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Weed Control in Christmas Trees with Flumioxazin and Other Residual Herbicides Applied Alone or in Tank Mixtures

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SUMMARY. Four studies were conducted from 2001 to 2004 in Michigan to determine Christmas tree tolerance and weed control with flumioxazin and other herbicide treatments. In Study 1, fraser fir (*Abies fraseri*) leader length was greater with fall-applied flumioxazin (0.38 lb/acre) than with halosulfuron (0.21 lb/acre), isoxaben (1 lb/acre), oxyfluorfen (1 lb/acre), simazine (2 lb/acre), or sulfentrazone (0.5 lb/acre). Flumioxazin applied in the fall provided preemergent control of common ragweed (*Ambrosia artemisiifolia*), field violet (*Viola arvensis*), and hoary alyssum (*Berteroa incana*) 79% to 98% the following summer. Preemergence weed control with the other herbicides was more variable. In Study 2, fraser fir treated in the spring with oxyfluorfen had the shortest leader length (terminal stem growth of the current growing season) at 4.3 inches. Trees treated in the spring with flumioxazin, isoxaben, simazine, and sulfentrazone had leader lengths of 6.7 to 8.7 inches. Flumioxazin applied preemergence in the spring controlled common ragweed 80%, but controlled field violet, hoary alyssum, and white campion (*Silene alba*) only 43% to 64%. In Study 3, fall-applied flumioxazin alone did not injure colorado blue spruce (*Picea pungens*). However, mixtures of flumioxazin plus pendimethalin (3 lb/acre) caused 5% and 6% tree injury at 6 months after treatment (MAT) and sulfentrazone plus pendimethalin caused 9% and 23% injury at 6 MAT in 2003 and 2004, and 52% injury at 9 MAT in 2004. There was no significant injury to the trees treated with isoxaben plus pendimethalin, oxyfluorfen plus pendimethalin, or simazine plus pendimethalin in 2003 and 2004. Leader length was reduced by sulfentrazone plus pendimethalin compared with flumioxazin plus pendimethalin and oxyfluorfen plus pendimethalin. Flumioxazin plus pendimethalin provided 84% to 88% preemergence control of annual grasses, common catsear (*Hypochoeris radicata*), horseweed (*Conyza canadensis*), and virginia pepperweed (*Lepidium virginicum*). In Study 4, spring-applied mixtures of flumioxazin plus pendimethalin resulted in minor (2%–10%) visual injury to colorado blue spruce, although leader length at the end of the season did not differ significantly from the control. In summary, flumioxazin controlled several weed species with acceptable selectivity in colorado blue spruce and fraser fir Christmas trees.

The Christmas tree industry in Michigan ranked third nationally in 2003, with 1.9 million trees sold [U.S. Department of Agriculture (USDA), 2007]. In 2005, there were 16,800 ha in commercial production, with cut-tree sales of $41.5 million at the producer level (Klewano and Matthews, 2005). Conifer seedlings typically are grown in nurseries for 3 to 5 years before transplanting in production fields. After transplanting, trees take an additional 8 to 12 years to reach harvestable size. Due to the length of rotation and sensitivity of some species (especially young transplants) to weed competition, adequate weed control continues to be an important issue facing the industry.

Chemical weed control provides numerous benefits over no weed control for intensive silviculture, such as greater than 25% increased biomass production for tree crops with rotations of less than 15 years (Mead, 2005). Seedling height, stem volume, and basal diameter of several conifers increased at four of five research sites when the weed-free area around the trees increased (Rose and Ketchum, 2002). In research trials with monterey pine (*Pinus radiata*), removing weed competition increased volumetric soil moisture 5% to 9%. The increase in available moisture increased midday needle water potential by up to 1.5 MPa (Sands and Nambiar, 1984). Foliar nutrition also has been shown to improve with better weed control. Woods et al. (1992) found that foliar nitrogen (N) levels increased consistently with increasing width of weed free area around monterey pine trees.

