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Weed Control for Pot-In-Pot Production using Preemergence Herbicides[1]

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Abstract

Four experiments were conducted to investigate herbicides currently labeled for field and/or container production for use in pot-in-pot production. Southern magnolia (*Magnolia grandiflora* L.), red maple (*Acer rubrum* Spach. 'Autumn Flame' and 'Franksred'), ornamental pear *(Pyrus calleryana* Decne. 'Bradford' and 'Cleveland Select'), river birch (*Betula nigra* L.), green ash (*Fraxinus pennsylvanica* Marsh. and *F. pennsylvanica* Marsh.'Marshall's Seedless'), and zelkova (*Zelkova serrata* Spach 'Village Green') were evaluated for herbicide tolerance. Barricade 65WG, Surflan 4AS, and Pendulum 60WDG, used alone or in combination with Princep and Gallery 75 DF, had no adverse effect on tree shoot growth or trunk caliper growth when applied as a directed band application. Weed control varied depending upon local site conditions, herbicide rate and weed species.

Index words: landscape trees, shade trees, container nursery production, nursery crops.

Herbicides used in this study: Barricade 65WG (prodiamine), N^3, N^3-dipropyl-2,4-dinitro-6-(trifluoromethyl)-phenylenediamine; Gallery 75 DF (isoxaben), *N*-[3-(1-ethyl-1-methylpropyl)-5-isoxazolyl]-2,6-dimethoxybenzamide; OH2 3G (oxyfluorfen + pendimethalin), 2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluromethyl) benzene + *N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine; Pendulum 60 WDG (pendimethalin), given above; Princep Liquid 4L (simazine), 2-chloro-4,6-bis(ethylamino)-s-triazine; Snapshot 2.5 TG (trifluralin + isoxaben), α,α,α-trifluoro-2,6-dinitro-*N*-*N*-dipropyl-*p*-toluidine + isoxaben, given above; Surflan 4AS (oryzalin), 3,5-dinitro-N^4-N^4-dipropylsulfanilamide.

Species used in this study: Southern magnolia (*Magnolia grandiflora* L.); red maples (*Acer rubrum* Spach. 'Autumn Flame' and 'Franksred'); ornamental pears *(Pyrus calleryana* Decne. 'Bradford' and 'Cleveland Select'); river birch (*Betula nigra* L.); green ash (*Fraxinus pennsylvanica* Marsh. and *F. pennsylvanica* Marsh.'Marshall's Seedless'); zelkova (*Zelkova serrata* Spach. 'Village Green).

Significance to the Nursery Industry

Pot-in-pot (PIP) production of ornamental trees is continually increasing in the nursery industry. Preemergence herbicide weed control in PIP is imperative not only for the growing container but in the field soil in the area surrounding the socket container. Many preemergence herbicides labeled for field use do not have a label for the same species grown in container production. These studies indicate that preemergence herbicides, when applied as a directed band application, were safe on several selections of ornamental trees. No visual damage was observed and height and caliper growth of the ornamental trees was minimally affected by the herbicide treatments. Weed control in pot-in-pot systems can be achieved with herbicides currently labeled for field nursery production. Individual herbicides such as Barricade, Pendulum, and Surflan provided acceptable control of grass and some broadleaf weeds, but when used in combination with Gallery or Princep, excellent weed control was achieved.

Introduction

Although the pot-in-pot (PIP) concept has existed for many years, it gained popularity in the early 1990s, as an alternative method for producing containerized landscape crops (10). In this hybrid system of field and container production, an empty container (socket pot) is recessed permanently in the ground with the top rim about 5.1 cm (2 in) above the soil line. The potted landscape plant is placed in the socket pot for the production cycle. The PIP system has gained widespread popularity in many nursery production areas because it eliminates the need for pot staking to prevent blow-over and provides winter protection to the root system (5, 12). The PIP system is often used to produce container grown trees in 56.8 and 94.6 liter (#15 and #25) containers or large shrubs in 26.5 liter (# 7) containers. Recent reports have evaluated benefits and problems with this new production system (2, 3, 4, 12, 13, 14). However, one production area of PIP that has received limited attention is weed control. In container-grown plants, weed competition can significantly reduce the growth of landscape crops in small containers (1) due to the limited substrate volume. In larger containers, more substrate surface area is exposed and vulnerable to weed establishment, especially with tree production.

With container production there are many reports evaluating weed competition, weed control, and weed management strategies (7, 8, 9, 16, 19). Similarly, in field production many reports exist which document weed control and weed management strategies (6, 8, 9, 11, 15, 17, 18). However, certain problems exist with PIP. Oryzalin (Surflan), a commonly used field and container herbicide, has a different list of plants labeled for field application verses container application. For example, with field and landscape plantings, the Surflan label lists: *Acer spp.*, *Cornus florida*, *Fraxinus spp.*, and *Magnolia grandiflora*; however, these are not on the container label list. Similarly, herbicides that are mainly used in container production may not be registered for crops that are typically grown in the field. For example, a combination prod-

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uct of trifluralin + isoxaben (Snapshot) is a widely used herbicide in container production systems (7); however, it is not registered for use on *Acer spp.*, *Fraxinus pennsylvanica*, or *Pyrus calleryana* in field production (Table 1).

Traditional granular herbicides and weed management strategies used in container production are not applicable in PIP for several reasons: permanent spacing of the socket container, distance between the containers, type of landscape crops grown, lack of equipment to band apply a granular herbicide, and high cost of herbicides. Therefore, producers have been using alternative weed control strategies. Geotextile material has been installed as a ground cover to control weeds adjacent to the socket pot, but the geotextile provides no control for weeds in the container and is costly to install and maintain. Post-emergence herbicides such as Roundup (glyphosate, Monsanto Company, St. Louis, MO) (non-selective) and Fusilade II (fluazifop-P-butyl, Syngenta, Greensboro, NC) (postemergence grass selective) are applied routinely to the weeds growing in the container substrate and the surrounding soil, but do provide preemergence control. Weed control in PIP systems is further confounded by differences in the weed spectrum found either solely in field or container production systems.

The objectives of these experiments were to evaluate the tolerance of ornamental trees to commonly used preemergence herbicides in a PIP production system and evaluate weed control.

