Evaluation of Selected Preemergence Herbicides in Field-Grown Landscape Crops in Kentucky[1]

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Abstract

Research was conducted during 1990 and 1991 at the Horticultural Research Farm in Lexington, Kentucky, to evaluate the efficacy of herbicides available for use on woody landscape plants (simazine and oryzalin), newly labelled herbicides (isoxaben, isoxaben plus oryzalin, metolachlor and metolachlor plus simazine) and those not widely labelled for the nursery industry (oxyfluorfen and dithiopyr). Herbicide phytotoxicity was also evaluated in 10 species of woody nursery crops. Results 6 WAT (weeks after treatment) indicated that the standard of simazine at 1.1 kg ai/ha (1.0 lb/A) plus oryzalin at 3.3 kg ai/ha (3.0 lb/A) provided adequate control of most common broadleaf weeds (98%) and annual grasses (98%) but not yellow nutsedge (31%). Isoxaben plus oryzalin at 4.2 kg ai/ha (4.0 lb/A) (DF formulation) and isoxaben plus trifluralin at 4.2 kg ai/ha (4.0 lb/A) (granular formulation) gave excellent full-season control of nearly all broadleaf and grass weeds with the exception of galinsoga and field bindweed. In addition, yellow nutsedge control was acceptable, ranging from 63 to 96% in these treatments. Isoxaben alone also provided excellent broadleaf control (93%) 6 WAT in 1990 but poorer (< 70%) control of giant foxtail, galinsoga and velvetleaf by 12 WAT. Dithiopyr (granular formulation) provided excellent full-season residual control of broadleaf weeds, nutsedge and grasses at the highest rate of 2.2 kg ai/ha (2.0 lb/A). Oxyfluorfen at the higher rate (2.2 kg ai/ha) (2.0 lb/A) also controlled all species except yellow nutsedge. Poor broadleaf control was obtained 12 WAT with 3.3 kg ai/ha (3.0 lb/A) metolachlor or metolachlor plus simazine at rates up to 4.4 kg ai/ha (4.0 lb/A) in both 1990 and 1991. Pronamide at 2.2 kg ai/ha (2.0 lb/A) did not provide adequate control of either broadleaf or grasses at 6 or 12 WAT. No visible phytotoxicity to woody ornamentals was observed in either season up to 8 weeks after application. However, growth reductions were noted in both common lilac and red oak stem or trunk diameter following treatment with isoxaben at 1.1 kg ai/ha (1.0 lb/A).

Index words: crop injury, nursery stock, phytotoxicity, selectivity, weed control.

Species used in this study: prickly sida (*Sida spinosa* L.); honeyvine milkweed (*Ampelamus albidus* (Nutt.) Britt.; field bindweed (*Convolvulus arvensis* L.); ivyleaf morningglory *(Ipomoea hederacea* (L.) Jacq.; common ragweed (*Ambrosia artemisiifolia* L.); jimsonweed (*Datura stramonium* L.); Pennsylvania smartweed (*Polygonum pensylvanicum* L.); green foxtail (*Setoria viridis* L. Beauv.); red sorrel (*Rumex acetosella* L.); smooth pigweed (*Amaranthus hybridus* L.); Canada thistle (*Cirsium arvense* (L.) Scop.); goosegrass (*Eleusine indica* (L.) Gaerth); pokeweed (*Phytolacca americana* L.); horsenettle (*Solanum carolinense* L.). field bindweed (*Convolvulus* arvensis L.):galinsoga [*Galinsoga ciliata* (Raf.) Blake]; giant foxtail (*Setaria faberi* Herrm.); velvetleaf *(Abutilon theophrasti*, Medik); yellow nutsedge (*Cyperus esculentus* L.).

Herbicides used in this study: Dimension or Stakeout (Dithiopyr), [3,5-pyridinedicarbothioic acid-2-(difluoromethyl)-4-(2-methylpropyl)-6-(trifluoromethyl)-S-S-dimethylester]; Gallery (isoxaben), N-[3-(1-ethyl-1-methylpropyl)-5-isoxazolyl]2,6-di-methoxy benzamide; Pennant (metolachlor), [2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl)acetamide]; Surflan (oryzalin), (3,5-dinitro-N4,N[4]-dipropylsulfanilamide); Goal (oxyfluorfen), [2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene]; Kerb (pronamide), [3,5-dichloro-N(1,1-dimethyl-2-propynyl)benzamide]; Princep (simazine), [2-chloro-4,6-bis(ethylamino)-s-triazine]; Snapshot 2.5G (2% trifluralin:0.5% isoxaben), α,α,α-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine); Derby (4% metolachlor:1% simazine); Snapshot 80DF (20% isoxaben:60% oryzalin).