Despite the importance of weed control for intensive silviculture, few herbicides are developed and registered for these applications (Woeste et al., 2005). Flumioxazin is an *N*-phenylphthalimide herbicide and inhibits the protoporphyrinogen oxidase [PPO (EC 1.3.3.4)] enzyme (Yoshida et al., 1991). Michigan registration of this herbicide was approved before the 2004 growing season for nursery crops and Christmas trees at use rates of 0.25 to 0.38 lb/acre (Valent U.S.A. Corp., 2004). Flumioxazin has been evaluated for use in many other crops, including cotton (*Gossypium hirsutum*), peanut (*Arachis hypogaea*), potato (*Solanum tuberosum*), soybean (*Glycine max*), sugarcane (*Saccharum* spp.), and in orchards, vineyards, certain ornamentals, and noncropland (Askew et al., 2002; Burke et al., 2002; Cranmer et al., 2000; Dunst et al., 2004; Richardson and Zandstra, 2006; Taylor-Lovell et al., 2002; Valent U.S.A. Corp., 2005; Wilson et al., 2002;

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.1	bar	MPa	10
0.3048	ft	m	3.2808
9.3540	gal/acre	$L\cdot ha^{-1}$	0.1069
2.54	inch(es)	cm	0.3937
1.1209	lb/acre	$kg\cdot ha^{-1}$	0.8922
6.8948	psi	kPa	0.1450
(°F − 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

Zandstra and Particka, 2004). In previous research, preemergence (PRE) applications of flumioxazin at 0.031 to 0.094 lb/acre controlled common chickweed (*Stellaria media*), common lambsquarters (*Chenopodium album*), common ragweed, hairy nightshade (*Solanum sarrachoides*), entireleaf morningglory (*Ipomoea hederacea* var. *integriuscula*), ivyleaf morningglory (*I. hederacea*), pitted morningglory (*I. lacunosa*), tall morningglory (*I. purpurea*), palmer amaranth (*Amaranthus palmeri*), redroot pigweed (*A. retroflexus*), smooth pigweed (*A. hybridus*), sicklepod (*Senna obtusifolia*), common mallow (*Malva neglecta*), prickly sida (*Sida spinosa*), and velvetleaf (*Abutilon theophrast*) (Askew et al., 2002; Price et al., 2002; Taylor-Lovell et al., 2002; Wilson et al., 2002).

The three most widely used PRE herbicides in Michigan Christmas trees in 2003 were simazine, atrazine, and hexazinone (USDA, 2004). The effectiveness of these products is decreasing because of the emergence of resistant weed biotypes (Gower et al., 2004; Kuhns and Harpster, 2003). Therefore, additional PRE broadleaf herbicides are needed to maintain economical production systems and increase options for resistance management. Research studies were conducted to evaluate flumioxazin and other PRE herbicides for residual weed control in Christmas trees.

Materials and methods

METHODS COMMON TO ALL EXPERIMENTS. Experiments were conducted in 2001 through 2004 on commercial Christmas tree farms in Michigan. Trees in each study were transplanted in Spring or Fall 2000 with 6 × 6 ft between-row and in-row spacing. Preplant fertilizer was applied at each site as determined by soil test recommendations. All herbicide treatments were applied over the tops of the trees, which is the most common practice among growers. Each experiment included an untreated control. The experiments were arranged as randomized complete-block designs with three replications. Herbicides were applied with a carbon dioxide- (CO_2) pressurized backpack sprayer delivering 20 gal/acre at 30 psi through XR 8003 flat fan spray tips (Spraying Systems, Wheaton, IL). Plot size was 6 × 50 ft in Studies 1 and 2 (seven trees per plot) and 18 × 20 ft in Studies 3 and 4 (eight trees per plot). Trees were dormant at the time of application in all studies. All annual weeds in the plots were dead at the time of fall applications.