Materials and Methods

Experiment 1. Poplarville, MS. Socket containers for PIP were installed in 4-row blocks 5.5 m (18 ft) wide with 1.4 m (4.5 ft) between rows and between pots in a row. Each block was covered with woven polypropylene fabric to eliminate weed pressure in the area surrounding the socket containers. In June, container-grown *Magnolia grandiflora* 'Little Gem' liners [3 liter (#1) container] were potted in 95 liter (#25) containers with pine bark substrate amended with 7.1 kg (12 lb) Osmocote 18N–2.6P–10.0K (18–6–12) (O.M. Scotts Co., Maryville, OH) and 0.9 kg (1.5 lb) Micromax (O.M. Scotts Co.) per m^3 (yd^3). Plants were maintained above ground then moved to the PIP socket containers the following April. Irrigation was applied as needed with overhead impact sprinklers while on the container yard and with micro-irrigation delivered through spray stakes in the PIP system. The following preemergence herbicides were applied May 6 and repeated on August 5 (after removing all weeds from the containers): Barricade 65WG (prodiamine) (Syngenta Corp., Wilmington, DE) at 0.8, 1.7, and 3.4 kg ai/ha (0.75, 1.5, and 3.0 lb ai/A) (½×, 1× and 2×); Gallery 75 DF (isoxaben) (Dow AgroSciences, Indianapolis, IN) at 0.6, 1.1, and 2.2 kg ai/ha (0.5, 1.0, and 2.0 lb ai/A) (½×, 1× and 2×); Pendulum 60 WDG (pendimethalin) (BASF, Research Triangle Park, NC) at 1.1, 2.2, and 4.5 kg ai/ha (1.0, 2.0, and 4.0 lb ai/A) (½×, 1× and 2×); Princep (simazine) (Novartis Crop Protection) at 1.1 and 2.2 kg ai/ha (1.0 and 2.0 lb ai/A) (1× and 2×); Surflan 4AS (oryzalin) (Dow AgroSciences) at 1.1, 2.2, and 4.5 kg ai/ha (1.0, 2.0, and 4.0 lb ai/A) (½×, 1×, and 2×); Barricade + Gallery at 0.8 + 0.6 kg ai/ha (0.75 + 0.5 lb ai/A) (½× + ½×); Barricade + Gallery at 1.7 + 1.1 kg ai/ha (1.5 + 1.0 lb ai/A) (1× +1×); Barricade + Gallery at 3.4 + 2.2 kg ai/ha (3.0 + 2.0 lb ai/A) (2× + 2×); Pendulum + Gallery at 1.1 + 0.6 kg ai/ha (1.0 + 0.5 lb ai/A) (½× + ½×); Pendulum + Gallery at 2.2 + 1.1 kg ai/ha (2.0 + 1.0 lb ai/A) (1× + 1×); Pendulum + Gallery at 4.5 + 2.2 kg ai/ha (4.0 + 2.0 lb ai/A) (2× + 2×); Surflan + Gallery at 1.1 + 0.6 kg ai/ha (1.0 + 0.5 lb ai/A) (½× + ½×); Surflan + Gallery at 2.2 + 1.1 kg ai/ha (2.0 + 1.0 lb ai/A) (1× + 1×); Surflan + Gallery at 4.5 + 2.2 kg ai/ha (4.0 + 2.0 lb ai/A) (2× + 2×); Surflan + Princep at 2.2 + 1.1 kg ai/ha (2.0 + 1.0 lb ai/A) (1× + 1×); Surflan + Princep at 4.5 + 2.2 kg ai/ha (4.0 + 2.0 lb ai/A) (2× + 2×); and OH2 (oxyfluorfen + pendimethalin) (O.M. Scotts Co.) at 3.4 kg ai/ha (3.0 lb ai/A) (1×). Barricade, Gallery, Pendulum, and Surflan were applied at the minimum use rate (½×), maximum (1×) and twice that rate (2×). Princep was applied at the anticipated use rate (1×) and twice that rate (2×), while OH2 was applied at the anticipated use rate (1×). Sprayed treatments were applied as a directed band application on each side of the containers that encompassed the container substrate and a 30 cm (1 ft) strip outside the containers as well as the area in the row between the containers. A CO_2 backpack sprayer with a single 8003 flat fan nozzle was calibrated to deliver 187 liters/ha (20 gal/A) at 207 kPa (30 psi). Granular herbicides were applied with a handheld shaker in an area that included the container substrate, the area between containers and a 30 cm (1 ft) strip on each side of the containers. A hand weeded control was also included and weeded at each observation date. Data collected were percent weed control (rated visually on a scale of 0 to 100 with 0 = no control and 100 = complete control) and plant injury (rated visually on a scale of 1 to 5 with 1 = healthy and 5 = dead) 30, 60 and 90 days after herbicide treatment (DAT). For simplicity, 30-1, 60-1, 90-1 and 30-2, 60-2, 90-2 will annotate days after the first and second herbicide application, respectively. Plant height and trunk diameter (measured at 15 cm [6 inches] above the soil line) were recorded at the start of the study and at termination. The experiment was arranged as a randomized complete block design with four replications of three plants each. Data from each tree species were subjected to regression analysis and means were separated using Duncan's Multiple

Table 1. Label registration status of preemergence herbicides used in these experiments.

Herbicides	Active ingredient	*Acer rubrum*	*Betula nigra*	*Fraxinus pennsylvanica*	*Magnolia grandiflora*	*Pyrus calleryana*	*Zelkova serrata*
Barricade 65WG	prodiamine	NL[z]	NL	NL	FO	FC	NL
Gallery 75 DF	isoxaben	FO	FC	NL	FC	NL	NL
Pendulum 60 WDG	pendimethalin	FC	FC	NL	FC	FC	NL
Princep Liquid	simazine	NL	NL	NL	NL	NL	NL
OH2	oxyfluorfen + pendimethalin	CO	CO	NL	CO	NL	NL
Snapshot 2.5TG	trifluralin + isoxaben	FO	FC	NL	FC	NL	NL
Surflan 4AS	oryzalin	FO	NL	FO	FO	NL	NL

[z]NL = not labeled, FC = field and container, FO = field only, CO = container only.

Range Test (DMRT, $\alpha = 0.05$). Data in all experiments were analyzed with the general linear model procedure (Proc GLM) in SAS with herbicide rate as a nested factor with herbicide product.

