Yellow Nutsedge Control in Landscape Plants

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Abstract. Preplant-incorporated, preemergence, and postemergence herbicides were evaluated for yellow nutsedge (*Cyperus esculentus* L.) control and for phytotoxicity to four container-grown woody plants. Preplant-incorporated or preemergence applications of chlorimuron at 0.07 kg a.i./ha or imazaquin at 1.12 kg a.i./ha provided the greatest control of yellow nutsedge. Imazaquin applied at 0.28, 0.56, 0.84, or 1.12 kg a.i./ha suppressed growth of *Rhododendron* × 'Copperman' azalea and *Lagerstroemia indica* × *sauriai* 'Natchez'. All other herbicides tested were safe on the four woody plants evaluated. Chlorimuron provided the best combination of yellow nutsedge control and tolerance on woody ornamental. Chemical names used: 2-[[[(4-chloro-6-methoxy-2-pyrimidinyl)amino]carbonyl]amino]sulfonyl]benzoic acid (chlorimuron); 2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-3-quinolinecarboxylic acid (imazaquin).

Yellow nutsedge is one of the most troublesome and widespread perennial weeds in

the United States (Jansen, 1973; Padgett and Frazer, 1962). The noxious character of this weed is due mainly to its carbohydrate-storing tubers that give rise to numerous aerial shoots. Under noncompetitive conditions with adequate light and moisture, a single tuber is capable of producing ≈ 7000 additional tubers and 1900 aerial shoots in a single season (Tumblison and Kommedahl, 1961).

Yellow nutsedge presents a severe problem in field nursery production of woody ornamentals (Ahrens, 1979). Although cultivation and hand-hoeing are common weed control methods, they are time-consuming, expensive (Padgett and Frazer, 1962), and often contribute to the spread of yellow nutsedge in the field. Few registered preemergence- and postemergence-applied herbicides

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Table 1. Influence of herbicide and method of application on yellow nutsedge control 4 and 8 weeks after treatment (WAT).

Herbicide	Rate (kg·ha ⁻¹)	Yellow nutsedge control (%) ^z					
		Method of application ^y					
		PPI		PRE		POE	
		4WAT	8WAT	4WAT	8WAT	4WAT	8WAT
Fomesafen	0.28	62	40	48	40	46	28
	0.56	44	54	64	52	52	48
	0.84	80	70	88	68	60	48
	1.12	86	62	90	72	64	50
Chlorimuron	0.02	50	40	36	42	42	42
	0.04	88	66	58	76	52	74
	0.05	74	68	88	78	56	80
	0.07	100	100	100	100	72	76
Imazaquin	0.28	54	58	62	60	36	28
	0.56	72	56	78	68	38	50
	0.84	100	68	94	68	46	58
	1.12	100	100	100	100	46	62
Untreated	---	0		0		0	
Significance (LSD) ^x		4WAT	8WAT				
Method of application		5	4				
Rate		6	5				
Method × rate		9	8				
Alachlor (PPI)	3.4	34	34				
Acetochlor (PPI)	2.2	58	20				
Metolachlor (PPI)	2.2	52	28				
Norflurazon (PPI)	1.7	76	76				
Vernolate (PPI)	2.2	94	28				
Vernolate + metolachlor (PPI)	2.2 + 2.2	100	56				
Bentazon (POE)	0.6	---		---		46	32
Bentazon (POE)	1.1	---		---		42	0
Glyphosate (PDS)	0.6	---		---		42	20
Glyphosate (PDS)	1.1	---		---		46	24
Untreated	---	0		0		0	0
LSD* (any two means)		9		8			

*100 = 100% control, 0 = no control.

^yPPI = preplant-incorporated, PRE = preemergence, POE = postemergence, and PDS = post-emergence-directed spray applications.