Significance to the Nursery Industry

Effective and economical long-term weed control in the field is a very important problem facing nurserymen. We have performed studies over a 3-year period to evaluate weed control provided by several labelled herbicides and combinations as well as new products and those under consideration for use in woody nursery crops. Split applications of these preemergence products were applied in early May and in October of each year at the same site. Residual weed control was evaluated over a 3-year period as well as phytotoxicity to ten woody species, including trees and shrubs. This data assists research and extension personnel in making accurate and reliable recommendations for weed management in the nursery.

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Introduction

Wholesale nursery production in Kentucky is currently valued at approximately $25 million annually. This industry has grown substantially in recent years and is identified as having significant potential for further growth in the Southern Region (20). One of the major problems in Kentucky nursery production is obtaining consistent full-season weed control at a reasonable cost.

Herbicides effectively reduce weed numbers in nurseries and if used properly, they are less expensive and more convenient than hand-weeding or cultivation (28, 37), particularly for container-grown woody crops (28). However, herbicide tolerance varies with species and cultivar and new products must be evaluated for potential damage to a diverse group of woody species.

An increasingly wide selection of products are available for weed control in the nursery and landscape. In Kentucky, simazine is commonly used for nursery production and controls many annual grasses and broadleaf weeds (21). Simazine is generally considered safe in nursery liners, but at rates greater than 1.1 kg ai/ha (1.0 lb/A), it can cause injury to deciduous azalea (*Rhododendron gandavense* Rehd.), euonymus (*Euonymus fortunei vegeta* Rehd.) and Japanese andromeda [*Pieris japonica* (Thunb.) D.Don] (4). At 4.5 kg ai/ha (4.0 lb/A), simazine provided excellent control of most major broadleaves and grasses in northeastern field-grown woody liners. At lower rates, simazine also provided good to excellent control of common annuals and yellow nutsedge when combined with metolachlor (17).

Oryzalin is a selective preemergence herbicide used for the control of annual grasses and many broadleaf weeds in established landscape plantings, ground covers and turfgrasses (10, 35). Oryzalin can provide superior weed control when combined with other herbicides such as simazine (14, 15, 40) in orchard and nursery crops and oxadiazon[-3-[2,4-dichloro-5-(1-methylethoxy)phenyl]-5-(1,1-dimethylethyl)-1,3,4-oxadiazol-2-(3H)-one] in woody landscape plants (30). Oryzalin has been reported to reduce the growth of several Southern landscape plants by 13 to 64%, including Chinese holly (*Ilex cornuta* Lindl. & Paxt.); Photinia (*Photinia* x *fraseri* Dress); and azalea [*Rhododendron indicum* (L.) Sweet] (34).

Metolachlor is used for grass and yellow nutsedge control in many annual and perennial broad-leaf crops and certain grain crops (10). At 4.5 kg ai/ha (4.0 lb/A), it effectively controlled yellow nutsedge without injury to Japanese holly (*Ilex crenata* Thumb. 'Hetzii') or Wards yew (*Taxus media* Rehd. Wardii), but did not provide adequate suppression of horseweed [*Conyza canadensis* (L.) Cronq.] and common groundsel (*Senecio vulgaris L.*) in Northeastern nurseries (1). It has been reported that combinations of metolachlor and simazine provided a broader spectrum of weed control (12, 14, 23) while maintaining safety to nursery liners (4, 8). Metolachlor has been reported to cause injury in *Euonymus fortunei* 'Emerald'N Gold' (4) while combinations with simazine caused chlorosis in pachysandra (*Pachysandra terminalis*) and Japanese pieris [(*Pieris japonica Thunb.*) D. Don] (16, 17).

Isoxaben is a relatively new preemergence herbicide for broadleaf weed control in woody landscape plants, turf and orchard crops. At 1.1 kg ai/ha (1.0 lb/A), isoxaben provided good control of smooth crabgrass [*Digitaria ischaemum* (Schreb. ex Schweig.) Schreb. ex Muhl] # DIGIS, fall panicum (*Panicum dichotomiflorum* Michx.) and witchgrass (*Panicum capillare* L.) and greater than 90% control of certain broadleaves including dandelion (*Taraxacum officinale* Weber), pigweeds (*Amaranthus* spp.) (26), common lambsquarters (*Chenopodium album* L.) and spotted spurge (*Euphorbia maculata* L.) (7). Most woody species are tolerant to isoxaben, but injury has been reported in newly planted *Eucalyptus*, pine seedlings (Pinus spp.) and burning bush[(*Euonymus alata*) (Thunb.) Siebold] (7), herbaceous perennials (31) and bedding plants (32). Combinations of isoxaben and trifluralin or isoxaben and oryzalin provided improved weed control of musk thistle (*Carduus thoermeri Weinm.* L.) and annual grasses (18, 24, 26). These combinations resulted in phytotoxicity to bedding plants (32) and growth reductions in European white birch (*Betula pendula* Roth.) (18).