STUDY 1. This study was initiated at Gobles and Hart, MI, in Fall 2001 and continued at Hart through Fall 2002 to compare fraser fir injury and weed control following fall applications of herbicides. Treatments were 0.38 lb/acre flumioxazin, 0.21 lb/acre halosulfuron, 1 lb/acre isoxaben, 1 lb/acre oxyfluorfen, 2 lb/acre simazine, and 0.5 lb/acre sulfentrazone. Treatments were selected to provide season-long weed control the following year. Sulfentrazone rate was selected as the maximum rate that would potentially be used in conifers and has been used in other Christmas tree trials (Ahrens, 2007). Treatments were applied 31 Oct. 2001 at Gobles and Hart. The air temperature at Gobles was 58 °F and the relative humidity was 47%. The soil temperature was 49 °F and the surface was damp. There was a good stand of quackgrass (*Elytrigia repens*) present at treatment. The air temperature at Hart was 43 °F and the relative humidity was 61%. The soil temperature was 43 °F with a damp surface. There were no weeds present. In 2002 at Hart, the treatments were applied 31 Oct. The air temperature was 40 °F and relative humidity was 81%. The soil surface was damp and soil temperature was 42 °F. There were many hoary alyssum present. Tree height was 1 to 2 ft in 2001 and 2 to 3 ft in year 2. The soil was an Oshtemo sandy loam (Typic Hapludalfs) at Gobles, a Spinks Benona sand (Lamellic Hapludalfs) at Hart in 2001, and a Spinks Benona sandy loam at Hart in 2002. Soil organic matter (OM) ranged from 0.8% to 1.8% in the three trials.

STUDY 2. This study was initiated at Gobles and Hart on 10 Apr. 2002 and continued at Hart on 24 Apr. 2003 to compare fraser fir injury and weed control with spring applications of residual herbicides. The air temperature at Gobles at the time of treatment in 2002 was 46 °F with a relative humidity of 59%. The soil temperature was 37 °F and the surface was damp. There were no weeds present. On the same day at Hart, the air temperature was 55 °F with a 40% relative humidity. The soil was 45 °F and the surface was damp. No weeds were present in the plots at treatment. In 2003 at Hart, when the treatments were applied, the air temperature was 60 °F and relative humidity was 33%. The soil surface was dry and the temperature was 53 °F. The plots were free of weeds. Treatments were flumioxazin at 0.38 lb/acre, isoxaben at 1 lb/acre, oxyfluorfen at 1 lb/acre, simazine at 2 lb/acre, and sulfentrazone at 0.5 lb/acre. Tree height at application was 2 to 3 ft in 2002 and 2.6 to 4 ft in 2003. Soil type was an Oshtemo sandy loam at Gobles, a Spinks Benona sand at Hart in 2002, and a Spinks Benona sandy loam at Hart in 2003. Soil OM ranged from 0.7% to 1.8% in the three trials.

STUDY 3. This study near Sidney, MI, was established to compare colorado blue spruce injury and weed control with fall applications of residual herbicides. Treatments were applied 12 Nov. 2002 with air temperature at 37 °F and relative humidity at 76%. The soil surface was damp and soil temperature was 40 °F. There were many dandelions (*Taraxacum officinale*) and horseweeds in the plots, along with a few hoary alyssum. The 2003 treatments were applied 12 Nov. with air temperature at 46 °F and relative humidity at 95%. The soil temperature was 46 °F and the surface was damp. Virginia pepperweed was prominent in the plots, along with a moderate stand of dandelion. Before treatment application, glyphosate at 0.37 lb/acre was applied in a 2-ft band to the base of the trees on each side of the rows to kill or stunt the weeds that were present. This rate of the original formulation of glyphosate without a surfactant is typically used by growers in Christmas tree plantations to avoid injury. Treatments were flumioxazin at 0.38 lb/acre, and mixtures of flumioxazin at 0.38 lb/acre plus pendimethalin at 3 lb/acre, isoxaben at 1 lb/acre plus pendimethalin at 3 lb/acre, oxyfluorfen at 1 lb/acre plus pendimethalin at 3 lb/acre, simazine at 2 lb/acre plus pendimethalin at 3 lb/acre, and sulfentrazone at 0.5 lb/acre plus pendimethalin at 3 lb/acre. The emulsifiable concentrate formulation of pendimethalin was used in Studies 3 and 4. Treatments were applied as a broadcast over-the-top application. Tree height at application was 2 to 3 ft in 2002 and 2.5 to 4 ft in 2003. Soil type was a McBride sandy loam (Alfic Fragiorthods) with 1.5% to 2.0% OM.

