Testing Herbicides for Tree Safety and Efficacy in Conifer Nurseries

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Abstract

Weeds are a significant challenge in forest tree nurseries. Few herbicides are currently registered in conifer nurseries, with none providing complete weed control. Two trials were therefore conducted to generate data to support future herbicide registrations. In the first trial, 22 herbicide treatments were applied to freshly transplanted Douglas-fir (*Pseudotsuga menziesii* Mirb. Franco) seedlings. Weed control was initially excellent, but waned with some treatments 3 to 4 months after treatment. Douglas-fir foliar injury was excessively high with several treatments though seedlings had largely recovered by harvest, with most growth measurements not differing from nontreated Douglas-fir. In the second trial, 13 herbicide treatments were applied in July to yellow fieldcress (*Rorippa sylvestris* [L.] Besser), a particularly difficult perennial species to control in conifer nurseries, then all plots were late-winter fumigated followed by transplanting to Fraser fir (*Abies fraseri* [Pursh] Poir.) or noble for (*A. procera* Rehder) seedlings the following May. Only imazapyr gave acceptable initial control of yellow fieldcress, reducing weed cover from an average of 20 percent to 2 percent 2 months after treatment. Four months after planting (14 months after application), however, seedlings exhibited significant injury from soil-residual imazapyr. This paper was presented at the joint annual meeting of the Western Forest and Conservation Nursery Association and the Intermountain Container Seedling Growers' Association (Troutdale, OR, September 14–15, 2016).

Introduction

Weeds are a significant challenge in forest tree nurseries. Reduced growth due to weed competition results in tree seedlings of lower vigor and quality, and may result in an inability to meet customer expectations and thus the loss of business in future years. In addition, tree seedlings contaminated with certain weed species (such as yellow nutsedge [*Cyperus esculentus* L.]) may result in a quarantine that prevents certain lots from being sold at all. Many forest nurseries fumigate with methyl bromide to control soilborne disease pathogens, but fumigation provides only partial weed control and thus is usually augmented with herbicides followed by periodic hand weeding (Weiland et al. 2016).

Several herbicides are registered for use in conifer nursery plantations, including oxyfluorfen (Goal® and GoalTender®), napropamide (Devrinol®), s-metolachlor (Pennant Magnum®), dimethenamid-p (Tower®), prodiamine (Endurance®), and oxadiazon (Ronstar®) for preemergence control of broadleaf weeds, whereas fluazifop (Fusilade II®), sethoxydim (Segment™), and clethodim (Envoy Plus™) are postemergence herbicides for grass weed control (Peachey 2016). Additionally, glyphosate (Roundup®) is available for use prior to tree seedling germination or for postemergence wiper/spot treatment. Of the broadleaf control products, most provide only limited control of certain weed species; in particular, members of Caryophyllaceae and Brassicaceae tend to increase in regional forest tree nurseries. Testing of new herbicides, particularly those with differing modes of action, may successfully identify products suitable for future registration while delaying the onset of herbicide resistance.

A particular weed of concern is yellow fieldcress (*Rorippa sylvestris* [L.] Besser), a species described as being difficult to control in Swedish conifer nurseries (Barring 1986) (figure 1). It is a rhizomatous perennial weed known to be allelopathic to lettuce (Yamane et al. 1992), and probably other crops as

Figure 1. Yellow fieldcress in flower. This weed is particularly damaging problematic in forest tree nurseries. (Photo by Tim Miller, 2011)

Figure 2. Yellow fieldcress infesting a bed of Douglas-fir seedlings. (Photo by Tim Miller, 2011)

well. Herbicides have been tested in the United States to help manage the weed with only moderate success (Elmore 2000, Koster et al. 1997, Kuhns and Harpster 1998). This species exists in forest tree nurseries in Oregon (figure 2), as well as sites in Washington and southern British Columbia, and although it is not yet abundant in the region, obtaining control data is a wise course of action. Herbicide application timing and combination treatments may assist in managing this weed, particularly if used prior to seedbed fumigation.

Two trials were conducted to generate data to support future herbicide registrations in forest tree nurseries. The first trial evaluated several nonregistered herbicides for weed-control efficacy and Douglas-fir safety. The second trial examined control of yellow fieldcress during the fallow year prior to fumigation and the potential for injury of subsequently transplanted tree seedlings.

Materials and Methods

Herbicide Screening Trial

This trial was conducted at Weyerhaeuser's Aurora Forest Nursery near Aurora, OR (figure 3). Twenty-two herbicide treatments were applied at varying rates preemergence (PRE to weeds, but after tree transplanting) or postemergence (POST to weeds), as appropriate, to freshly transplanted Douglas-fir seedlings. Oxyfluorfen was included in the trial as the industry standard, as well as a nontreated control. PRE herbicides were applied to dormant tree seedlings on May 15, 2015 (4 days after transplanting, prior to onset of new growth), and POST herbicides were applied on June 15, 2015. A CO2-pressurized backpack sprayer equipped with a three-nozzle boom was used for all applications. Treatments were applied to 4-by-8 ft (1.2-by-2.4 m) plots (four per treatment).

Visual estimates of weed control and tree injury percentages were made on June 15, July 1, and September 9, 2015. Trees were lifted January 20, 2016, for growth analyses. Three trees in each plot were measured for fresh weight of shoots and roots, stem height, and stem diameter at the lowest branch. Trees were additionally checked for abnormalities (crooked stems, swellings at the soil line, etc.). The experimental design was a randomized complete block with four replicates. Analysis of variation (ANOVA) was performed using SAS 9.2, and means were separated using Tukey's Honestly Significant Difference (HSD) test ($P \leq 0.05$).