Experiment 2. McMinnville, TN. This test was conducted similarly to Experiment 1 with the following exceptions. Snapshot 2.5 TG (trifluralin + isoxaben) (Dow AgroSciences) at 2.2 and 4.5 kg ai/ha (2.0 and 4.0 lb ai/A) was applied in lieu of the granular herbicide OH2. Treatments were applied on April 24 and July 21 with a CO_2 backpack sprayer equipped with a single 8003VS flat fan nozzle and calibrated to deliver 280 liters/ha (25 gal/A) at 207 kPa (30 psi). Experimental trees, southern magnolia (*Magnolia grandiflora* L.), Red Sunset red maple (*Acer rubrum* Spach. 'Franksred'), and Cleveland Select pear (*Pyrus calleryana* 'Cleveland Select' Decne.), were potted during March in 56.7 liter (#15) containers. Container substrate was pine bark amended with 5.3 kg (9 lb) Osmocote 17N–3.1P–10.0K (17–7–12) (O.M. Scotts Co.) and 0.6 kg (1.0 lb) Micromax (O.M. Scotts Co.) per m^3 (yd^3). Magnolia, maple, and pear liners were initially 61, 181, and 156 cm (24, 71.2, and 61.4 in) tall with a caliper of 1.1, 2.0, and 3.2 cm (0.4, 0.8, and 1.3 in), respectively. The PIP system was designed with single rows, 2.4 m (8 ft) apart with 0.6 m (2 ft) spacing between socket containers within rows. Plants were irrigated daily as needed with micro-spray stakes. Experimental design was a randomized complete block with four replications of three plants per replicate (tree species randomized separately). Broadleaf and grass weed control were rated visually on a scale of 0 to 100 (0 = no control and 100 = complete control) 30, 60, and 90 DAT from each herbicide treatment date.

Experiment 3. McMinnville, TN. Herbicide treatments were applied as previously described for Experiment 2 with the following exceptions. Experimental trees were green ash (*Fraxinus pennsylvanica* Marsh.*)* and river birch (*Betula nigra* L.) potted in 95 liter (# 25) containers during April and placed in a PIP production system with 1.5 m (5 ft) in-row spacing and 2.1 m (7 ft) between rows. Preemergence herbicides were applied May 13 and repeated on July 27: Barricade 65WG at 1.7 and 3.4 kg ai/ha (1.5 and 3.0 lb ai/A) (1× and 2×), Gallery 75 DF at 0.8 and 1.7 kg ai/ha (0.75 and 1.5 lb ai/A) (1× and 2×), Princep at 1.1 and 2.2 kg ai/ha (1.0 and 2.0 lb ai/A) (1× and 2×), Surflan 4AS at 2.2 and 4.5 kg ai/ha (2.0 and 4.0 lb ai/A) (1× and 2×), Barricade + Gallery at 1.7 + 0.8 kg ai/ha (1.5 + 0.75 lb ai/A) (1× + 1×), and Surflan + Gallery at 2.2 + 0.8 kg ai/ha (2.0 + 0.75 lb ai/A) (1× + 1×). The experimental design was a randomized complete block with three replications of three plants per replicate (tree species randomized separately). Broadleaf and grass weed control were rated visually on a scale of 0 to 100 (0 = no control and 100 = complete control) 30, 60, and 90 DAT from each herbicide treatment date.

Experiment 4. McMinnville, TN. Red maple (*Acer rubrum* Spach.'Autumn Flame'), Bradford pear (*Pyrus calleryana* Decne. 'Bradford'), Marshall's seedless ash (*Fraxinus pennsylvanica* Marsh. 'Marshall's Seedless') and Village Green zelkova (*Zelkova serrata* Spach. 'Village Green') were potted in 56.7 liter (#15) containers, placed in a PIP system and treated on April 18 and June 23. Herbicide treatments were applied similarly to Experiment 3, with the exception of several changes: Barricade at 0.8 and 1.1 kg ai/ha (0.75 and 1.0 lb ai/A) (1× and 2×), Gallery at 1.1 and 2.2 kg ai/ha (1.0 and 2.0 lb ai/A) (1× and 2×), Pendulum at 3.4 and 6.7 kg ai/ha (3.0 and 6.0 lb ai/A) (1× and 2×), Barricade + Gallery at 0.8 and 1.1 kg ai/ha (0.75 + 1.0 lb ai/A) (1× + 1×), Pendulum + Gallery at 3.4 + 1.1 kg ai/ha (3.0 + 1.0 lb ai/A) (1× + 1×), and Surflan + Gallery at 2.2 + 1.1 kg ai/ha (2.0 + 1.0 lb ai/A) (1× + 1×). Plants were irrigated daily as needed with micro-irrigation. Experimental design was a randomized complete block with four replications of three plants per replicate (tree species randomized separately). Broadleaf and grass weed control were rated visually on a scale of 0 to 100 (0 = no control and 100 = complete control) 30, 60, and 90 DAT from each herbicide treatment date.

Results and Discussion

Experiment 1. No visual injury or reduced growth of Little Gem magnolia resulted from two applications of herbicides. Height and caliper increase was similar among treatments, 106.7 cm (3.5 ft) and 1.8 cm (0.7 in), respectively (data not shown).

At 30-1 DAT, all herbicide treatments provided excellent weed control (greater than 90%) (Table 2). Rates within herbicide products affected weed control in some instances, and thus regression analyses of rate response are presented, along with means separation to separate herbicide products across rates. At 60-1 DAT, weed control efficacy was unacceptable (less than 80%) with Gallery (½×), Surflan + Gallery (½×) and Surflan (1×). Natural populations of oxalis (*Oxalis stricta* L.), bittercress (*Cardamine hirsute* L.), prostrate spurge (*Euphorbia maculata* (L.) Small) and large crabgrass (*Digitaria sanguinalis* (L.) Scop.) established in the container substrate of herbicide treated containers, as well as the hand weeded control containers. By 90-1 DAT, treatments providing excellent weed control were Gallery (1×), Pendulum (2×), and tank mixes of Barricade + Gallery (½× + ½× and 1× + 1×), Surflan + Gallery (1× + 1× and 2× + 2×), and Surflan + Princep (2× + 2×). Acceptable weed control was observed with Barricade (½×, 1×, and 2×), Gallery (2×), Pendulum (½× and 1×), Surflan (2×), Barricade + Gallery (2× + 2×), Pendulum + Gallery (½×, 1×, and 2×), Surflan + Princep (1× + 1×), and OH2 (1×). Herbicides with unacceptable levels of weed control included Gallery (½×), Princep (1× and 2×), Surflan (½× and 1×), and Surflan + Gallery (½×) treatments. Herbicide combinations (a grass-active and broadleaf-active) at anticipated use rates and twice those rates, provided acceptable or excellent weed control and concur with previous reports (15, 17, 18). This data confirms that when two active ingredients are combined, anticipated use rates should be used because weed control could be ineffective at lower rates.

After the 90-1 DAT rating, all weeds were removed prior to the second herbicide application on Aug 5. Excellent weed control was observed in all treatments 30-2, 60-2, and 90-2 DAT. The authors observed weed pressure had been greatly reduced during the first 90 days of this experiment, as evident in the hand weeded control treatment, which had acceptable weed presence (89.8, 91.5, and 83.6% at 30-2, 60-2 and 90-2 DAT, respectively).