STUDY 4. This study was initiated in Spring 2003 and continued in Spring 2004 near Sydney to compare colorado blue spruce injury and weed control with various flumioxazin rates and mixtures applied in the spring. Treatments were applied as a broadcast application on 6 May 2003 and 27 Apr. 2004. In 2003, the soil temperature at application was 58 °F and the surface was damp. The air temperature was 62 °F with a 57% relative humidity. There was a small amount of quackgrass and a moderate stand of dandelion present. In 2004, the soil temperature at application was 40 °F and the surface was damp. The air temperature was 34 °F with a 53% relative humidity. A few dandelions were present in the plot. Before treatment application, glyphosate at 0.37 lb/acre was applied in a 2-ft band to the base of the trees on each side of the rows in the entire experimental area to kill or stunt the weeds present. Treatments included flumioxazin at 0.13, 0.25, and 0.38 lb/acre, and mixtures containing flumioxazin at 0.25 lb/acre plus pendimethalin at 3 lb/acre, *S*-metolachlor at 1.2 lb/acre, simazine at 1.5 lb/acre, and simazine at 1.5 lb/acre plus pendimethalin at 3 lb/acre. Flumioxazin at 0.13 lb/acre plus simazine at 1.5 lb/acre and oxyfluorfen at 0.5 lb/acre plus pendimethalin at 3 lb/acre were also applied. Tree height at application was 2 to 3 ft in 2003 and 2.5 to 4 ft in 2004. Soil type was a McBride sandy loam with 1.6% to 2.0% OM.

DATA COLLECTION AND ANALYSIS. In all studies, visible injury and weed control were rated on a 0% to 100% scale, with 0% equal to no plant response and 100% equal to complete plant death. Visual weed ratings evaluated PRE control, and tree ratings evaluated the result of fall dormant applications and spring-applied foliar treatments. Foliar necrosis, chlorosis, and plant stunting were considered when making the visual estimates. Visible crop injury was rated 6 and 9 months after treatment (MAT) for fall-applied treatments or 1 and 3 MAT for spring-applied treatments. Weed control was rated 9 or 10 MAT for fall-applied treatments and 3 or 4 MAT for spring-applied treatments. Christmas tree leader length (terminal stem growth of the current growing season) was measured each year in September before trimming. Leaders are typically trimmed during the dormant season to obtain desired length and bud characteristics for a particular species and age class. Leader length has been used by other researchers as a measure of conifer growth and is considered to be a good measure of tree vigor (Cristy, 1986; Lyytikäinen-Saarenmaa, 1999; Straw and Green, 2001; Will, 2005). Percentage of weed control and crop injury was arcsine square root transformed before statistical analysis, but original means are presented in the tables. All data were subjected to analysis of variance and means were separated using Fisher's protected least significant difference at $P \leq 0.05$. Data were combined over years in which there was no treatment by year interactions. The untreated control was not included in statistical analyses of visual ratings, but was included in leader length analyses. Data were analyzed using Agriculture Research Manager (ARM; version 7.1.1; Gylling Data Management, Brookings, SD).

Results and discussion

STUDY 1. There was no visual herbicide injury to the trees from any treatment (data not presented). Fraser fir trees treated with flumioxazin had a leader length of 4.0 inches, which was longer than leader length of all other treatments (Table 1). Leader length was 2.0 inches with simazine and sulfentrazone and 2.7 inches with the remaining treatments. Minor differences in leader length would not be commercially significant and could represent natural variability rather than superior herbicidal performance. Fraser fir, balsam fir (*Abies balsamea*), and douglas fir (*Pseudotsuga menziesii*) Christmas trees have been tolerant to flumioxazin in previous research (Kuhns and Harpster, 2003, 2004).

Halosulfuron and simazine provided the best common ragweed control at 89% (Table 1). Control was 72% and 79% with isoxaben and flumioxazin, respectively, but did not exceed 51% with oxyfluorfen and sulfentrazone. In previous research, flumioxazin at 0.063 to 0.094 lb/acre controlled common ragweed 76% to 99% (Price et al., 2002; Scott et al., 2001), which was better than control with sulfentrazone (Niekamp et al., 1999).

