.39 g of nitrogen) per pot placed just below each transplant. Plants were watered to 100% container capacity daily, and grown in a double poly greenhouse at a minimum set temperature of 65F (18.3C).

Plant growth index [(height + width + width)/3], total shoot number (or leaf number of soft rush), visual shoot rating (a scale of 0 to 5 with 5 being a large healthy plant and 0 being dead), and medium solution pH and soluble salt concentration were determined 60 days after potting (DAP) for each plant. Due to the rapid growth of canna, visual root rating and plants shoot dry weight were determined. At 90 DAP growth index, total shoot number, and root and shoot visual ratings were determined for each iris, rush, and smooth cordgrass plant. Plants were then harvested to determine shoot dry weights.

**Results and Discussion:** Growth index for canna at 60 DAP (Table 1) were greater for pot-in-pot plants and plants produced in pots with holes half way up while plants produced in containers with holes three fourths of the way up had the lowest growth index. Plants in the pot-in-pot containers had the highest shoot dry weight and plants produced in traditional containers with holes at the bottom had the least dry weight. Visual root and shoot ratings for canna were highest in the pot-in-pot treatment and similar for all other treatments.

Soft rush grown in the pot-in-pot treatment (Table 2) had a higher growth index, higher leaf and root ratings, and greater dry weights than plants grown in the other four pot types. There were no treatment differences with any growth parameters for smooth cord grass or iris. Although medium solution pH and soluble salts ranges varied among species, treatment differences were similar. A higher pH and lower salts level was present in the pot-in-pot treatment than the other treatments. Medium solution pH averaged 5.7 for pot-in-pot soft rush while the remaining four treatments averaged 5.0 and ranged from 4.6 to 5.3. Soluble salt levels in pots with no holes, holes half way up, and holes three fourths way up ranged from 4.0 to 5.5 dS/m, while salt levels for the container with holes at the bottom, and pot-in-pot averaged at 0.5 dS/m.

**Significance to the Industry:** Growing canna and soft rush in a pot-in-pot system produces larger, more marketable plants than conventional containers regardless of hole position.

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Table 1. Influence of container hole position on growth of canna at 60 DAT.

| Treatment | Growth index (inches) | Shoot rating | Root rating | Top dry weight (g/plant) |
|---|---|---|---|---|
| No holes | 23.7ab[z] | 2.4b | 2.2b | 57.6bc |
| Bottom | 23.9ab | 2.7b | 2.9b | 47.8c |
| 1/2 up | 25.3a | 2.7b | 2.4b | 71.3ab |
| 3/4 up | 21b | 3.1b | 2.6b | 64.5bc |
| Pot in pot | 26.4a | 4.1a | 4.6a | 83.7 |

[z] Mean separation within columns by Duncan's multiple range test P <= 0.05.

Table 2. Influence of container hole position on growth of soft stem rush at 90 DAT.

| Treatment | Growth index (inches) | Leaf rating | Root rating | Top dry weight (g/plant) |
|---|---|---|---|---|
| No holes | 29.2b[z] | 3.0b | 3.0b | 52.6b |
| Bottom | 26.8b | 2.7b | 3.0b | 40.4c |
| 1/2 up | 26b | 2.9b | 3.1b | 47.0bc |
| 3/4 up | 26.8b | 2.6b | 3.1b | 48.3bc |
| Pot in pot | 31.2a | 4.0a | 5.0a | 88.7a |

[z] Mean separation within columns by Duncan's multiple range test $P <= 0.05$.

# Herbaceous Perennials Response to Triexpec-Ethyl (Primo) Applications

**Russell Smith, W. B. Miller, and T. Whitwell**
**South Carolina**

**Nature of Work:** The demand for color in the landscape has increased the market for more container nursery production of herbaceous perennials. Along with this increased demand, retail markets are requesting lower prices. One way to meet this market opportunity is through the production of shorter plants, which in return lowers the shipping cost (i.e., more plants per truck).

