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ABSTRACT

A 2-yr field study evaluated different preemergence herbicide treatments for weed control efficacy and tolerance of newly transplanted Canaan fir. Herbicide treatments consisted of two rates of each of Lumax at 2 and 4 qts/acre, Sureguard at 6 and 12 oz/acre, Westar at 5 and 10 oz/acre, Marengo at 3.75 and 7.5 floz/acre, and Princep 4L plus Surflan AS at 3 qt + 1.5 qt/acre and 3 qt + 3 qt/acre. All PRE treatments controlled giant foxtail, large crabgrass, and redroot pigweed at least 80% throughout the summer. Only the high rates of Lumax maintained >80% season-long control of yellow foxtail. Horseweed was controlled >85% with Sureguard at both rates and at high rates of Lumax, Westar, and Marengo. The season-long PRE control of both red sorrel and wild carrot was maintained ≥80% with Lumax and Sureguard regardless of application rate. No discernible injury was observed in Canaan fir with any PRE treatment in both study years.

INTRODUCTION

Preemergence (PRE) herbicides are the backbone of a successful weed management program in Christmas tree production. However, Christmas tree sensitivity to preemergence herbicides varies depending upon tree species, age of the transplant, growth stage, establishment year, herbicide chemistry, and such variables as rate, time, and method of application (Ahrens 2005; Ahrens 2007; Peachey et al 2017). For example, Douglas fir [*Pseudotsuga menzeisii* var. *menziesii* (Mirb.) Franco] is more sensitive to injury from oryzalin herbicide than most true firs, pines, and spruces. Tolerance of Colorado blue spruce (*Picea pungens* Engelm.), Douglas fir, true firs (*Abies* spp.), Fraser fir [*Abies fraseri* (Pursh) Poir], and white pine (*Pinus strobus* L.) to hexazinone plus sulfometuron methyl varied with the age of transplant and application rate (Ahrens and Mervosh 2000; Ahrens 2005; Ahrens and Newton 2008; Kuhns and Harpster 2005a; Weston et al. 2005). In Connecticut and Pennsylvania research trials, 4 yr or older transplants of Fraser fir and white pine tolerated hexazinone plus sulfometuron methyl up to 421 g ai ha^{-1} when applied over the top before bud break (Ahrens 2007; Ahrens and Mervosh 2000; Kuhns and Harpster 2003; Kuhns and Harpster 2005a; Rick et al 2005), whereas newly planted Christmas trees of diverse species and age groups tolerated flumioxazin up to 429 g ai ha^{-1} very well when it was applied over the top before bud break (Ahrens and Mervosh 2013; Kuhns and Harpster 2002; Kuhns and Harpster 2005b; Richardson and Zandstra 2009). In addition, flumioxazin controlled a broader spectrum of weed species for longer durations compared with the most widely used combinations of simazine and oryzalin or pendimethalin (Fausey 2003; Kuhns and Harpster 2005b).

Only a few PRE herbicides are registered for weed control in Christmas trees. Commonly used PRE herbicides in Christmas tree production control weeds by targeting only one or two sites of action. Selection pressure for herbicide resistance in plantation crops is increasing, mostly as a result of lack of herbicide rotation or mixing herbicides with different modes of action (Fausey 2003; Kuhns and Harpster 2005b; Sosnoskie and Hansen 2015). Currently in New England, common lambsquarters (*Chenopodium album* L.) and redroot pigweed are two widespread weed species with confirmed resistance to PS II inhibitors (Heap 2019). Some Christmas tree growers also suspect that PS II-resistant horseweed and common ragweed (*Ambrosia artemisiifolia* L.) are resistant to ALS-inhibitor herbicides. In addition, a major weed shift has happened toward biennial and perennial weed species that are naturally tolerant to many of the currently available PRE and POST herbicides. Example weed species include Asiatic dayflower (*Commelina communis* L.), European blackberry (*Rubus fruticosis* L.), common evening primrose (*Oenothera biennis* L.), field bindweed (*Convolvulus arvensis* L.), hedge bindweed (*Calystegia sepium* L.), horsenettle (*Solanum carolinense* L.), red sorrel (*Rumex acetosella* L.), wild carrot (*Daucus carota* L.), and many non-native invasive shrubs and woody vines (personal observation, 2016). In order to effectively deal with rising problems of herbicide-resistant weeds and weed species shift, Christmas tree growers throughout the Northeast and Midwest are looking for more robust and safer weed management options (Fausey 2003). Mixtures of herbicides with different sites of action have been recommended as one of the best management practices for reducing the risk for herbicide resistance as well as for broadening the weed control spectrum (Diggle et al. 2003). This publication reports the results of experiments involving different PRE herbicides applied alone or as mixtures for weed control efficacy and tolerance of Canaan fir.