Experiment 2. Plant height and caliper growth of magnolia and 'Cleveland Select' pear were not adversely affected by herbicides (data not shown). *Acer rubrum* 'Franksred' had similar height growth among herbicide treated plants com-

Table 2. Effects of preemergence herbicides on weed control in a PIP system with container grown 'Little Gem' magnolia, Experiment 1, Poplarville, MS.

Herbicide	Rate kg ai/ha	Rate lb ai/A	Rate	May 6[z] 30-1 DAT[y]	May 6 60-1 DAT	May 6 90-1 DAT	Aug 5 30-2 DAT	Aug 5 60-2 DAT	Aug 5 90-2 DAT
				Weed control[x]					
Barricade 65WG	0.8	0.75	½×	98.1AB[w]	89.5A	84.8A	100.0A	99.8AB	97.9A
	1.7	1.5	1×	97.7	93.6	89.1	96.8	100.0	99.5
	3.4	3	2×	98.6	95.9	87.7	99.5	99.4	97.3
				NS[v]	NS	NS	NS	NS	NS
Gallery 75 DF	0.6	0.5	½×	94.1AB	67.7ABC	49.5AB	90.0C	98.5AB	94.3C
	1.1	1	1×	100.0	97.1	91.4	98.9	99.6	97.5
	2.2	2	2×	98.6	90.7	83.6	99.5	98.3	96.5
				Q**	Q**	Q**	L**	NS	NS
Pendulum 60 WDG	1.1	1	½×	95.9AB	89.1AB	81.4A	99.8A	99.4BC	95.7ABC
	2.2	2	1×	98.0	92.7	87.3	99.5	98.6	98.6
	4.5	4	2×	100.0	98.2	95.9	99.8	99.5	99.1
				NS	NS	NS	NS	NS	NS
Princep Liquid	1.1	1	1×	96.8AB	80.0ABC	65.5B	98.0A	99.4AB	93.4BC
	2.2	2	2×	98.6	90.9	75.1	99.4	99.6	97.7
Surflan 4AS	1.1	1	½×	93.2B	80.0C	59.5B	100.0A	97.4CD	94.5ABC
	2.2	2	1×	95.0	66.8	51.7	96.8	99.4	97.5
	4.5	4	2×	99.1	85.5	84.5	100.0	95.5	96.4
				L***	NS	Q*	NS	Q*	NS
Barricade+ Gallery	0.8 + 0.6	0.75 + 0.5	½× + ½×	96.6AB	88.5AB	90.5A	100.0A	99.5AB	99.2ABC
	1.7 + 1.1	1.5 + 1.0	1× + 1×	97.8	95.0	94.1	100.0	99.8	99.5
	3.4 + 2.2	3.0 + 2.0	2× +2×	98.6	94.5	89.1	97.3	100.0	99.2
				NS	NS	NS	NS	NS	NS
Pendulum + Gallery	1.1 + 0.6	1.0 + 0.5	½× + ½×	97.5AB	86.8ABC	83.2A	96.2A	98.7AB	97.4ABC
	2.2 + 1.1	2.0 + 1.0	1× + 1×	99.4	90.7	87.7	100.0	99.8	98.8
	4.5 + 2.2	4.0 + 2.0	2× +2×	98.7	93.2	88.2	100.0	99.8	98.2
				NS	NS	NS	NS	NS	NS
Surflan + Gallery	1.1 + 0.6	1.0 + 0.5	½× + ½×	94.4AB	77.7ABC	68.6A	90.9A	98.5AB	96.7ABC
	2.2 + 1.1	2.0 + 1.0	1× + 1×	97.5	90.0	92.1	98.9	97.2	94.1
	4.5 + 2.2	4.0 + 2.0	2× +2×	99.5	98.2	97.7	99.1	99.8	99.1
				NS	L**	L**	NS	NS	NS
Surflan + Princep	2.2 + 1.1	2.0 + 1.0	1× + 1×	97.7A	90.9A	81.8A	96.4A	98.3AB	95.5ABC
	4.5 + 2.2	4.0 + 2.0	2× + 2×	100.0	99.1	97.7	100.0	99.1	98.5
OH2	3.4	3	1×	95.5B	81.4BC	83.2A	99.0A	100.0A	99.6AB
Hand weeded control	—	—		87.1C	42.7D	21.4C	89.8B	91.5C	83.6D

[z]Herbicide applications were made May 6 and Aug 5.

[y]Days after treatment.

[x]Weed control, 0 = no control and 100 = complete control.

[w]Herbicide products, across rates, were separated within each column by Duncan's Multiple Range Test, $p \leq 0.05$.

[v]NS, L, or Q represents not significant, linear, or quadratic regression response for each herbicide.

*, **, and *** represents significance where $P \leq 0.05$, 0.01, and 0.001.

pared to the hand weeded and weedy controls. Maple caliper growth was somewhat erratic but may be attributed to the herbicide treatments. Rates within herbicides did not affect caliper, so only herbicides are presented with means separation (Table 3). Maples treated with Barricade had the greatest caliper increase (9.1 cm), while the weedy and hand weeded control treatments had caliper growth similar to the other herbicide treated plants.

Broadleaf and grass weed control responded differently to herbicides. Rate within herbicide products affected broadleaf weed control, and thus regression analyses of rate response are presented, along with means separation to separate herbicide products across rates (Table 4) (weed control data in the ornamental pear plot not shown due to similarity with weed control data in the maple plot). At 30-1 and 60-1 DAT following the April 24 herbicide application, broadleaf weed control was excellent in the magnolia plot with all herbicide treatments (Table 4). The weedy and handed weeded control treatments had acceptable broadleaf weed control at 30-1 and 60-1 DAT. At 90-1 DAT, excellent control was observed in all herbicide treatments, with the exception of Gallery (1×) and Princep (1×), which were acceptable at 86.7

Table 3. Increase in trunk caliper for Red Sunset red maple grown in a PIP system, Experiment 2, McMinnville, TN.

Treatments	Caliper[z], mm
Barricade 65WG	9.1a[y]
Gallery 75DF	8.8ab
Pendulum 60 WDG	8.6abc
Princep Liquid	7.4c
Surflan 4AS	7.7bc
Barricade+ Gallery	7.6bc
Pendulum + Gallery	7.7bc
Surflan + Gallery	8.6abc
Surflan + Princep	8.0abc
Snapshot 2.5 TG	7.3c
Weedy control	8.5abc
Hand weeded control	7.4c

[z]Caliper increase (final caliper – initial caliper) during experiment final caliper was measured at 90 days after July 21 herbicide application.