Preliminary work at Carolina Nurseries (1) revealed that few labeled growth regulators are effective in controlling the height of herbaceous perennials. The chemicals which are effective quickly lose their control within four weeks after treatment. This study evaluated Primo (triexpec-ethyl), a turf growth regulator, for potential use in perennial plant production. Primo controlled the vegetative growth of turfgrasses for 7 to 12 weeks (2, 3), which is twice as long as the current labeled nursery products for height control in landscape plants.

Six species were used for this study: *Chrysanthemum* x *superbum* 'Snow Lady,' *Dianthus gratianopolitanus* 'Firewitch,' *Liatris spicata*, *Rudbeckia maxima*, *Sedum* x 'Autumn Joy,' and *Veronica* sp. 'Goodness Grows.' All plants were potted in one gallon containers in the fall of 1995 and overwintered at Carolina Nurseries. The media was a 80% bark/ 20% sand mix amended with fertilizer and lime. On March 21, 1996 the plants were removed from nursery production and placed in the Clemson research area, located at Carolina Nurseries.

The treatments were applied to the foliage using a hand held sprayer, calibrated to deliver 2 qt./100 sq. ft. The first treatment was on March 21, 1996 and a second treatment was applied May 9, 1996. Primo (triexpec-ethyl) at 500, 1000, and 2000 ppm was evaluated. Two standard growth regulator treatments, Bonzi (paclobutrazol) at 200 ppm and a tank mix of B-Nine (daminozide) + Cycocel (chlormequat) at 2500 + 1500 ppm, were included for comparison purposes. An untreated check was also present.

A randomized complete block design was used for each species with five single plant replications. Height and phytotoxicity measurements were taken weekly. Data was subjected to analysis of variance and means separated by LSD at P = 0.05.

**Results and Discussion:** B-Nine + Cycocel failed to suppress growth in any of the six species tested whereas Bonzi reduced the height of *Chrysanthemum*, *Sedum*, and *Veronica*. In these three species, Primo was not effective in controlling height. For the remaining three species (*Liatris, Dianthus, Rudbeckia*), Primo reduced height and Bonzi did not affect plant height. (See Tables 1 and 2).

Sanderson (4) reported flower color could be influenced by Primo. He detected this only in the red and purple flowers of *Chrysanthemum* sp. We observed flower color effects from Primo on *Dianthus, Liatris* and *Veronica*. These are also pink and purple flowering species. The higher the rate of Primo the greater the bleaching of the flower pigment. Bleaching was uniform in each plant and persisted through the duration of the study. The yellow pigment of the *Rudbeckia* flowers and white pigment of the *Chrysanthemum* flowers were not affected visibly. There were no flowers present on *Sedum*.

In turfgrass research, Primo caused chlorosis and suppression of seedhead numbers (2, 3). This also was observed in *Chrysanthemum* but it was not consistent with all rates. There was also a reduction in *Dianthus* flower numbers (data not shown). *Sedum* was the only specie in this study to demonstrate undesirable growth characteristics following Primo application with yellow and distorted apical growing points.

**Significance to the Industry:** Primo greatly reduced height in species that were not responsive to Bonzi or B-nine + Cycocel. The flower discoloration was uniform but it does not make the plant unmarketable. Sanderson (4) stated that if used correctly the color change from Primo could be used to expand the market of red to purple flowering species while maintaining desirable shipping height. Primo has potential for use as a growth regulator in specific perennial crops but more research needs to be done.