^zFisher's protected LSD ($P \leq 0.05$). Yellow nutsedge control (%) as a function of herbicide rate (x):

Fomesafen:

4WAT PPI: $y = 71.1 - 69.2x + 76.9x^2$, $R^2 = 0.65$, $P > 0.0025$.

4WAT PRE: $y = 20.5 + 103.7x - 36.3x^2$, $R^2 = 0.94$, $P > 0.0018$.

4WAT POE: $y = 39.9 + 22.1x$, $R^2 = 0.85$, $P > 0.0001$.

8WAT PPI: $y = 9.2 + 125.1x - 68.6x^2$, $R^2 = 0.89$, $P > 0.0001$.

8WAT PRE: $y = 20.1 + 74.8x - 24.7x^2$, $R^2 = 0.86$, $P > 0.0002$.

8WAT POE: $y = -0.09 + 123.7x - 74.5x^2$, $R^2 = 0.86$, $P > 0.0001$.

Chlorimuron:

4WAT PPI: $y = 19.4 + 1863.5x - 10833.3x^2$, $R^2 = 0.79$, $P > 0.0488$.

4WAT PRE: $y = -4.7 + 2140.1x - 9062.5x^2$, $R^2 = 0.94$, $P > 0.0268$.

4WAT POE: $y = 37.8 + 126.7x + 5104.2x^2$, $R^2 = 0.97$, $P > 0.0002$.

8WAT PPI: $y = 23.1 + 800.7x + 3854.2x^2$, $R^2 = 0.97$, $P > 0.0464$.

8WAT PRE: $y = -5.9 + 2067.1x - 10729.2x^2$, $R^2 = 0.97$, $P > 0.0001$.

8WAT POE: $y = -14 + 3380.5x - 29895.8x^2$, $R^2 = 0.98$, $P > 0.0001$.

Imazaquin:

4WAT PPI: $y = 18.1 + 138.5x - 57.8x^2$, $R^2 = 0.95$, $P > 0.0001$.

4WAT PRE: $y = 32.1 + 13.4x$, $R^2 = 0.77$, $P > 0.0001$.

4WAT POE: $y = 29.3 + 23.4x - 7.2x^2$, $R^2 = 0.79$, $P > 0.1769$.

8WAT PPI: $y = 77.7 - 97.4x + 103.6x^2$, $R^2 = 0.98$, $P > 0.0001$.

8WAT PRE: $y = 73.5 - 61.5x + 73.7x^2$, $R^2 = 0.91$, $P > 0.0001$.

8WAT POE: $y = 2.1 + 118.8x - 57.4x^2$, $R^2 = 0.98$, $P > 0.0001$.

are currently available to provide yellow nutsedge suppression without injuring ornamental species. Those that are available for weed control in nursery fields often result in the proliferation of yellow nutsedge by eliminating other competitive weed species. In addition, yellow nutsedge control from currently registered herbicides is often inconsistent (Ahrens, 1981; Pereira et al., 1987).

Fomesafen, chlorimuron, and imazaquin are new herbicides in the diphenyl ether, sul-

fonylurea, and imidazolinone herbicide families, respectively. Although they are only registered for use in agronomic crops, they reportedly control yellow nutsedge (Nandihalli and Bendixen, 1988; Reddy and Bendixen, 1988; G. R. W., unpublished data). Until recently, little information was available on the tolerance of woody ornamental to the sulfonylurea and imidazolinone herbicides (Derr, 1989; Beste and Frank, 1989; Moore et al., 1989). These herbicides pro-

vide effective control of numerous weed species at very low rates, consequently reducing the environmental impact of weed management programs.

The objectives of this study were to compare fomesafen, chlorimuron, and imazaquin with existing herbicide standards for: a) control of yellow nutsedge, b) influence on yellow nutsedge tuber viability, and c) phytotoxicity to four container-grown woody ornamental species.