Pronamide is used for preemergence grass control and early postemergence control of certain broadleaf weeds and grasses (36). It is primarily used by the Kentucky nursery industry for fall weed control of quackgrass [(*Agropyron repens* L.Beauv.)], perennial ryegrass (*Lolium perenne* L.), orchardgrass (*Dactylis glomerata* L.) and tall fescue (*Festuca arundinacea* Schreb.) (27).

Oxyfluorfen is a preemergence herbicide with some postemergence activity (5, 9, 39) and is labelled for use in conifer species (22). Oxyfluorfen has shown excellent control of common groundsel, common chickweed [*Stellaria media* (L.) Vill.], hairy bittercress (*Cardamine hirsuta* L.) and horseweed (14). The granular formulation has been reported to be safe to a wide range of woody plants (2, 3, 9), but crop species respond differently with various formulations. Fretz, et.al. (13) reported that the 2E formulation was more injurious to woody plants but provided superior weed control compared to the granular or WP formulation (38).

Dithiopyr (MON 15159) belongs to a new class of pyridine herbicides and provides excellent preemergence control of annual grasses and certain broadleaves and postemergence control of crabgrass in turfgrass and rice (*Oryza* spp.) (25, 29). Efficacious control has been obtained in limited experimentation with woody (> 90%) and herbaceous landscape plants, with little injury to container or field-grown landscape species at rates of up to 1.1 kg ai/ha (1.0 lb/A) of dithiopyr (6, 33).

It is important in nursery production to utilize herbicide treatments which provide effective control of both annual and perennial weeds and safety to a wide variety of crops. The recommended and newly released herbicides were selected for evaluation at recommended rates and in combinations in sequential applications (fall and spring) to evaluate full-season weed control and potential phytotoxicity to established woody ornamentals over a three-year period.

Materials and Methods

Field studies were conducted in 1989, 1990 and 1991 at the Horticulture Research Farm in Lexington, KY, on a Maury silt loam soil (fine, mixed, mesic, typic Paleudalfs), with a pH of 6.2 and organic matter content of 3.0%. During April 1989, plots measuring 30.4 × 5.5 m (100 × 18 ft) were planted with ten tree and shrub species, using 3 plants of each species per plot for a total of 30 plants per plot. The species selected for evaluation varied somewhat among treatments, (Table 1) reflecting a specific need for tolerance information for certain landscape species in selected unlabelled treatments. Each herbicide treatment in 1989 through 1991 was replicated 3 times and treatments were arranged in a randomized complete block design.

Herbicide applications were performed bi-annually in 1990 and 1991 on May 25 and 26 and November 2 and 13, respectively. Herbicide sprays were applied with a CO_2 pressurized sprayer equipped with flat fan 8004 nozzles (Tee Jet, Inc.) calibrated to deliver 240 L/ha (26 GPA) at 275 kPa (28 lb psi pressure). Granular treatments were applied in pre-weighed aliquots using a calibrated rotary granular spreader. The herbicides evaluated, and their application rates and manufacturers are presented in Table 2. The woody ornamental species evaluated are summarized in Table 1.

Data is presented for 1990 and 1991 experiments only. Visual weed control ratings were conducted on a percentage basis from 0 to 100, with 0 representing no control and 100 representing complete control. Weed control ratings were performed at 6 and 12 weeks after treatment in 1990 and 1991 and weed population percentages were estimated for annual grasses, broadleafs and yellow nutsedge in each plot.

Table 1. Woody landscape crops evaluated in 1989–1991.

All herbicide treatments included:
Japenese yew (*Taxus cuspidata* Siebold and Zucc 'Densa')
Burning bush (*Euonymus alata* (Thunb.) Siebold 'Compacta')
Viburnum (*Viburnum lantana* L. 'Mohican')
Chinese juniper (*Juniperus chinensis* L. 'Pfitzeriana')
American arbovitae (*Thuja occidentalis* L. 'Techny')
Norway spruce (*Picea abies*) (L.) Karst
Herbicide treatments 1–6 also included:
Pear (*Pyrus calleryana* Decne. 'Aristocrat')
White ash (*Fraxinus americana* L. 'A. Purple')
Sugar maple (*Acer saccharum* Marsh)
Linden (*Tilia cordata* Mill.)
Herbicide treatments 7–9 also included:
Common lilac (*Syringa vulgaris* L.)
Red oak (*Quercus rubra* L.)
Hawthorn (*Crataegus viridis* L. 'Winter King')
Honey locust (*Gleditsia triacanthos* L. 'Shademaster')
Herbicide treatments 10–14 also included:
Common lilac (*Syringa vulgaris* L.)
Red oak (*Quercus rubra* L.)
Honey locust (*Gleditsia triacanthos* L. 'Skyline')
Red maple (*Acer rubrum* L.)