[y]Herbicide rates were not significant with regression analysis. Herbicide means separated by Duncan's Multiple Range Test, $p \leq 0.05$.

and 88.3%, respectively. Control treatments had unacceptable levels of broadleaf weeds.

Prior to the second herbicide application on July 21, all containers were hand weeded and all weeds were removed from the treated area between and around the containers. By 60-2 DAT extensive broadleaf weed pressure was encountered. Unacceptable control was observed with Gallery (½×, 1×, and 2×), Pendulum (½×), Princep (1× and 2×), Surflan ½×, 1×, and 2×), Pendulum + Gallery (½× + ½× and 1× +1×), Surflan + Gallery (½× +½×, 1× + 1× and 2× +2×), Surflan + Princep (1× +1× and 2× + 2×), and Snapshot (1× and 2×). The broadleaf weeds identified in the container and surrounding area were oxalis (*Oxalis stricta* L.), prostrate spurge (*Euphorbia maculata* L.), hairy galinsoga (*Galinsoga ciliata* (Raf.) Blake, and cutleaf eveningprimrose (*Oenothera laciniata* Hill). At 90-2 DAT, Barricade (½×, 1×, and 2×) was the only herbicide providing weed control greater than 90%. Pendulum (2×) and Barricade + Gallery (2× + 2×) provided acceptable control. All other herbicides were ineffective.

A similar trend was observed in the maple plot during the experiment. Broadleaf weed control in all herbicide treatments was excellent for 90 days following the April 24 herbicide application. At 60-2 DAT, weed control declined to unacceptable control with the exceptions: excellent control occurred with Barricade (2×), Pendulum (2×), Barricade + Gallery (1× + 1× and 2× + 2×), Pendulum + Gallery (2× + 2×), and Snapshot (2×), and acceptable control with Barricade (1×) and Pendulum (1×). At 90-2 DAT, Pendulum (2×), Barricade + Gallery (1× +1× and 2× + 2×), Pendulum + Gallery (2×), and Snapshot (2×) provided greater than 90% weed control.

Rates within herbicide treatments had no effect on grass control, thus data were analyzed by herbicide (Table 5). In the Magnolia plot, excellent grass control in the growing container was obtained at 30-1 DAT with most herbicide treatments. Acceptable control with Princep and Gallery was expected since both of these materials are labeled for broadleaf weed control (8, 17). Similar weed control was observed 60-1 and 90-1 DAT following the April 24 application, and 90-2 DAT following the July 21 application. We observed that weed pressure was greater in the area surrounding the socket container due to the natural weed populations in the native field soils (not rated) compared to the soilless container substrate.

A similar trend was observed in the maple plot as reported in the magnolia plot. At all evaluation dates, grass control was excellent with most herbicide treatments with the exception of Gallery and Princep. These herbicides provided unacceptable control 90-1 DAT after the April 24 application. Following the July 21 application, grass control was unacceptable with Princep at 30-2, 60-2, and 90-2, while Gallery had unacceptable control on 60-2 and 90-2 DAT. By 90-2, grass control with Surflan had dropped to 78.9%.

Experiment 3. River birch and green ash showed no injury or reduction in height or caliper growth from herbicide treatments (data not shown).

Weed control in this experiment was assessed by broadleaf and grass weeds in the container and the area surrounding the socket container (Table 6) (60-1 DAT data not shown due to similarity to 30-1 DAT). Weed control was similar in the river birch and green ash plots and were combined for data analysis. At 30-1 DAT, broadleaf weed control in the herbicide treated containers was excellent compared to the hand weeded control, which was acceptable (81.2%). Broadleaf weeds outside the container were less than 90% with Gallery (1×). Very little grass had germinated at 30-1 DAT in the container and herbicide treatment ratings were greater than 96%. Outside of the container, grass control was excellent with Barricade, Gallery (2×), Princep (2×), Surflan, and combinations of Barricade + Gallery, Barricade + Princep, and Surflan + Gallery. There was suppression of grass outside of the container with l× rates of Gallery and Princep. The hand weeded control provided unacceptable grass control of 68.3%.

At 90-1 DAT, broadleaf weed control had declined to unacceptable levels in the growing container and outside of the container in all treatments. Grass control was excellent in all treatments compared to the control. After the second herbicide application on July 27, a similar weed control response was observed at 30-2, 60-2, and 90-2 DAT (data not shown).

Experiment 4. There were no injury symptoms or reduction in height or caliper growth from herbicide treatments with 'Autumn Flame' red maple, 'Bradford' pear, 'Marshall's Seedless' ash, and 'Village Green' zelkova (data not shown).

Herbicide treatments were applied on April 18 and weed control rated 30-1 and 60-1 DAT (data not shown). Due to extensive rainfall during May and June, herbicide efficacy was depleted in all treatments by 60-1 DAT. All weeds were removed from the containers and surrounding area and herbicides were applied on June 23 (Table 7).

Weed control was similar with herbicide treatments in the 'Autumn Flame' red maple, 'Bradford' pear, 'Marshall's Seedless' ash, and 'Village Green' zelkova and were combined for data analysis. At 30-2 DAT, broadleaf weed control in the containers were excellent with all herbicide treatments compared to the hand weeded control (70.8 %). Broadleaf weeds outside the containers were controlled with all herbicide treatments with the exception of Gallery (1×). The hand weeded control was rated at 58.3%. At 30-2 DAT, Gallery at 1× and 2× provided unacceptable grass control in and around the containers. All other treatments exhibited excellent grass control.

Table 4. Effects of preemergence herbicides on broadleaf weed control in a PIP system with container grown Southern magnolia and Red Sunset red maple, Experiment 2, McMinnville, TN.