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Table 1. Plant heights (cm) of six herbaceous perennials threee weeks after foliar application growth regulators.

| Treatment | Chrysanthemum | Liatris | Rudbeckia | Dianthus | Sedum | Veronica |
|---|---|---|---|---|---|---|
| Untreated | 22.4 a | 38.0 a | 45.0 a | 19.8 a | 22.8 a | 31.6 a |
| Primo 500 | 22.6 a | 32.4 b | 38.8 b | 14.8 c | 21.4 a | 32.4 a |
| Primo 1000 | 22.2 a | 32.0 b | 29.8 c | 11.0 d | 21.6 a | 31.4 a |
| Primo 2000 | 20.0 a | 19.8 c | 26.4 c | 10.2 d | 20.8 a | 31.2 a |
| Bonzi | 16.8 b | 33.6 ab | 40.6 ab | 17.0 b | 16.2 b | 21.6 b |
| B-nine/ Cycocel | 22.6 a | 36.2 ab | 39.2 b | 19.4 a | 21.0 a | 28.6 a |
| LSD | 2.8 | 4.4 | 4.5 | 3.9 | 2.8 | 4.4 |

Means following by the same letter are not significantly different within a column according to LSD at P = 0.05.

Table 2. Plant heights (cm) of six herbaceous perennials three weeks after foliar application of growth regulators. The first spray was made 10 weeks prior to data collection.

| Treatment | Chrysanthemum | Liatris | Rudbeckia | Dianthus | Sedum | Veronica |
|---|---|---|---|---|---|---|
| Untreated | 32.4 a | 60.6 ab | 121.0 a | 21.2 a | 28.0 a | 38.0 ab |
| Primo 500 | 36.0 a | 55.4 bc | 78.4 c | 15.2 b | 27.8 a | 39.8 a |
| Primo 1000 | 34.8 a | 52.2 c | 65.8 c | 11.2 c | 28.4 a | 40.6 a |
| Primo 2000 | 33.4 a | 30.0 d | 45.6 d | 11.8 c | 27.6 a | 39.0 ab |
| Bonzi | 23.8 b | 62.6 a | 108.0 ab | 19.2 a | 22.4 b | 25.0 c |
| B-nine/ Cycocel | 32.4 a | 65.0 a | 100.2 b | 20.0 a | 26.0 a | 36.2 b |
| LSD | 5.3 | 6.8 | 14.6 | 2.1 | 3.3 | 3.2 |

Means following by the same letter are not significantly different within a column according to LSD at P = 0.05.

# Capillary Mats Modify Media Moisture Content During Mist Propagation

**Jennifer J. Marohnic, Robert L. Geneve, and Jack W. Buxton**
**Kentucky**

**Nature of work:** Mist propagation of unrooted cuttings speeds rooting and produces higher quality plants than conventional poly systems, cold or hot frames, or indoor polytents (1). A central feature of the propagation of leafy cuttings is that lacking roots they readily develop water deficits (4). Slight water deficits, even though insufficient to cause any visual symptoms of distress, can result in considerable delay or reduction in the rooting response (4). Therefore, it is important that turgor of the cutting be maintained to achieve optimum rooting. With the use of intermittent mist a film of water remains on the leaf surfaces lowering the vapor pressure deficit and reducing transpirational water loss (7). Wet foliage allows the evaporative demand of the environment to be satisfied by the externally applied water, rather than by leaf transpiration, thus avoiding severe tissue water deficits. However, misting, either applied too frequently or too long at each interval, can result in excessive wetness leading to restricted aeration and reductions in root development (5).

Capillary mats can be used to add or reduce the water content of growing media in containers (2,3). In the present study, Vatex capillary mats added or removed water from Smithers-Oasis one-inch rootcubes® during mist propagation. Mats placed on the surface of the propagation bench extended over the edge of the bench and downward into a water reservoir located a distance of 0cm, 5cm, or 10cm below bench level. The water table established at bench level was determined by the location of the water reservoir. The amount of water in the capillary mat, and in turn the oasis cube, was determined by the distance of the water below bench level.

Oasis blocks with chrysanthemum cuttings ‘Boaloi’ and ‘Salmon Charm’ were placed on the mats under intermittent mist (ten seconds every five minutes) between 5a.m. and 8p.m. Leaf relative water content and quantity of water in the growing medium (ml of water/gram oasis) were measured every three days for fifteen days. After 21 days, the number of roots per cutting was evaluated. The objective of this study was to evaluate the efficacy of using capillary mats to maintain uniform moisture in the medium during mist propagation. The 0, 5, and 10cm mat treatments were evaluated to provide three levels of moisture in the medium.