Field violet was controlled 96% to 100% with flumioxazin, oxyfluorfen, and sulfentrazone (Table 1). Control was 78% with isoxaben, 50% with halosulfuron, and 65% with simazine. Hoary alyssum control was 82% to 95% with flumioxazin, halosulfuron, and isoxaben. Sulfentrazone controlled hoary alyssum 80%, which was similar to control with flumioxazin and halosulfuron, while control with oxyfluorfen and simazine did not exceed 57%.

STUDY 2. Fraser fir visual injury rating did not exceed 6% with flumioxazin, isoxaben, oxyfluorfen,

Table 1. Fraser fir leader length and weed control 10 mo. after treatment in study 1. Herbicide treatments were applied Fall 2001 at Gobles and Hart, MI, and Fall 2002 at Hart, MI.[z]

Herbicide	Rate (lb/acre)[w]	Fraser fir leader length[x] (inches)[w]	Weed control (%)[y] Common ragweed	Field violet	Hoary alyssum
Flumioxazin	0.38	3.9	79	98	82
Halosulfuron	0.21	2.8	89	50	87
Isoxaben	1	2.8	72	78	95
Oxyfluorfen	1	2.8	51	100	39
Simazine	2	2.0	89	65	57
Sulfentrazone	0.5	2.0	31	96	80
Untreated control	—	2.8	—	—	—
LSD ($P \leq 0.05$)[v]		0.8	16	12	14

[z]Herbicides were applied 31 Oct. 2001 at Gobles and Hart, and 31 Oct. 2002 at Hart. Data were pooled over three experiments. Leader length and field violet control were evaluated in two trials, and common ragweed control was rated in all three experiments.

[y]Weed control was rated in July or early September each year, 0% = no plant response to 100% = complete death.

[x]Leader length was measured in September each year.

[w]1 lb/acre = 1.1209 $kg \cdot ha^{-1}$; 1 inch = 2.54 cm.

[v]Least significant difference.

simazine, or sulfentrazone (data not presented). All treatments had average leader lengths slightly shorter (6.7–7.5 inches) than the untreated controls (8.7 inches) (Table 2). However, only oxyfluorfen-treated trees had significantly shorter leaders (4.3 inches). The reason for reduced leader length with oxyfluorfen is not known, but weed competition may play a role. Hoary alyssum and common ragweed were not controlled well in the oxyfluorfen plots, but these were present in the untreated control plots also, and that treatment had the longest leader length. However, oxyfluorfen did control field violet greater than other treatments. Greater control of field violet may have permitted greater hoary alyssum populations and thus, more competition in oxyfluorfen plots.

Flumioxazin controlled common ragweed 80%; other treatments controlled it 11% to 54% (Table 2). Common ragweed control was generally lower in Study 2 than Study 1 and may be due to greater ragweed populations in Study 2 trial locations. White campion control was 37% to 64% with all herbicides (Table 2). Field violet was controlled 91% with oxyfluorfen, but control did not exceed 48% with other treatments. Hoary alyssum control was 92% with sulfentrazone and 85% with isoxaben, but did not exceed 55% with other treatments. Control of these weeds would be improved with utilization of a foliar contact herbicide in the fall or spring. Richardson and Zandstra (2005) reported good hoary alyssum control with fall applications of flumioxazin plus glyphosate or simazine plus oxyfluorfen.

STUDY 3. Colorado blue spruce had slight but statistically significant visual injury (5% and 6%) 6 MAT in 2003 and 2004 after treatment with flumioxazin plus pendimethalin (Table 3). No injury was visible 9 MAT in either year, and there was no reduction in leader length. Sulfentrazone plus pendimethalin resulted in 9% visual injury 6 MAT and 6% injury 9 MAT in 2003, and 23% and 52% injury 6 and 9 MAT in 2004. Injury symptoms with flumioxazin plus pendimethalin included needle discoloration and some needle abscission, but new growth during the summer following application was unaffected. Injury to dormant conifers from flumioxazin plus pendimethalin mixtures has not been reported previously. Injury symptoms from sulfentrazone plus pendimethalin were similar to flumioxazin plus pendimethalin injury, but were more severe in 2004 than in 2003. Injury from sulfentrazone plus pendimethalin in 2004 was obvious as the season progressed due to phytotoxicity to new growth. Leader length from this treatment (10.2 inches) was significantly less than the untreated controls (13.0 inches). Other treatments were similar to the untreated trees, with leader lengths of 12.6 to 14.6 inches. Foliar injury symptoms may be due to increased absorption of flumioxazin and sulfentrazone into colorado blue spruce needles as a result of application with the emulsifiable concentrate (EC) formulation of pendimethalin. The high sulfentrazone rate probably contributed to crop injury.