Predominant weed species encountered in each plot were also recorded at 6 and 12 WAT (weeks after treatment). Herbicide phytotoxicity to each woody landscape species was evaluated at 2, 4, 8 and 12 WAT on a 0 to 5 scale with 0 representing no phytotoxicity and 5 representing plant death. Potential growth reductions due to weed control treatments were evaluated in March of 1991 by measuring height and caliper diameter of all plants in each treatment at 15 cm (6 in) above soil surface. Results are presented after data were subjected to appropriate analysis of variance for a randomized complete block design. Data were transformed if variance was non-homogeneous as measured by Bartlett's test. Data were analyzed separately by year since year effect was highly significant. Treatment means were separated using Fisher's protected LSD test.

Results and Discussion

Weed control. At 6 WAT, oryzalin at 3.3 kg ai/ha (3.0 lb/A) did a poor job in controlling yellow nutsedge (23%) while providing good control of annual broadleafs and grasses (84 to 100%) in both 1990 and 1991 (Table 3). By 12 WAT oryzalin gave poor control of broadleaf weeds including honeyvine milkweed [*Ampelamus albidus* (Nutt.) Britt.] , horsenettle (*Solanum carolinense* L.), field bindweed, common ragweed (*Ambrosia artemisifolia* L.) and yellow nutsedge (Table 4). These results agree with those of Stamps and Neal (34) who found poor control of annual broadleaf weeds with oryzalin alone and improved control when oryzalin was combined with oxyfluorfen or isoxaben (15).

At 6 WAT, the standard treatment of simazine plus oryzalin at 1.1 and 3.3 kg ai/ha, (1.0 and 3.0 lbs/A) respectively, provided adequate control of most common broadleaf weeds [common lambsquarters, smooth pigweed (*Amaranthus retroflexus* L.) Pennsylvania smartweed (*Polygonum pensylvanicum* L.)] and annual grasses [large crabgrass (*Digitaria sanguinalis* (L.) Scop.), goosegrass (*Eleusine indica* (L.) Gaertn.), green foxtail (*Setaria viridis* (L.) Beauv.) and yellow foxtail (*Setaria glauca* (L.) Beauv.)] (Tables 3, 4 and 5). Yellow nutsedge control ranged from 31 to 47% in 1990 and 1991 and became established in dense stands by 12 WAT particularly in 1991 (Tables 3 and 4). Broadleaf control was also poor at 12 WAT, with honeyvine milkweed and field bindweed predominating in both years (Tables 4 and 5).

Isoxaben at 0.84 kg ai/ha provided excellent control of most broadleaf weeds 6 WAT including common chickweed, henbit (*Lamium amplexicaule* L.), red sorrel (*Rumex acetosella* L.) smooth pigweed, Pennsylvania smartweed and common ragweed which were encountered in both 1990 and 1991 (Tables 3 and 6). Control of giant foxtail, velvetleaf, galinsoga and prickly sida (*Sida spinosa* L.) was less effective (Table 5) and by 12 WAT broadleaf and annual grass control was reduced to 53 to 80% in 1990 and 1991, respectively (Table 4). Similar results were reported by Neal and Senesac (26), and Colbert and Ford (7), who observed excellent broadleaf control early in the season with isoxaben at rates of 0.84 to 1.12 kg ai/ha (1.0 lb/A), but less effective control later in the season. When isoxaben was combined with an additional herbicide to supplement grass control,

Table 2. Herbicide treatments applied in the spring and fall of 1990 and 1991.