Ten yellow nutsedge tubers were planted ≈ 3 cm deep in 0.95-liter plastic cups containing a Dothan loamy sand (Plinthic Paleudults). Chlorimuron, 5-[2-chloro-4(trifluoromethyl)phenoxy]-N-(methylsulfonyl)-2-nitrobenzamide (fomesafen), and imazaquin were applied preplant-incorporated (PPI), preemergence (PRE), or post-emergence (POE). Herbicides were applied with a chain-driven belt sprayer equipped with flat fan nozzles, using compressed air for propellant (operating at 193 kPa) in 112 liters water carrier/ha. A randomized complete-block design was used with four replications. For all methods of application, fomesafen and imazaquin were applied at 0.28, 0.56, 0.84, and 1.12 kg a.i./ha, while chlorimuron was applied at 0.02, 0.04, 0.05, and 0.07 kg a.i./ha. For PPI and PRE applications, the herbicides were applied to the soil surface of pots containing recently planted nutsedge tubers. To simulate PPI applications, herbicides were applied to the soil surface of each cup, and all the soil in the cup was poured into a plastic bag, mixed thoroughly, and returned to the cup. For POE evaluation, the same herbicides were applied at the aforementioned rates to previously untreated 10-cm-tall yellow nutsedge plants ≈ 4 weeks after PPI or PRE treatments. Fomesafen, chlorimuron, and imazaquin were applied with a nonionic surfactant (X-77, a mixture of alkylaryl-polyoxyethylene glycols, free fatty acids, and isopropanol; Valent USA Corp., Walnut Creek, Calif.) at 0.25% (v/v) for all POE applications.

Registered herbicides were also compared for yellow nutsedge control. These herbicides included (all in kg·ha⁻¹): 2-chloro-N-(2,6-diethylphenyl)-N-(methoxymethyl)-acetamide (alachlor), 3.4 (PPI); 2-chloro-N-(ethoxymethyl)-N-(2-ethyl-6-methylphenyl)acetamide (acetochlor), 2.2 (PPI); 2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl)acetamide (metolachlor), 2.2 (PPI); 4-chloro-5-(methylamino)-2-(3-trifluoromethylphenyl)-3(2H)-pyridazinone (norflurazon), 1.7 (PPI); S-propyldipropylcarbamothiate (vernolate), 2.2 (PPI); vernolate plus metolachlor, 2.2 plus 2.2 (PPI); 3-(1-methylethyl)-(1H)-2,1,3-benzothiadiazin-4(3H)-one-2,2-dioxide (bentazon), 0.6 or 1.1 (POE); and N-(phosphonomethyl)glycine (glyphosate), 0.6 and 1.1 postemergence-directed spray (PDS). Bentazon was applied with a crop oil concentrate (Agridex, a mixture of paraffin-base petroleum oil, polyoxyethylene polyol fatty acid ester, and polyol fatty ester; Helena Chemical Co, Memphis, Term.) at 1.25% (v/v) of the spray volume. Yellow nutsedge control

Table 2. Influence of herbicide and method of application on tuber viability of yellow nutsedge 10 weeks after treatment.

Herbicide ^a	Rate (kg·ha ⁻¹)	Method of application ^b	
		PPI	PRE
		<i>No. of viable tubers</i>	
Fomesafen	0.28	0.5	0.7
	0.56	0.3	0.2
	0.84	0.3	0.3
	1.12	0.4	0.3
Chlorimuron	0.02	3.0	0.7
	0.04	1.7	1.5
	0.05	0.8	0.2
	0.07	0	0
Untreated		9.1	8.8
Significance (LSD) ^c			
Method of application	1.1		
Rate	0.9		
Method × rate	1.3		
Any two means	0.8		

^aImazaquin at 0.28 to 1.12 kg·ha⁻¹ killed all tubers.

^bPPI and PRE designate preplant-incorporated and preemergence applications, respectively, to 10 tubers.

^cFisher's protected LSD ($P \leq 0.05$). Yellow nutsedge tuber viability as a function of herbicide rate (x):

Fomesafen:

PPI: $y = 0.8 - 1.3x + 0.9x^2$, $R^2 = 0.31$, $P > 0.0013$.