**Results and Discussion:** Water content in the oasis propagation cube was significantly reduced by 47.5%, 17.9%, and 2.3% for the 10, 5, and 0cm mat treatments, respectively. This change in water content remained uniform over time for all treatments and both cultivars. However, the water status of the cuttings varied significantly during the 21 day rooting period (as much as 33% relative water content). This was possibly due to variation in daily irradiance. Severe water deficits can develop in the leaves of cuttings exposed to high irradiance levels (5,6). Irradiance varied from 250 $\mu$mol $sec^{-1}$ $m^2$ to 1450 $\mu$mol $sec^{-1}$ $m^2$ during the course of this study. The relative water content of the cutting correlated poorly with the oasis water content ($r^2$=0.22 and 0.33 for 'Boaloi' and 'Salmon Charm', respectively). Leaf relative water content of the cuttings was not significantly different between capillary mat treatments for both cultivars (Table 1). This suggests that the cuttings water status varied due to the environment (light levels and temperature) and that mist frequency and duration could be changed to meet this demand; capillary mats could then be used to prevent over saturating of the medium.

After 21 days on the propagation bench, the oasis cubes were cut from the cuttings and the number of primary roots were counted. A significant treatment effect (0, 5, 10cm), for mean number of primary roots, was observed at the $p \leq .01$ level and 'Boaloi' had greater number of roots than 'Salmon Charm' (Table 1). Root number per cutting was greater at the 5cm mat treatment for both cultivars compared to the 0cm and 10cm treatments. This suggests that a capillary mat extending 5cm below the bench can maintain moisture content in the propagation medium for improved rooting of the two cultivars of chrysanthemums used in the study.

**Significance to the Nursery Industry:** The use of capillary mats in a mist propagation system resulted in a 18% to 48% decrease in the media water content when the mat extended 5cm and 10cm below bench level, respectively. This decrease in media water content shows that it is possible to remove excess water from the propagation media in a mist propagation system. Capillary mats will prevent overwatering and fluctuation in media water content when cuttings demand more frequent misting. The reduction in media water content can lead to increased media aeration and possibly improved root development. Furthermore, it may be possible to design a propagation system based on misting intervals determined by vapor pressure deficit or irradiance.

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Table 1. Roots per cutting, relative water content (%), and oasis water content (% of initial weight) of cuttings rooted in oasis propagation cubes on capillary mats in a mist propagation system.

| Cultivar mat level (cm) | Mean roots per cutting | Relative water content (15 day average) | Oasis water content (15 day average) |
|---|---|---|---|
| Boaloi | | | |
| 0 | 14 ± 0.8[Z] | 73.1 ± 3.7[Z] | 97.4 ± 0.6[Z] |
| 5 | 18 ± 1.1 | 74.5 ± 3.2 | 83.3 ± 3.6 |
| 10 | 15 ± 1.2 | 76.2 ± 4.3 | 52.3 ± 2.5 |
| Salmon Charm | | | |
| 0 | 10 ± 0.6 | 69.5 ± 4.1 | 98.1 ± 0.5 |
| 5 | 12 ± 0.8 | 68.0 ± 4.2 | 80.9 ± 4.4 |
| 10 | 11 ± 0.6 | 74.1 ± 4.6 | 52.7 ± 1.6 |

| Anova | F-value Sig[Y] | F-value Sig | F-value Sig |
|---|---|---|---|
| Cultivar | .0001 ** | .0027 ** | .2887 ns |
| Mat | .0038 ** | .3787 ns | .0218 * |
| Cultivar x Mat | .0631 ns | .1427 ns | .6067 ns |

[Z] standard error.
[Y] **, * is significant at p≤ .01 and .05 level, respectively.