MATERIALS AND METHODS

Experiments were conducted at a commercial Christmas tree farm in Hamden, CT during 2016 and 2017 on a silt loam (63% silt, 28% sand, 9% clay) with 2.5% organic matter, and 5.1 pH. Canaan fir trees 8- to 12-inch tall (plug + 2) were planted in the spring of 2016 at 5 feet spaced plants in 6 feet apart rows. Emerged weeds were controlled with a semi-directed application of Roundup Pro at 24 fl oz/acre using a single OC-2 nozzle at 20 GPA. Herbicide treatments consisted of combinations of four PRE herbicides and two application rates (Appendix1). Preemergence herbicides were applied before bud break with a compressed CO_2 backpack sprayer delivering 20 GPA through a single off-center flat-spray OC-2 nozzle in 2016 and with two 45-cm spaced Teejet 8002 nozzles in 2017. Herbicides were applied as a semi-directed application on April 19, 2016, and both sides of each row were sprayed, allowing herbicide contact with the lower 15 to 30 cm of all trees. In 2017, herbicides were applied over the top of trees on April 27, 2017. Weed control and Christmas tree injury were assessed visually at 4, 8, 12, and 16 wk after treatment (WAT) using a scale ranging from 0 (no control) to 100% (complete control) for weed control and a scale of 0 (no injury) to 10 (dead plant) for injury. Visual control estimates were based on chlorosis, necrosis, and stunting of the weeds compared with the weeds in the nontreated control plots. Injury estimates were based on chlorosis, necrosis, and stunting of the new growth of Christmas trees compared with the trees in the nontreated control plot. Weed species density was determined at 16 WAT by counting the number of weeds within two 0.5-m^2 quadrats randomly placed over the treated row. Christmas tree leader length was recorded at 16 WAT. Data were analyzed using the PROC GLIMMIX procedure in SAS. For weed control and density data, data were combined over the years after a nonsignificant F test for the experiment year.

RESULTS AND DISCUSSION

The mean weekly air temperature and cumulative weekly rainfall data indicated similar weather conditions during each experimental year. Mean weekly air temperatures from April to August were in the range of 9 to 23 C during each year and the cumulative rainfall from April through August was around 40 cm in both study years.

Canaan fir injury: None of the PRE herbicide treatments caused noticeable injury to Canaan fir in either study year. However, there were significant differences in leader length mainly because of a relatively slow growth rate in the transplanting year. The average leader lengths of Canaan fir were 4.5-inch and 12-inch in 2016 and 2017, respectively.

Large crabgrass control: The PRE herbicides differed significantly for large crabgrass control (Appendix 2). By mid-August (16 WAT), Lumax at both 2 and 4 qt/acre, Marengo SC at both 3.75 and 7.5 floz/acre, Sureguard at both 6 and 12 oz/acre, tank-mix of Princep 4L (3 qt/acre) plus Surflan AS (3 qt/acre), and Westar at both 5 and 10 oz/acre controlled large crabgrass at least 85%. Crabgrass control throughout the summer was excellent (>92%) with Lumax at both 2 and 4 qt/acre, Marengo at 7.5 floz/acre, Sureguard at 12 oz/acre, and Westar at 10 oz/acre.

Giant and yellow foxtail control: Two months following PRE application (8 WAT), both giant and green foxtails were controlled at least 80% (Appendix 2) with Lumax and Westar at any of the tested rates, flumioxazin at 12 floz/acre, Marengo at 7.5 floz/acre, and tank-mix of Princep 4L (3 qt/acre) plus Surflan AS (3 qt/acre). By mid-August (16 WAT), all PRE treatments except for Suregurad at 6 oz/acre, Westar at 5 oz/acre, Marengo at 3.75 floz/acre, and Princep 4L (3 qt/acre) plus Surflan AS (1.5 qt/acre) controlled giant foxtail at least 82%. Yellow foxtail control remained above 72% by mid-August with both rates of Lumax and Westar and Suregaurd at 12 floz/acre. With Marengo and tank-mixes of Princep 4L and Surflan AS yellow foxtail control was in 60 to 70% range.