PRE: $y = 1.3 - 2.5x + 1.5x^2$, $R^2 = 0.55$, $P > 0.0003$.

Chlorimuron:

PPI: $y = 4.9 - 100.7x + 437.5x^2$, $R^2 = 0.97$, $P > 0.0024$.

PRE: $y = -0.1 + 64.5x - 927.1x^2$, $R^2 = 0.44$, $P > 0.0051$.

Table 3. Influence of herbicide applied postemergence on phytotoxicity of ornamentals 8 weeks after treatment.^a

Herbicide	Rate (kg·ha ⁻¹)	Phytotoxicity ratings (%)	
		Copperman azalea	Natchez crape myrtle
Fomesafen	0.28	0	0
	0.56	6	6
	0.84	25	0
	1.12	26	6
Chlorimuron	0.02	14	0
	0.04	6	0
	0.05	8	0
	0.07	8	14
Imazaquin	0.28	80	42
	0.56	81	54
	0.84	78	56
	1.12	81	62
Untreated	---	0	0
LSD ^b		9	8

^a100% = dead, 0% = no injury.

^bWisher's protected LSD ($P \leq 0.05$). Ornamental phytotoxicity ratings as a function of herbicide rate (X):

Fomesafen:

Azalea: $y = -17 + 60.4x - 19.1x^2$, $R^2 = 0.89$, $P > 0.0386$.

Crape myrtle: $y = -2.9 + 8.6x$, $R^2 = 0.70$, $P > 0.0001$.

Chlorimuron:

Azalea: $y = 23.6 - 574x + 5000x^2$, $R^2 = 0.81$, $P > 0.001$.

Crape myrtle: $y = 12.4 - 839.2x + 12395.8x^2$, $R^2 = 0.97$, $P > 0.0001$.

Imazaquin:

Azalea: $y = 80 + 0.5x$, $R^2 = 0.01$, $P > 0.55$.

Crape myrtle: $y = 29 + 53.3x - 21.5x^2$, $R^2 = 0.88$, $P > 0.0024$.

was compared to untreated plants and evaluated on the basis of weed density and vigor on a scale of 0% (no control) to 100% (complete control) at 4 and 8 weeks after treatment (WAT). The experiment was replicated.

The effect of fomesafen, chlorimuron, and imazaquin on yellow nutsedge tuber viability was investigated in a second experiment. The herbicides were applied PPI and PRE at the aforementioned rates to 10 tubers. Ten weeks

after treatment, plants were removed from the soil and examined to determine whether tubers were nonviable (rotted, brown, or darkened) or viable (firm and white). The experiment was replicated.

For phytotoxicity evaluations, plants of *Liriope muscari* 'Big Blue' (lirope), *Rhododendron* × 'Copperman' azalea, *Buxus sempervirens* (common boxwood), and *Lagerstroemia indica* × 'fauriei' 'Natchez' (crape

myrtle) received POE applications of fomesafen, chlorimuron, or imazaquin as previously described. Soil type, pot size, and growth conditions were also as previously described. The experiment was repeated.

Data in all experiments were analyzed first as an embedded factorial and, where appropriate, all data, including the imbedded factorial, were reanalyzed and means were tested for differences by Fisher's protected least significant difference test at $P = 0.05$. Since results between experiments did not differ, data were combined for presentation. Regression analyses were also used to predict yellow nutsedge control, number of viable tubers, and phytotoxicity on ornamental species from chlorimuron, fomesafen, and imazaquin applications.