				Southern magnolia						Red Sunset red maple					
	Rate			April 24[z]			July 21			April 24			July 21		
Herbicide	kg ai/ha	lb ai/A	Rate	30-1 DAT[y]	60-1 DAT	90-1 DAT	30-2 DAT	60-2 DAT	90-2 DAT	30-1 DAT	60-1 DAT	90-1 DAT	30-2 DAT	60-2 DAT	90-2 DAT
				Weed control[x]						Weed control					
Barricade 65WG	0.8	0.75	½×	100.0A[w]	100.0A	100.0A	100.0A	97.3A	93.3A	100.0A	100.0A	100.0A	91.7ABC	48.3ABCD	30.0ABC
	1.7	1.5	1×	100.0	100.0	100.0	100.0	92.7	90.0	100.0	100.0	100.0	96.7	85.0	65.0
	3.4	3	2×	100.0	100.0	100.0	100.0	98.0	95.0	100.0	100.0	100.0	100.0	91.7	81.7
				NS[v]	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Gallery 75 DF	0.6	0.5	½×	100.0A	98.3B	91.7B	80.0C	20.0D	0.0EF	100.0A	100.0AB	95.0AB	73.3CD	10.0CD	0.0DE
	1.1	1	1×	100.0	90.0	86.7	66.7	10.0	0.0	100.0	96.7	98.3	93.3	68.3	41.7
	2.2	2	2×	100.0	98.3	96.7	83.3	30.0	28.3	100.0	100.0	96.7	91.7	38.3	13.3
				NS	Q***	Q**	NS	NS	NS	NS	Q***	NS	NS	Q*	Q*
Pendulum 60 WDG	1.1	1	½×	100.0A	100.0A	100.0A	78.3AB	6.7BC	0.0BCD	100.0A	100.0A	100.0A	95.0A	66.7AB	55.0AB
	2.2	2	1×	100.0	100.0	100.0	100.0	87.3	80.0	100.0	100.0	100.0	98.3	88.3	83.3
	4.5	4	2×	100.0	100.0	100.0	100.0	81.7	71.7	100.0	100.0	100.0	100.0	96.7	95.0
				NS	NS	NS	Q**	Q**	Q**	NS	NS	NS	NS	NS	NS
Princep Liquid	1.1	1	1×	100.0A	93.3B	88.3B	78.3BC	10.0CD	0.0DEF	100.0	95.0B	95.0B	76.7DE	16.7D	13.3DE
	2.2	2	2×	100.0	98.3	95.0	88.3	43.3	33.3	100.0	100.0	95.0	75.0	50.0	25.0
Surflan 4AS	1.1	1	½×	100.0A	100.0A	100.0A	78.3BC	0.0CD	0.0EF	100.0A	100.0A	100.0A	85.0ABCD	35.0ABCD	26.7CDE
	2.2	2	1×	100.0	100.0	100.0	75.0	20.0	0.0	100.0	100.0	100.0	90.0	56.7	40.0
	4.5	4	2×	100.0	100.0	100.0	91.7	58.3	40.0	100.0	100.0	100.0	90.0	68.3	43.3
				NS	NS	NS	L**	L**	L*	NS	NS	NS	NS	NS	NS
Barricade+ Gallery	0.8 + 0.6	0.75 + 0.5	½× + ½×	100.0A	100.0A	100.0A	100.0A	86.7AB	71.7AB	100.0A	100.0A	100.0A	93.3A	63.3A	60.0A
	1.7 + 1.1	1.5 + 1.0	1× + 1×	100.0	100.0	100.0	100.0	86.7	75.0	100.0	100.0	100.0	100.0	96.7	96.0
	3.4 + 2.2	3.0 + 2.0	2× +2×	100.0	100.0	100.0	100.0	93.3	88.3	100.0	100.0	100.0	100.0	93.3	91.7
				NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Pendulum + Gallery	1.1 + 0.6	1.0 + 0.5	½× + ½×	100.0A	100.0A	100.0A	93.3A	70.0AB	58.3ABC	100.0A	100.0A	100.0A	96.7AB	78.3AB	68.3ABC
	2.2 + 1.1	2.0 + 1.0	1× + 1×	100.0	100.0	100.0	90.0	61.7	51.7	100.0	100.0	100.0	93.3	70.0	60.0
	4.5 + 2.2	4.0 + 2.0	2× +2×	100.0	100.0	100.0	100.0	85.7	78.3	100.0	100.0	100.0	100.0	97.3	90.0
				NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Surflan + Gallery	1.1 + 0.6	1.0 + 0.5	½× + ½×	100.0A	100.0A	100.0A	90.0AB	48.3AB	38.3BCD	100.0A	100.0A	100.0A	81.7BCD	53.3BCD	50.0BCD
	2.2 + 1.1	2.0 + 1.0	1× + 1×	100.0	100.0	100.0	96.7	71.7	45.0	100.0	100.0	100.0	85.0	30.0	13.3
	4.5 + 2.2	4.0 + 2.0	2× +2×	100.0	100.0	100.0	91.7	69.0	55.0	100.0	100.0	100.0	93.3	61.7	60.0
				NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Surflan + Princep	2.2 + 1.1	2.0 + 1.0	1× + 1×	100.0A	100.0A	100.0A	88.3AB	46.7AB	16.7CDE	100.0A	100.0A	100.0A	86.7ABCD	55.0ABCD	30.0CDE
	4.5 + 2.2	2.0 + 2.0	2× + 2×	100.0	100.0	100.0	98.3	78.3	60.0	100.0	100.0	100.0	90.0	58.3	40.0
Snapshot 2.5TG	2.2	2	1×	100.0a	100.0A	100.0A	88.3AB	50.0BC	36.7CDE	100.0A	100.0A	100.0A	88.3ABC	61.7ABC	50.0ABC
	4.5	4	2×	100.0	100.0	100.0	91.7	65.0	48.3	100.0	100.0	100.0	100.0	91.7	92.7
Weedy control	—	—		83.3C	80.0C	68.3C	66.7C	10.0D	8.3EF	66.7C	75.0D	48.3D	46.7F	0.0E	0.0E
Hand weeded control	—	—		85.0B	81.7C	71.7C	78.3C	13.3D	0.0F	80.0B	81.7C	63.3C	61.7EF	0.0E	0.0E

[z]Herbicide applications were made April 24 and July 21.

[y]Days after treatment.

[x]Weed control was rated on a scale of 0 to 100.0, 0 = no control and 100.0 = complete control.

[w]Herbicide products, across rates, were separated within each column by Duncan's Multiple Range Test, $p \leq 0.05$.

[v]NS, L, or Q represents no significant, linear, or quadratic regression response for each herbicide.

*, **, and *** represents significance where $P \leq 0.01$, and 0.001.

Table 5. Effects of preemergence herbicides on grass weed control in a PIP system with container grown Southern magnolia and Red Sunset red maple, Experiment 2, McMinnville, TN.