Treatments	Common name	Formulation	Rate kg ai ha^{-1}	Manufacturer
Princep	simazine	4L	1.12	Ciba
Surflan	oryzalin	75W	3.36	DowElanco
Pennant	metolachlor	7.8L	3.36	Ciba
Pennant	metolachlor	7.8L	6.72	Ciba
Surflan	oryzalin	75W	3.36	DowElanco
Derby	4% metolachlor, 1% simazine	5G	2.24	Ciba
Derby	4% metolachlor 1% simazine	5G	4.48	Ciba
Snapshot	20% isoxaben, 60% oryzalin	80DF	4.20	DowElanco
Snapshot	0.5% isoxaben, 2% trifluralin	2.5G	4.20	DowElanco
Gallery	isoxaben	75DF	0.84	DowElanco
Stakeout	dithiopyr	1G	1.12	Rohm and Haas
Stakeout	dithiopyr	1G	2.24	Rohm and Haas
Kerb	pronamide	50WP	2.24	Rohm and Haas
Goal	oxyfluorfen	1.6E	1.12	Rohm and Haas
Goal	oxyfluorfen	1.6E	2.24	Rohm and Haas
Unweeded check	—	—	—	—

Table 3. Weed control ratings 6 weeks after treatment in 1990 and 1991.

Herbicide treatment	% Weed control in 1990[z]				% Weed control in 1991[z]			
	Broadleaf	Annual grass	Yellow nutsedge	Overall	Broadleaf	Annual grass	Yellow nutsedge	Overall
simazine + oryzalin	89.3a	94.3a	46.7bc	76.7abc	98.3ab	97.7a	31.0bc	91.0a
metolachlor 1×	79.3ab	96.3a	96.7a	90.7ab	76.0bc	100.0a	100.0a	86.0a
metolachlor 2×	88.3a	98.3a	100.0a	95.3a	97.3ab	100.0a	100.0a	98.3a
oryzalin	84.0ab	88.3ab	23.3cd	65.0bc	98.0ab	100.0a	23.3c	87.7a
metolachlor + simazine 1×	61.7bc	95.7a	96.7a	85.0ab	81.0abc	92.0a	100.0a	87.0a
metolachlor + simazine 2×	88.7a	98.3a	100.0a	95.7a	80.0abc	100.0a	100.0a	88.7a
isoxaben + oryzalin	97.3a	95.7a	98.3a	97.0a	100.0a	100.0a	99.0a	100.0a
isoxaben + trifluralin	97.3a	88.0ab	86.7a	90.7ab	100.0a	100.0a	89.7a	98.3a
isoxaben	93.3a	87.3ab	100.0a	93.3ab	100.0a	96.0a	99.3a	99.0a
dithiopyr 1×	91.7a	92.3a	36.7c	73.7abc	96.7ab	100.0a	70.0ab	93.7a
dithiopyr 2×	96.0a	89.7ab	86.7a	91.0ab	100.0a	100.0a	99.3a	100.0a
pronamide	40.0c	40.0c	73.3ab	51.0c	61.7c	51.7b	10.0c	51.3b
oxyfluorfen 1×	88.3a	88.3a	40.0c	72.0abc	100.0a	100.0a	0.0c	86.0a
oxyfluorfen 2×	96.0a	96.0a	88.3a	93.3ab	100.0a	100.0a	66.0ab	95.3a
unweeded check	0.0d	0.0d	0.0d	0.0d	0.0d	0.0c	0.0c	0.0c

[z]Means were separted using Fisher's protected LSD test. Means followed by the same letter are not significantly different at the (0.05) level.

the combinations proved to be as effective as oryzalin in combination with simazine and/or oxyfluorfen (15). In both 1990 and 1991, isoxaben plus oryzalin at 4.2 kg ai/ha (4.0 lb/A) (DF formulation) provided superior full season control of nearly all broadleaf and grass weeds (Tables 3, 4, 5 and 6). Overall weed control averaged 95% 12 WAT in both 1990 and 1991 (Table 4) and control continued through October of each year. In 1990 and 1991, the granular formulation of isoxaben plus trifluralin at 4.2 kg ai/ha (4.0 lb/A) provided good season-long control of broadleaf weeds (86%) and annual grasses (94%) but not yellow nutsedge (67%) (Table 4). Similar results were observed in 1991 (Table 4).

In 1990 and 1991, metolachlor at 3.3 kg ai/ha (3.0 lb/A) provided excellent annual grass control at 6 WAT (96-100%) but poorer broadleaf control (76–79%,) (Table 4). By 12 WAT, plots were dominated by velvetleaf, morningglories (*Ipomoea* spp.), field bindweed, common ragweed, Pennsylvania smartweed, honeyvine milkweed and prickly sida (Table 5). However, broadleaf control was better 6 WAT with metolachlor at the higher rate of 6.6. kg ai/ha (6.0 lb/A) in both 1990 and 1991 (88–97%) (Table 3). Excellent control of yellow nutsedge was obtained with both rates of metolachlor in both years (Table 6). Ahrens (1) also reported that metolachlor was effective for control of yellow nutsedge without injury in woody landscape crops, however, poor control of annual broadleafs was obtained (14).