Annual broadleaf weed control: Horseweed was controlled >85% throughout the summer with Lumax at 4 qt/acre, Sureguard at 6 oz/acre or higher, Marengo at 7.5 floz/acre and Westar at 10 oz/acre (Appendix 3). Lumax at 2 qt/acre and Westar at 5 oz/acre, and tank-mix of Princep 4L plus Surflan AS (3,366 + 3,366 g ai ha^{-1})

controlled horseweed at least 80% through 12 WAT, after which control was reduced to approximately 75%. With Marengo at 3.75 floz/acre, and tank-mix of Princep 4L (3qt/acre) plus Surflan AS (1.5 qt/acre), horseweed control was around 65% by mid-August (16 WAT). Redroot pigweed was controlled ≥90% from 4 through 12 WAT without significant differences in PRE treatments (Appendix 3). At 16 WAT, Lumax and Sureguard regardless of application rate, Marengo at 7.5 floz/acre, and Westar at 10 oz/acre controlled redroot pigweed ≥90% which was significantly more than 82% with tank-mixtures of Princep 4L (3 qt/acre) plus Surflan AS (1.5 qt/acre).

Biennial and perennial broadleaf weed control: Lumax and Westar, regardless of application rate, provided >80% preemergence control of red sorrel and wild carrot throughout the summer (Appendix 4). Sureguard had no effect on wild carrot, whereas preemergence control of red sorrel with Sureguard did not exceed 65%. With Marengo or tank-mixtures of Princep 4L plus Surflan AS, PRE control of red sorrel and wild carrot did not exceed 65% at any evaluation time.

SUMMARY

In this study, Canaan fir has demonstrated excellent levels of tolerance to all PRE treatments. Lumax or Westar, regardless of application rate, effectively controlled most of the weed species evaluated in this study. Marengo, Sureguard, and tank-mixtures of Princep 4L plus Surflan AS, regardless of application rate, were effective on horseweed, large crabgrass, and redroot pigweed, whereas the PRE control of green and yellow foxtails, red sorrel, and wild carrot was in the poor to fair range, depending upon the application rate. Lumax, the prepackaged mixture of atrazine plus mesotrione plus S-metolachlor, is currently not labeled for weed control in Christmas trees. Both Marengo and Sureguard has been found safe on most true firs, spruces, and pines grown in the northeast. Further research is required to evaluate Lumax for tolerance of other Christmas tree species.

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Appendix 1. Herbicides, products, and application rates of PRE herbicides used in the field study at Hamden, CT, during 2016 and 2017.

Herbicide name	Active ingredient (s)	Product/acre
Lumax	Atrazine + mesotrione + *S*-metolachlor	2 qts and 4 qts
Sureguard	Flumioxazin	6 oz and 12 oz
Westar	Hexazinone + sulfometuron methyl	5 oz and 10 oz
Marengo	Indaziflam	3.5 floz and 7.5 floz
Simazine + Oryzalin	Princep 4L + Oryzalin	3 qt + 1.5 qt and 3 qt + 3 qt

Appendix 2. Annual grass weed control with different PRE treatments at Hamden, CT.