	Southern magnolia						Red Sunset red maple					
	April 24[z]			July 21			Apr 24			July 21		
Herbicide	30-1 DAT[y]	60-1 DAT	90-1 DAT	30-2 DAT	60-2 DAT	90-2 DAT	30-1 DAT	60-1 DAT	90-1 DAT	30-2 DAT	60-2 DAT	90-2 DAT
	Weed control[x]						Weed control					
Barricade 65WG	100.0a[w]	100.0a	100.0a	100.0a	100.0a	100.0a	100.0a	100.0a	100.0a	100.0a	98.3a	98.9a
Gallery 75 DF	90.0b	88.3b	84.4b	97.2a	86.1a	81.1b	86.1b	82.8b	67.8b	87.2b	51.1b	40.6b
Pendulum 60 WDG	100.0a	100.0a	100.0a	100.0a	97.8a	96.7ab	100.0a	100.0a	100.0a	97.8a	95.6a	93.9a
Princep Liquid	88.3b	86.7b	81.7b	96.7a	85.0a	83.3ab	85.8b	82.5b	60.8bc	70.8c	20.8c	13.3bc
Surflan 4AS	100.0a	100.0a	100.0a	98.3a	92.2a	88.3ab	100.0a	100.0a	100.0a	90.6ab	83.9a	78.9a
Barricade + Gallery	100.0a	100.0a	100.0a	100.0a	100.0a	100.0a	100.0a	100.0a	100.0a	100.0a	95.6a	93.9a
Pendulum + Gallery	100.0a	100.0a	100.0a	100.0a	100.0a	100.0a	100.0a	100.0a	100.0a	100.0a	98.3a	97.2a
Surflan + Gallery	100.0a	100.0a	100.0a	99.4a	98.3a	96.7ab	100.0a	100.0a	100.0a	97.8a	91.1a	88.3a
Surflan + Princep	100.0a	100.0a	100.0a	100.0a	100.0a	100.0a	100.0a	100.0a	100.0a	100.0a	97.5a	94.2a
Snapshot 2.5TG	100.0a	100.0a	100.0a	100.0a	100.0a	100.0a	100.0a	100.0a	100.0a	99.2a	96.7a	95.5a
Weedy control	81.7c	76.7d	71.7d	80.0b	33.3c	26.7c	76.7c	75.0c	56.7c	50.0d	0.0c	0.0c
Hand weeded control	80.0c	81.7c	76.7c	80.0b	56.7b	25.0c	70.0d	81.7b	60.0c	50.0d	0.0c	0.0c

[z]Herbicide applications were made April 24 and July 21.

[y]Days after treatment.

[x]Weed control was rated on a scale of 0 to 100, 0 = no control and 100 = complete control.

[w]Herbicide rates were not significant with regression analysis. Herbicide means separated within columns by Duncan's Multiple Range Test, $p < 0.05$.

At 90-2 DAT, herbicide efficacy had declined to acceptable control in the containers and the surrounding area with all treatments. Natural populations of crabgrass (*Digitaria sanguinalis* (L) Scop.), Johnsongrass (*Sorghum halepense* (L) Pers.), red sorrel (*Rumex acetosella* L.), cutleaf eveningprimrose (*Oenothera laciniata* Hill), prostrate spurge (*Euphorbia maculata* L.), and horsenettle (*Solanum carolinense* L.) were present.

Dinitroaniline (DNA) herbicides, such as Barricade, Pendulum, and Surflan, are generally used to control grass and some small seeded broadleaf weeds. Conversely, herbicides such as Gallery or Princep are expected to provide at least 75–90 days control of many broadleaf weeds. A tank mix of a DNA herbicide with a broadleaf herbicide should provide an expanded spectrum of grass and broadleaf weed control. In experiment 2, the PIP system had been in place for several years and weeds had previously been controlled with Roundup. In experiments 3 and 4, the PIP system was new and located in an area that had previously been in field production, which could explain the heavy weed pressure.

These experiments were conducted with recommendations from the IR-4 program, which oversees labeling of pesti-

Table 6. Effects of preemergence herbicides on broadleaf and grass weed control 30 and 90 DAT in a PIP system, Experiment 3, McMinnville, TN.

				30-1 DAT[z]				90-1 DAT			
	Rate			Broadleaf weeds in containers	Broadleaf weeds outside containers[y]	Grass in containers	Grass outside containers	Broadleaf weeds in containers	Broadleaf weeds outside containers	Grass in containers	Grass outside containers
Herbicide	kg ai/ha	lbs ai/a	Rate								
Barricade 65WG	1.7	1.5	1×	94.5ab[xw]	95.8ab	99.7a	100.0a	79.1a	77.5a	100.0a	100.0a
Barricade 65WG	3.4	3	2×	98.2a	96.3ab	100.0a	98.3a	79.2a	80.0a	100.0a	100.0a
Gallery 75 DF	0.0.8	0.0.75	1×	93.3ab	88.7b	97.5a	83.3b	79.2a	65.8ab	95.0b	96.7a
Gallery 75 DF	1.7	1.5	2×	98.0a	94.2ab	96.3a	96.7a	79.2a	76.7a	99.2a	95.8a
Princep	1.1	1	1×	90.0b	96.3ab	99.7a	82.5b	79.2b	76.7a	95.0b	99.2a
Princep	2.2	2	2×	95.0ab	98.3a	97.5a	99.2a	79.2ab	78.3a	100.0a	97.5a
Surflan 4AS	2.2	2	1×	90.5b	93.3ab	100.0a	95.0a	79.2ab	70.0ab	100.0a	100.0a
Surflan 4AS	4.5	4	2×	95.0ab	95.0ab	100.0a	98.3a	79.2a	68.3ab	97.5ab	96.7a
Barricade+ Gallery	1.7 + 0.8	1.5 + 0.75	1× + 1×	95.3ab	95.7ab	100.0a	100.0a	79.2a	78.3a	100.0a	100.0a
Barricade+ Princep	1.7 + 1.1	1.5 + 1.0	1× + 1×	99.3a	98.3a	100.0a	100.0a	79.2ab	78.3a	100.0a	100.0a
Surflan + Gallery	2.2 + 0.8	2.0 + 0.75	1× + 1×	98.7a	95.0ab	100.0a	98.3a	79.2a	66.7a	100.0a	100.0a
Hand weeded control	—	—	—	81.2c	72.5c	96.7a	68.3c	79.2b	55.8b	75.0c	65.7b

[z]Days after treatment from May 13 herbicide application.

[y]Natural population of broadleaf and grass weeds within a 12-inch perimeter around recessed socket container.

[x]Treatment means separated within columns by Duncan's Multiple Range Test $p \leq 0.05$.

[w]Weed control was rated on a scale of 0 to 100, 0 = no control and 100 = complete control.

Table 7. Effects of preemergence herbicides on broadleaf and grass weed control 30 and 90 DAT in a PIP system, Experiment 4, McMinnville, TN.