Metolachlor is currently labelled for use in a wide variety of woody and herbaceous ornamentals and its use for yellow nutsedge control in these crops is increasing (24). It has been reported that when metolachlor was combined with simazine, weed control was substantially improved compared to metolachlor applied alone (14, 23). At 2.2 kg ai/ha (2.0 lb/A), however, this combination did not result in significantly improved broadleaf control over metolachlor applied alone in 1990 or 1991. Broadleaf weed populations were greater in 1991, and overall control of broadleafs provided by metolachlor or metolachlor plus simazine was greatly reduced. At 4.4 kg ai /ha (4.0 lb/A), the combination of metolachlor plus simazine also provided excellent yellow

Table 4. Weed control ratings 12 weeks after treatment in 1990 and 1991.

Herbicide treatment	% Weed control in 1990[z]				% Weed control in 1991[z]			
	Broadleaf	Annual grass	Yellow nutsedge	Overall	Broadleaf	Annual grass	Yellow nutsedge	Overall
simazine + oryzalin	46.7cd	90.0a	60.0ab	65.7abc	36.7cdef	98.3ab	20.0bc	51.7efg
metolachlor 1×	40.0d	95.0a	98.3a	77.7ab	0.0f	98.7a	100.0a	65.7cdefg
metolachlor 2×	62.7abcd	97.0a	100.0a	86.7ab	0.0f	100.0a	100.0a	67.0cdef
oryzalin	73.3abcd	93.3a	28.3bc	64.7abc	43.3cde	100.0a	16.7bc	53.3efg
metolachlor + simazine 1×	65.0abcd	53.3c	73.3ab	63.7abc	13.3ef	82.7b	100.0a	65.0cdefg
metolachlor + simazine 2×	72.7abcd	95.0a	100.0a	89.3ab	20.0def	98.3ab	100.0a	73.0bcde
isoxaben + oryzalin	92.7ab	98.0a	95.0a	95.3a	88.3ab	99.3a	96.3a	95.0ab
isoxaben + trifluralin	85.7abc	93.7a	66.7ab	82.3ab	83.3ab	100.0a	63.3ab	82.0abc
isoxaben	80.0abc	63.3bc	96.7a	80.0ab	53.3bcd	88.7ab	100.0a	80.0abcd
dithiopyr 1×	80.0abc	95.0a	0.0c	58.3abc	71.9abc	98.3ab	33.3bc	45.0fg
dithiopyr 2×	90.0ab	97.0a	73.3ab	86.7ab	96.3a	100.0a	95.0a	97.3a
pronamide	53.3bcd	10.0d	33.3bc	32.0cd	23.3def	36.7c	66.7ab	42.3g
oxyfluorfen 1×	73.3abcd	85.0ab	0.0c	52.7bc	71.7abc	98.3ab	0.0c	56.7defg
oxyfluorfen 2×	95.3a	82.0ab	63.3ab	80.0ab	95.3a	99.0a	64.3ab	86.0abc
unweeded check	0.0d	0.0d	0.0d	0.0d	0.0f	0.0d	0.0c	0.0h

[z]Means were separted using Fisher's protected LSD test. Means followed by the same letter are not significantly different at the (0.05) level.

Table 5. Predominant uncontrolled weed species associated with each herbicide treatment 12 weeks after application.

Treatment	Predominant weeds in 1990	Predominant weeds in 1991
simazine + oryzalin	prickly sida, honeyvine milkweed, field bindweed, yellow nutsedge	giant foxtail, yellow nutsedge, field bindweed, honeyvine milkweed
metolachlor 1×	prickly sida, ivyleaf morningglory, common ragweed, jimsonweed, yellow nutsedge	velvetleaf, common ragweed, pokeweed, Pennsylvania smartweed, field bindweed, ivyleaf morningglory, honeyvine milkweed
metolachlor 2×	prickly sida, ivyleaf morningglory, red sorrel	common ragweed, ivyleaf morningglory
oryzalin	prickly sida, honeyvine milkweed, common ragweed, jimsonweed, yellow nutsedge	yellow nutsedge, horsenettle, honeyvine milkweed, field bindweed
metolachlor + simazine 1×	prickly sida, ivyleaf morningglory, Pennsylvania smartweed, giant foxtail, green foxtail	common ragweed, velvetleaf, giant foxtail, Pennsylvania smartweed, ivyleaf morningglory
metolachlor + simazine 2×	prickly sida, ivyleaf morninglory, field bindweed, jimsonweed	common ragweed, velvetleaf, Pennsylvania smartweed, horsenettle, ivyleaf morningglory
isoxaben + oryzalin	prickly sida, red sorrel, field bindweed	pokeweed
isoxaben + trifluralin	prickly sida, field bindweed	galinsoga
isoxaben	prickly sida, velvetleaf, green foxtail, giant foxtail	giant foxtail, galinsoga
dithiopyr 1×	ivyleaf morningglory, prickly sida, honeyvine milkweed, smooth pigweed, yellow nutsedge	yellow nutsedge, common ragweed
dithiopyr 2×	ivyleaf morningglory, common ragweed, yellow nutsedge	Canada thistle
pronamide	ivyleaf morningglory, velvetleaf, common ragweed, field bindweed, giant foxtail, green foxtail, yellow nutsedge	common ragweed, velvetleaf, honeyvine milkweed, field bindweed, giant foxtail, green foxtail, goosegrass, yellow nutsedge
oxyfluorfen 1×	ivyleaf morningglory, field bindweed, yellow nutsedge	field bindweed, honeyvine milkweed, yellow nutsedge
oxyfluorfen 2×	yellow nutsedge	yellow nutsedge