Herbicide treatment	Product/acre	Large crabgrass				Giant foxtail			Yellow foxtail		
		4 WAT	8 WAT	12 WAT	16 WAT	8 WAT	12 WAT	16 WAT	8 WAT	12 WAT	16 WAT
Lumax	2 qt	99	95 ab	95 ab	90 ab	90 ab	85 a	82 ab	88 ab	80 ab	76 ab
Lumax	4 qt	99	98 a	95 ab	93 a	95 a	90 a	86 a	95 a	85 a	81 a
Sureguard	6 oz	99	95 ab	95 ab	92 ab	80 b	65 b	64 c	65 d	60 e	48 e
Sureguard	12 oz	99	99 a	95 ab	90 ab	90 ab	85 a	85 a	82 abc	70 cd	72 bc
Westar	5 oz	95	90 b	90 b	87 ab	88 ab	80 a	72 bc	85 abc	80 ab	74 ab
Westar	10 oz	98	95 ab	95 ab	94 a	92 ab	85 a	83 ab	95 a	80 ab	76 a
Marengo	3.75 floz	99	90 b	90 b	85 ab	85 ab	80 a	76 ab	72 cd	65 de	60 d
Marengo	7.5 floz	99	99 a	98 a	96 a	90 ab	85 a	84 a	80 bc	75 bc	62 cd
Princep 4L+ Surflan AS	3 qt + 1.5 qt	97	90 b	90 b	80 b	80 b	80 a	78 ab	75 bcd	70 cd	66 bcd
Princep 4L+ Surflan AS	3 qt + 3.0 qt	99	95 ab	95 ab	90 ab	85 ab	84 a	82 ab	80 bc	75 bc	71 bc

Abbreviations: WAT, weeks after treatment.
Means within a column followed by the same letter are not significantly different according to the "Adj = simulate" option in SAS

Appendix 3. Annual broadleaf weed control with different PRE treatments at Hamden, CT.

Herbicide treatment	Product/acre	Horseweed 4 WAT	8 WAT	12 WAT	16 WAT	Redroot pigweed 4 WAT	8 WAT	12 WAT	16 WAT
		%							
Lumax	2 qt	90 ab	85 ab	80 bc	74 c	95	95	90	90 ab
Lumax	4 qt	99 a	99 a	98 a	97 a	99	99	99	97 a
Sureguard	6 oz	99 a	98 a	96 a	91 a	99	99	95	92 ab
Sureguard	12 oz	99 a	99 a	98 a	93 a	99	99	97	95 a
Westar	5 oz	88 ab	80 b	80 bc	76 bc	95	90	90	88 ab
Westar	10 oz	99 a	99 a	97 a	95 a	99	99	98	98 a
Marengo	3.75 floz	70 c	65 c	58 d	56 d	93	90	90	88 ab
Marengo	7.5 floz	95 a	90 a	90 ab	87 ab	99	99	99	95 a
Princep 4L+ Surflan AS	3 qt + 1.5 qt	80 b	80 b	72 c	65 cd	97	95	90	82 b
Princep 4L+ Surflan AS	3 qt + 3.0 qt	90 ab	85 ab	81 bc	77 bc	99	99	98	88 ab

Abbreviations: WAT, weeks after treatment.
Means within a column followed by the same letter are not significantly different according to the “Adj = simulate” option in SAS

Appendix 4. Preemergence control of biennial and perennial broadleaf weeds with different PRE treatments at Hamden, CT.

Herbicide treatment	Product/acre	Red sorrel 4 WAT	8 WAT	12 WAT	16 WAT	Wild carrot 4 WAT	8 WAT	12 WAT	16 WAT
Lumax	2 qt	98 a	98 a	95 a	95 a	98 a	90 a	90 a	88 a
Lumax	4 qt	99 a	98 a	98 a	95 a	99 a	98 a	98 a	96 a
Sureguard	6 oz	60 b	40 b	31 c	28 bc	0 d	0 d	0 d	0 d
Sureguard	12 oz	65 b	60 b	50 b	39 b	0 d	0 d	0 d	0 d
Westar	5 oz	98 a	98 a	95 a	90 a	90 a	90 a	85 a	80 a
Westar	10 oz	99 a	95 a	95 a	95 a	99 a	97 a	95 a	95 a
Marengo	3.75 floz	55 b	47 b	33 bc	20 c	40 c	37 c	20 c	12 cd
Marengo	7.5 floz	65 b	60 b	44 b	25 bc	45 c	40 c	30 c	20 c
Princep 4L+ Surflan AS	3 qt + 1.5 qt	53 b	45 b	37 bc	22 bc	54 bc	49 bc	48 b	40 b
Princep 4L+ Surflan AS	3 qt + 3.0 qt	58 b	48 b	30 c	20 c	65 b	59 b	56 b	50 b

Abbreviations: WAT, weeks after treatment.
Means within a column followed by the same letter are not significantly different according to the “Adj = simulate” option in SAS