Degree of control. Yellow nutsedge control at 4 WAT was generally greater when fomesafen, chlorimuron, and imazaquin were applied PPI or PRE rather than as a POE application (Table 1). For fomesafen and imazaquin at 4 WAT, the level of control increased as the rate was increased from 0.28 to 0.84 kg·ha⁻¹, while the degree of control at 0.84 and 1.12 kg·ha⁻¹ was similar. Imazaquin applied PPI at 0.84 and 1.12 kg·ha⁻¹ or as a PRE application at 1.12 kg·ha⁻¹ provided 100% control. Complete control at 4 WAT was also obtained with chlorimuron applied either PPI or PRE at 0.07 kg·ha⁻¹. Vernolate applied PPI provided 94% to 100% control alone or in combination with metolachlor, respectively. Poor control resulted from PPI applications of alachlor, acetochlor, metolachlor, and norflurazon. Greatest control (about two-thirds) at 4 WAT from POE applications was obtained with fomesafen applied at 0.84 and 1.12 kg·ha⁻¹ or with chlorimuron at 0.07 kg·ha⁻¹. The two currently registered postemergence herbicides, bentazon and glyphosate, provided less control than any POE applications of fomesafen and chlorimuron and similar levels of control as imazaquin applied at 0.56 kg·ha⁻¹ or higher.

Eight weeks after treatment, chlorimuron at 0.07 kg·ha⁻¹ or imazaquin at 1.12 kg·ha⁻¹ applied PPI or PRE provided 100% control, while POE applications were much less effective. Greatest control from fomesafen was also achieved with PPI or PRE applications, but control was inferior to that provided by the others. At the rates tested, no currently registered herbicide provided control equivalent to that obtained with imazaquin or chlorimuron. Norflurazon applied PPI at 1.7 kg·ha⁻¹ provided the greatest control of the registered herbicides. Yellow nutsedge control following treatment with acetochlor, alachlor, metolachlor, vernolate, bentazon, or glyphosate was unsatisfactory. Although Ahrens (1981) reported that sequential applications of metolachlor, but not alachlor, applied 3 months apart at 6.6 to 9.0 kg·ha⁻¹ provided good control, a single application was frequently inadequate (Ahrens, 1979). Our low level of control with alachlor and metolachlor following a single application was much lower than control reported by Ahrens (1979). In addition, Ahrens (1979, 1981) also

reported unsatisfactory yellow nutsedge control from a single postemergence application of bentazon.

Regression analyses of yellow nutsedge control comparing herbicide and method of application revealed a curvilinear response to herbicide rate, with coefficients of determination at 8 WAT of at least 0.86, 0.97, and 0.91 for fomesafen, chlorimuron, and imazaquin, respectively, depending on method of application (Table 1). However, fomesafen POE and imazaquin PRE provided a linear response for yellow nutsedge control. A curvilinear response indicated that a certain level of yellow nutsedge control was reached and that no further increase in control was achieved with the herbicide rates we used. A linear response indicates that control was increasing with increased rate of application and that the control maximum was not yet achieved with that particular herbicide application.

Postemergence control of yellow nutsedge with chlorimuron and imazaquin was equivalent to, or better than, that with bentazon and glyphosate. Successful yellow nutsedge control with foliar-applied herbicides requires rapid absorption and translocation of the active ingredient to the meristematic cells of the basal bulb, rhizome apices, and tubers in sufficient quantities to kill the entire plant (Bhan et al., 1970; Hauser, 1963; Sprinkle et al., 1975; Wills and Briscoe, 1970; Wills et al., 1980). Bentazon control of yellow nutsedge is often restricted due to the absence of basipetal translocation to parent tubers and very little acropetal translocation to other plant parts (Stoner et al., 1975). In addition, both chlorimuron and imazaquin may have been absorbed by yellow nutsedge from the soil, since POE applications would have contacted both the soil and the yellow nutsedge foliage, whereas glyphosate and bentazon have exhibited no significant residual activity.