nutsedge and annual grass control at 12 WAT (Table 6). At 2.2 kg ai/ha (2.0 lb/A), grass and yellow nutsedge control did not last longer than 8 weeks into the growing season (Table 5).

Pronamide at 2.2 kg ai/ha (2.0 lb/A) did not provide control of broadleaf weeds, grasses or yellow nutsedge in 1990 or 1991 (Tables 1 and 2). By 12 WAT, plots were dominated by common ragweed, velvetleaf, honeyvine milkweed, field bindweed, goosegrass, giant foxtail and yellow nutsedge (Table 5). Contrary to these results, Neidlinger (27) reported that pronamide at 1.7 kg ai /ha (1.5 lb/A) or higher provided good control of annual and perennial grasses in an orchard setting in the Pacific Northwest. Warmer temperature and greater weed pressures encountered in Lexington, KY, may have reduced efficacy observed with pronamide in 1990 and 1991.

Oxyfluorfen at 1.1 kg ai/ha (1.0 lb/A) gave complete control of broadleaf weeds and annual grasses at 6 WAT but yellow nutsedge control was only 40% in 1990 and 0% in 1991 (Tables 3, 4, 5 and 6). By 12 WAT, control of broadleafs was reduced to 72–73% (Table 4) and plots were infested with field bindweed, honeyvine milkweed and morningglories (Table 5). Gallitano and Skroch (14), and House and Whitcomb (19) reported similar results in that oxyfluorfen gave excellent control of annual grasses but not spotted or prostrate spurge. Oxyfluorfen at 2.2. kg ai/ha (2.0 lb/A) in 1990 and 1991 provided excellent control of broadleaf weeds and annual grasses at both 6 and 12 WAT (Tables 3 and 4) but yellow nutsedge control at 12 WAT averaged only 63 and 64% (Table 4).

Dithiopyr at 2.2. kg ai/ ha (2.0 lb/A) provided excellent control of winter annual and common broadleaf species (common chickweed, henbit, red sorrel, smooth pigweed and Pennsylvania smartweed), annual grasses (large crabgrass and giant foxtail) and yellow nutsedge in both 1990 and 1991 (Table 6). At the lower rate of 1.1 kg ai/ha (1.0 lb/A), dithiopyr provided excellent control of broadleaf weeds and annual grasses at 6 WAT but not yellow nutsedge (Table 3). By 12 WAT, broadleaf weed control was reduced to 80% and yellow nutsedge control averaged 0% in 1990 and 33% in 1991 (Table 4). Dernoeden and Krouse (11) reported that in Maryland dithiopyr controlled smooth crabgrass effectively throughout the summer. In container-grown nursery stock, Smith and Treaster (33) found that dithiopyr at 2.2 kg ai/ha (2.0 lb/A) was also effective in controlling annual grass, common groundsel, bittercress (*Cardamine cordifolia* A. Gray), yellow wood sorrel (*oxalidaceae*) and lettuce (*Lactuca* spp.). In our studies, excellent weed control was provided by dithiopyr at 2.2 kg ai/ha (2.0 lb/A) throughout the summer and fall.