				30-1 DAT[z]				90-1 DAT			
	Rate			Broadleaf weeds in containers	Broadleaf weeds outside containers[y]	Grass in containers	Grass outside containers	Broadleaf weeds in containers	Broadleaf weeds outside containers	Grass in containers	Grass outside containers
Herbicide	kg ai/ha	lbs ai/a	Rate								
Barricade 65WG	0.8	0.75	1×	99.6a[x,w]	93.8ab	93.3ab	91.2ab	76.7b	81.7ab	72.1bcd	73.3abc
Barricade 65WG	1.7	1.5	2×	98.6a	92.5ab	99.2a	94.6ab	82.1ab	83.8ab	85.8a	71.2abc
Gallery 75 DF	1.1	1	1×	98.3a	85.0c	70.0d	82.0c	75.0b	80.0bc	52.5e	54.2d
Gallery 75 DF	2.2	2	2×	99.2a	92.0ab	77.5c	80.0c	79.6ab	76.7c	54.6e	53.3d
Pendulum 60 WDG	1.1	1	1×	98.3a	94.6ab	98.3ab	93.3ab	83.3ab	87.0ab	74.2bcd	77.5a
Pendulum 60 WDG	2.2	2	2×	99.6a	92.9ab	99.6a	96.2a	86.7a	86.7ab	76.7abc	70.0abc
Surflan 4AS	2.2	2	1×	96.7a	92.5ab	96.2ab	92.5ab	79.2ab	83.3ab	77.5abc	65.4bc
Surflan 4AS	4.5	4	2×	97.9a	89.6bc	99.6a	90.4bc	81.2ab	79.2bc	80.4ab	65.0c
Barricade + Gallery	0.8 + 1.1	0.7 + 1.0	1× + 1×	96.7a	96.6a	93.8ab	97.1a	81.2ab	86.7a	71.2cd	69.6abc
Pendulum + Gallery	3.3 + 1.1	3.0 + 1.0	1× + 1×	98.3a	92.1ab	96.7ab	93.3ab	82.5ab	80.0bc	65.4d	77.5a
Surflan + Gallery	2.2 + 1.1	2.0 + 1.0	1× + 1×	99.2a	95.0ab	90.0b	89.1b	82.1ab	84.2ab	65.0d	75.0abc
Surflan + Princep	2.2 + 1.1	2.0 + 1.0	1× + 1×	98.7a	91.7ab	98.7a	92.1ab	82.9ab	79.6bc	69.6d	72.9abc
Hand weeded control	—	—	—	70.8b	58.3c	33.3e	42.5d	55.8c	51.2d	23.8e	25.0e

[z]Days after treatment from June 23 herbicide application.

[y]Natural population of broadleaf and grass weeds within a 12-inch perimeter around recessed socket container.

[x]Treatment means separated within columns by Duncan's Multiple Range Test $p \leq 0.05$.

[w]Weed control was rated on a scale of 0 to 100, 0 = no control and 100 = complete control.

cides for minor use crops. Herbicide protocols may change from year to year, especially with use rates and application methods as indicative of these experiments. All herbicide treatments were safe to landscape trees and did not affect height and caliper growth when applied as a directed banded application. These data demonstrate that in general, herbicides labeled for field-grown landscape crops are safe and effective for ornamental trees grown in a PIP system.

Literature Cited

1. Berchielli-Robertson, D.L., C.H. Gilliam, and D.C. Fare. 1990. Competitive effects of weeds on the growth of container-grown ornamentals. HortScience 25:77–79.

2. Fain, G.B., K.M. Tilt, C.H. Gilliam, H.G. Ponder, and J.L. Sibley. 1998. Effects of cyclic micro-irrigation and substrate in pot-in-pot production. J. Environ. Hort. 16:215–218.

3. Fare, D.C. and W.E. Davis. 1995. The use of trifluralin for root control in the PIP system. Proc. of South. Nursery Assoc. Res. Conf. 40:149–151.

4. Fare, D.C., M. Halcomb, and S. Mullican. 1999. Application method affects controlled-release fertilizer response in pot-in-pot production. Proc. of South. Nursery Assoc. Res. Conf. 44:97–102.

5. Halcomb, M.A. and D.C. Fare. 1995. A survey of the pot-in-pot growers in middle Tennessee. Proc. of South. Nursery Assoc. Res. Conf. 40:147–148.

6. Gilliam, C.H., G. Wehtje, J.E. Evans, T.V. Hicks, and D.C. Fare. 1989. Weed control with Gallery and other herbicides in field grown nursery crops. J. Environ. Hort. 7:69–72.

7. Gilliam, C.H., W.J. Foster, J.L. Adrain, and R.L. Shumack. 1990. A survey of weed control costs and strategies in container production nurseries. J. Environ. Hort. 8:133–135.

8. Neal, J.C. and A.F. Senesac. 1990. Preemergent weed control in container and field grown woody nursery crops with Gallery. J. Environ. Hort. 8:103–107.

9. Neal, J.C. and A.F. Senesac. 1990. Summer annual and winter annual weed control in field soil and soilless media with Gallery (isoxaben). J. Environ. Hort. 8:124–127.

10. Parkerson, C.H. 1990. P & P: A new field-type operation. Proc. Intern. Plant Prop. Soc. 40:417–419.

11. Reeder, J.A., C.H. Gilliam, G.R. Wehtje, D.B. South, and G.J. Keever. 1994. Evaluation of selected herbicides on field-grown woody ornamentals. J. Environ. Hort. 12:236–240.

12. Ruter, J.M. 1993. Growth and performance of three landscape plants produced in conventional and pot-in-pot production systems. J. Environ. Hort. 11:124–127.

13. Ruter, J.M. 1994. Evaluation of control strategies for reducing rooting-out problems in pot-in-pot production systems. J. Environ. Hort. 12:51–54.

14. Ruter, J.M. 1997. The practicality of pot-in-pot. American Nurseryman 185:32–37.

15. Setyowati, N., L.A. Weston, and R.E. McNiel. 1995. Evaluation of selected preemergence herbicides in field-grown landscape crops in Kentucky. J. Environ. Hort. 13:196–202.

16. Stamps, R.H. and C.A. Neal. 1990. Evaluation of dinitroaniline herbicides for weed control in container landscape plant production. J. Environ. Hort. 8:52–57.

17. Wehtje, G., C. Gilliam, T. Whitwell, C. Pounders, and W. Webster. 1986. Weed control in field-grown boxwood and photinia. HortScience 21:445–448.

18. Wehtje, G. and C.H. Gilliam. 1991. Weed control in field-grown holly. J. Environ. Hort. 9:29–32.

19. Wilcut, J.W., C.H. Gilliam, G.R. Wehtje, and D.C. Fare. 1989. Grass control in container-grown ornamentals with pre- and postemergence herbicide combinations. HortScience 24:456–459.