Tuber viability. In the second experiment, imazaquin applied PPI or PRE, regardless of rate of application, killed all tubers. Chlorimuron applied at 0.07 kg-ha⁻¹ as a PPI or PRE application also killed all tubers (Table 2). Regression analyses of yellow nutsedge control from chlorimuron applied PPI indicated a strong curvilinear response, $R^2 = 0.97$. However, the variability in yellow nutsedge tuber viability from chlorimuron applied PRE and from fomesafen applied PPI or PRE prevented a good correlation for these treatments. These results support those presented in Table 1, in which 100% control of yellow nutsedge was obtained from PPI and PRE applications of imazaquin and chlorimuron. Nandihalli and Bendixen (1988) reported that soil applications of imazaquin above the tubers (mimicking PPI and PRE applications) inhibited regrowth more than placement below the tuber.

Phytotoxicity. Neither 'Big Blue' liriop nor common boxwood exhibited symptoms of injury from any of the herbicides 8 weeks after treatment (data not shown). All rates of imazaquin were injurious to the foliage of 'Natchez' crape myrtle and 'Copperman'

azalea (Table 3). Phytotoxicity was characterized by stunted plants with lanceolated leaves arising in a fashion similar to witches'-broom. Fomesafen at all rates initially caused chlorotic spotting on all species, particularly in azalea and crape myrtle. However, chlorosis was no longer evident on crape myrtle 8 weeks after treatment. Chlorimuron applied at 0.07 kg-ha⁻¹ initially stunted crape myrtle and azalea, but by 8 weeks these plants were similar to control plants. Phytotoxicity evaluations exhibited a curvilinear response to postemergence applications of chlorimuron for both azalea and crape myrtle. Fomesafen injury was a curvilinear response for azalea and linear for crape myrtle. Injury to crape myrtle from imazaquin also exhibited a curvilinear response ($R^2 = 0.88$). However, for azalea, neither a linear nor a curvilinear response to imazaquin was noted ($R^2 = 0.01$). This lack of a response may be explained by the apparent greater sensitivity of azalea to POE applications of imazaquin, with 80% injury even at the lowest rate of application. Moore et al. (1989) reported little injury from chlorimuron applications and significant injury from all applications of imazaquin on container-grown 'Gloria' azaleas and 'Merritt Supreme' hydrangeas. Beste and Franke (1989) found little injury on *Ilex crenata* 'Helleri', *Juniperus conferta* 'Blue Pacific', and *Rhododendron catawbiense* 'Roseum elegans'. Derr (1989) also found little or no injury on five container-grown woody ornamental. However, he also reported moderate to severe injury (27% to 47%) on 'Hinocrimson' azalea, depending on chlorimuron rate.

Fomesafen, chlorimuron, and imazaquin, if registered, would allow more flexibility in method of application for the control of yellow nutsedge than existing registered herbicides. Chlorimuron applied at 0.02 to 0.07 kg-ha⁻¹ was not injurious on the four ornamental species tested. However, excellent yellow nutsedge control was achieved only with 0.07 kg-ha⁻¹ applied either PPI or PRE. Although chlorimuron is not currently registered for use on woody nursery stock, it provided the best combination of yellow nutsedge control and tolerance by woody ornamentals. Consequently, chlorimuron may provide nursery workers with an effective postemergence alternative to directed applications of glyphosate for yellow nutsedge control. Imazaquin was very injurious to two of four ornamental species treated, severely limiting its usefulness for weed control around woody ornamental. Fomesafen, while not as active on yellow nutsedge as chlorimuron, provided better yellow nutsedge control than bentazon. However, since fomesafen is a member of the same herbicide family as acifluorfen and oxyfluorfen, ornamental injury could be a problem (Ahrens, 1981).

These studies were conducted in the greenhouse under uniform environmental growing conditions. It is difficult to extrapolate greenhouse findings to a field environment. Soil differences, watering regimes, moisture stresses, and other environmental factors may also influence soil-herbicide

(Hance, 1988) and plant-herbicide (Hess, 1985) interactions. Thus, while chlorimuron shows potential for yellow nutsedge control in a greenhouse, its performance under field conditions is still unknown.

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