Annual grasses, primarily large crabgrass (*Digitaria sanguinalis*), were controlled 78% to 89% with all treatments containing pendimethalin (Table 3). Flumioxazin alone gave the least grass control at 53%. Common catsear control was 71% to 84% with all treatments except isoxaben plus pendimethalin at 68% and sulfentrazone plus pendimethalin at 40%. Horseweed control was 85% to 87% with flumioxazin and flumioxazin plus pendimethalin (Table 3). Control with other treatments was 48% to 70%. Virginia pepperweed control was 86% to 96% with flumioxazin, flumioxazin plus pendimethalin, and sulfentrazone plus pendimethalin. Control with other treatments was 53% to 68%. Kuhns and Harpster (2004) reported good control of horseweed, common ragweed, and virginia pepperweed in Christmas trees with flumioxazin.

STUDY 4. Colorado blue spruce injury at 1 MAT was 9% to 10% with flumioxazin plus pendimethalin and flumioxazin plus simazine plus pendimethalin (Table 4). At 3 MAT, injury was 7% with flumioxazin plus pendimethalin and only 2% with flumioxazin plus pendimethalin plus simazine. No injury was seen with other treatments at 1 or 3 MAT. None of the treatments resulted in leader lengths significantly shorter than the untreated control.

Common catsear control was 81% with flumioxazin plus pendimethalin, but only 57% to 60% with flumioxazin at 0.13 and 0.25 lb/acre (Table 4). Other treatments controlled common catsear 53% to 77%. None of the treatments provided sufficient dandelion control. Horseweed control did not exceed 69% with any treatment. Marginal control of weeds with all treatments may have been due to use of a glyphosate rate (0.37 lb/acre) too low to kill these emerged weeds.

In these studies, flumioxazin controlled several problematic weeds of Christmas trees, but gave inadequate control of white campion, dandelion, and horseweed. Fraser fir and colorado blue spruce tolerance to flumioxazin was commercially acceptable in all the trials. Phytotoxicity with tank mixes of flumioxazin

Table 2. Fraser fir leader length and weed control after spring preemergence herbicide applications in 2002 and 2003 in study 2.[z]

Herbicide	Rate (lb/acre)[x]	Fraser fir leader length[y] (inches)[x]	Weed control (%)[y] Common ragweed	Field violet	Hoary alyssum	White campion
Flumioxazin	0.38	7.5	80	48	43	64
Isoxaben	1	7.5	43	11	85	37
Oxyfluorfen	1	4.3	46	91	24	44
Simazine	2	6.7	54	46	55	37
Sulfentrazone	0.5	6.7	11	44	92	46
Untreated control	—	8.7	—	—	—	—
LSD ($P \leq 0.05$)[w]		2.4	17	17	17	10

[z]Herbicides were applied 10 Apr. 2002 and 24 Apr. 2003. Data were pooled over experiments. Fraser fir leader length and hoary alyssum, white campion, and field violet control were evaluated in two experiments; common ragweed control was rated in all three experiments.
[y]Weed control was rated in July or early September each year, 0% = no plant response to 100% = complete death. Leader length was measured in September each year.
[x]1 lb/acre = 1.1209 kg·ha^{-1}; 1 inch = 2.54 cm.
[w]Least significant difference.