Crop injury. Visual symptoms of herbicide phytotoxicity to woody ornamentals were not observed in 1990 or 1991. In 1989, when studies were first initiated, slight necrosis and discoloration were noted in burning bush, common lilac and red oak with isoxaben plus trifluralin or oryzalin at

Table 6. **Weed species controlled with each herbicide treatment during 1990 and 1991.**

Treatment	Weeds controlled
simazine + oryzalin	common lambsquarters, smooth pigweed, large crabgrass, goosegrass, Pennsylvania smartweed, common ragweed, common chickweed, henbit
metolachlor 1×	smooth pigweed, large crabgrass, goosegrass, giant foxtail, some yellow nutsedge
metolachlor 2×	smooth pigweed, large crabgrass, goosegrass, giant foxtail, yellow nutsedge
oryzalin	common lambsquarters, redroot pigweed, large crabgrass, goosegrass, Pennsylvania smartweed, giant foxtail, common chickweed, henbit
metolachlor + simazine 1×	smooth pigweed, large crabgrass, goosegrass, henbit, some yellow nutsedge
metolachlor + simazine 2×	smooth pigweed, large crabgrass, goosegrass, giant foxtail, common chickweed, henbit, yellow nutsedge
isoxaben + oryzalin	common lambsquarters, smooth pigweed, large crabgrass, Pennsylvania smartweed, common ragweed, yellow foxtail, common chickweed, henbit
isoxaben + trifluralin	common lambsquarters, smooth pigweed, large crabgrass, Pennsylvania smartweed, common ragweed, giant foxtail, common chickweed, henbit, red sorrel
isoxaben	common lambsquarters, smooth pigweed, Pennsylvania smartweed, common ragweed, common chickweed, henbit, red sorrel
dithiopyr 1×	large crabgrass, goosegrass, giant foxtail, common chickweed, henbit
dithiopyr 2×	large crabgrass, goosegrass, giant foxtail, common chickweed, henbit, yellow nutsedge
pronamide	common chickweed, red sorrel
oxyfluorfen 1×	common lambsquarters, redroot pigweed, large crabgrass, goosegrass, Pennsylvania smartweed, giant foxtail, henbit, red sorrel
oxyfluorfen 2×	common lambsquarters, redroot pigweed, Pennsylvania smartweed, large crabgrass, goose grass, giant foxtail, henbit, red sorrel

4.2 kg ai/ha (4.0 lb/A) or oxyfluorfen at 1.1 or 2.2 kg ai/ha (1.0 or 2.0 lb/A) (data not presented) but no visible phytotoxicity was observed in these treatments in later years. However, longterm growth reductions were noted in selected treatments of common lilac and red oak when caliper measurements were made to record stem or trunk diameter with treatments containing isoxaben. Despite relatively low weed pressure, smaller stem diameters were observed in both species only with treatments of isoxaben plus trifluralin or oryzalin at 4.2 kg ai/ha (4.0 lb/A) (Table 7). Greatest reductions were observed with isoxaben (0.8 kg ai/ha) (0.75 lb/A) alone, but greater weed pressures may have contributed to reduced stem or trunk diameters in this treatment.

Table 7. **Stem and trunk diameter of *Syringa vulgaris* and *Quercus ruba* in March 1991.**

Herbicide treatment	Stem diameter *Syringa vulgaris* (cm)	Trunk diameter *Quercus rubra* (cm)
isoxaben + oryzalin	28.3b[z]	1.03bc
isoxaben + trifluralin	24.0bc	1.13abc
isoxaben	18.0c	0.67c
dithiopyr 1×	26.7bc	0.97bc
dithiopyr 2×	29.7ab	1.20ab
pronamide	28.0bc	1.23ab
oxyfluorfen 1×	30.6ab	1.40ab
oxyfluorfen 2×	38.7a	1.57a

[z]Means were separated using Fisher's protected LSD test. Means followed by the same letter are not significantly different at the (0.05) level.

The herbicide combination of 20% isoxaben plus 60% oryzalin (DF formulation) and 0.5% isoxaben plus 2% trifluralin (G formulation) at 4.2 kg ai/ha (4.0 lb/A) provided excellent long-term suppression of annual and perennial weeds and no visible injury to common ornamentals. Based on our findings related to stem diameter, further research on the effect of these combinations on long-term growth of woody species is needed. Dithiopyr (1% G) at 2.2 kg ai/ha (2.0 lb/A) also provided excellent long-term suppression of annual weeds and yellow nutsedge and showed strong residual activity, based on continued weed suppression, well into October of each year. No significant phytotoxicity to ornamentals was apparent after application or upon long-term growth. Metolachlor or metolachlor plus simazine treatments provided excellent grass suppression (> 95%) and good (> 90%) control of yellow nutsedge. Metolachlor plus isoxaben may prove to be an effective combination for management of a broad weed spectrum. Further research is needed to investigate selectivity and phytotoxicity of these promising herbicides and combinations in a wide selection of landscape species.

(*Ed. note*: This paper reports the results of research only and does not imply registration of a pesticide and/or growth regulant under amended FIFRA. Before using any of the products mentioned in this research paper, be certain of their registration by appropriate state and/or federal authorities.)

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