Table 3. Colorado blue spruce injury and leader length, and weed control with herbicides applied 12 Nov. 2002 and 12 Nov. 2003 in study 3.[z]

Herbicide[v]	Rate (lb/acre)[u]	Colorado blue spruce Injury (%)[y] 6 MAT[x] 2003	6 MAT 2004	9 MAT 2003	9 MAT 2004	Leader length[w] (inches)[u]	Weed control (%)[y] Annual grasses	Common catsear	Horseweed	Virginia pepperweed
Flumioxazin	0.38	0	0	0	0	12.6	53	71	85	96
Flumioxazin plus pendimethalin	0.38 3	5	6	0	0	14.6	87	84	87	88
Isoxaben plus pendimethalin	1 3	0	1	0	0	12.6	78	68	48	68
Oxyfluorfen plus pendimethalin	1 3	0	1	0	0	13.0	81	76	70	68
Simazine plus pendimethalin	2 3	0	0	0	0	12.6	80	83	61	53
Sulfentrazone plus pendimethalin	0.5 3	9	23	6	52	10.2	89	40	58	86
Untreated control	—	—	—	—	—	13.0	—	—	—	—
LSD ($P \leq 0.05$)[t]		3	1	3	2	2.4	10	13	11	16

[z]Colorado blue spruce injury is presented by year due to a significant year interaction; other data are pooled over 2 years.
[y]Colorado blue spruce injury and weed control were rated 0% = no plant response to 100% = complete death.
[x]Months after treatment.
[w]Leader length was measured in September each year. Weed control was rated in August each year.
[v]Glyphosate at 0.37 lb/acre was applied as a directed application for partial control of emerged weeds before treatment application.
[u]1 lb/acre = 1.1209 $kg\cdot ha^{-1}$; 1 inch = 2.54 cm.
[t]Least significant difference.

Table 4. Evaluation of flumioxazin-based herbicide programs applied 6 May 2003 and 27 Apr. 2004 on colorado blue spruce injury and leader length, and weed control in study 4.

Herbicide[y]	Rate (lb/acre)[x]	Colorado blue spruce Injury (%)[z] 1 MAT[w]	3 MAT	Leader length[z] (inches)[x]	Weed control (%)[z] Common catsear	Dandelion	Horseweed
Flumioxazin	0.13	0	0	11.4	57	54	46
Flumioxazin	0.25	0	0	13.4	60	62	61
Flumioxazin	0.38	0	0	11.8	81	66	71
Flumioxazin plus pendimethalin	0.25 3	10	7	12.2	81	67	69
Flumioxazin plus *S*-metolachlor	0.25 1.2	0	0	13.0	76	67	68
Flumioxazin plus simazine	0.25 1.5	0	0	13.8	49	62	67
Flumioxazin plus simazine	0.13 1.5	0	0	13.8	53	60	55
Flumioxazin plus simazine plus pendimethalin	0.13 1.5 3	9	2	11.0	77	67	66
Simazine plus oxyfluorfen plus pendimethalin	1.5 0.5 +3	1	0	13.4	71	68	56
Untreated control	—	—	—	11.8	—	—	—
LSD ($P \leq 0.05$)[w]		1	1	2.0	14	7	15

[z]Colorado blue spruce injury and weed control was rated 0% = no plant response to 100% = complete death. Leader length was measured in September each year. Weeds were rated 28 Aug. 2003 and 10 Aug. 2004. All data are pooled over years.
[y]Glyphosate at 0.37 lb/acre was applied as a directed application for partial control of emerged weeds before treatment application.
[x]1 lb/acre = 1.1209 $kg\cdot ha^{-1}$; 1 inch = 2.54 cm.
[w]MAT = mo. after treatment, LSD = least significant difference.

plus the emulsifiable concentrate formulation of pendimethalin may be of concern. Other researchers have reported greater phytotoxicity to onions (*Allium cepa*) with tank mixtures of flumioxazin plus pendimethalin EC compared with flumioxazin plus the water-based formulation of pendimethalin (Zandstra and Ott, 2007). The petroleum solvent system probably increases the penetration and absorption of flumioxazin into foliage. Additional research should be conducted to compare crop safety with flumioxazin plus the EC or the water-based formulations of pendimethalin. An effective Christmas tree weed control program should include several residual herbicides that are safe on the tree species and that provide control of most of the target weeds.

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