Yellow Fieldcress Trial

This trial was also conducted at Weyerhaeuser's Aurora Forest Nursery in an area infested with yellow fieldcress. Thirteen herbicide treatments, including a nontreated control, were applied in 8-by-8 ft (2.4-by-2.4 m) plots (four per treatment) on July 1, 2015, to 3-to-6 in (1.2-to-2.4 cm) tall yellow fieldcress. Imazapyr and sulfometuron treatments were mixed with methylated seed oil (MSO) at 0.25 percent (volume/volume) prior to application. Percent visual

Figure 3. Herbicide trial to evaluate several potential products for us in forest tree nurseries. (Photo by Tim Miller, 2011)

yellow fieldcress cover was estimated at the time of herbicide application and again on September 2, 2015.

Plots were tilled in fall 2015 and fumigated in spring 2016. In May 2016, two beds (consisting of two of the four replicates) were then transplanted with Fraser fir (*Abies fraseri* [Pursh] Poir.) seedlings, and two beds were transplanted with noble fir (*A. procera* Rehder) seedlings. Fraser and noble fir seedlings were evaluated for herbicide injury on September 7, 2016. Since plots contained no appreciable growth of yellow fieldcress on the date of evaluation, plots were only rated for common groundsel (*Senecio vulgaris* L.) control. The experimental design was a randomized complete block design with four replicates. ANOVA was performed using SAS 9.2, and means were separated using Tukey's HSD test ($P \leq 0.05$).

Results and Discussion

Herbicide Screening Trial

Douglas-fir injury due to PRE treatments was excessively high by June 15 (4 weeks after PRE treatment) for both rates of flazasulfuron, both rates of saflufenacil, the 9 pt/ac rate of oxyfluorfen plus penoxsulam, and pyroxasulfone at 1.25 oz/ac (table 1). Injury from these PRE products was still high through September 9 (12 weeks after PRE treatment), although seedlings in plots treated with flazasulfuron or pyroxasulfone showed substantial recovery compared with June observations. POST treatments with triclopyr caused up to 74 percent injury by July 1 (2 weeks after POST treatment), and seedlings did not appreciably recover by September 9 (8 weeks after POST treatment). All other PRE and POST treatments had relatively low damage and did not differ significantly from the nontreated control.

Primary weeds in the plots were common groundsel and annual bluegrass (*Poa annua* L.); some plots contained white clover (*Trifolium repens* L.) and annual sowthistle (*Sonchus oleraceus* L.). Weed control was good to excellent for most treatments, generally 85 percent or more through September 9 (table 1). Exceptions to good weed control were triclopyr at either rate, pyroxasulfone at 1.25 oz/ac, saflufenacil at either rate, or flazasulfuron at either rate.

Douglas-fir seedling biomass in most herbicide-treated plots was similar to trees in nontreated plots (table 2). Saflufenacil at 2 oz/ac (PRE) reduced stem diameter significantly, and other parameters nonsignificantly, compared to nontreated trees. Though not statistically significant, triclopyr at 5 pt/ac (POST) and isoxaben at 11 oz/ac (PRE) tended to reduce all measured parameters; oxyfluorfen plus penoxsulam at 9 pt/ac reduced root and shoot biomass; and saflufenacil at 1 oz/ac (PRE), triclopyr at 3 pt/ac (POST), and oxyfluorfen plus penoxsulam at 6 pt/ac (PRE) reduced shoot biomass.

Based on these data, herbicides offering excellent weed control and low injury potential to Douglas-fir seedlings include indaziflam at 5 oz/ac, dithiopyr at 12 fl oz/ac, isoxaben at 11 oz/ac, mesotrione at 7 fl

Table 1. Douglas-fir injury and weed control in a forest tree nursery after treatment with several herbicides (2015).

Chemical name	Trade name	Manufacturer	Rate (product/ac)	Timing[b]	Douglas-fir injury (%)			Weed control (%)		
					Jun 15	Jul 1	Sep 9	Jun 15	Jul 1	Sep 9
Dithiopyr	Dimension®	Dow	8 fl oz	PRE	0 d	0 f	1 f	95 b	88 abc	88 ab
Dithiopyr	Dimension®	Dow	12 fl oz	PRE	0 d	4 f	3 f	98 ab	85 bc	89 ab
Flazasulfuron[a]	Mission®	ISK	1 oz	PRE	63 ab	36 de	14 ef	99 ab	98 abc	79 abc
Flazasulfuron[a]	Mission®	ISK	2 oz	PRE	79 a	66 abc	29 def	99 ab	99 ab	80 abc
Indaziflam	Alion®	Bayer	3 fl oz	PRE	0 d	3 f	1 f	100 a	100 a	100 a
Indaziflam	Alion®	Bayer	5 fl oz	PRE	1 d	3 f	0 f	99 ab	98 abc	98 a
Isoxaben	Gallery®	Dow	8 oz	PRE	1 d	1 f	0 f	99 ab	95 abc	94 ab
Isoxaben	Gallery®	Dow	11 oz	PRE	3 d	3 f	0 f	98 ab	89 abc	91 ab
Oxyfluorfen	GoalTender®	Dow	3 pt	PRE	0 d	1 f	0 f	100 a	100 a	98 a
Oxyfluorfen	GoalTender®	Dow	6 pt	PRE	1 d	2 f	0 f	100 a	100 a	99 a
Oxyfluorfen + penoxsulam	Pindar™ GT	Dow	3 pt	PRE	1 d	0 f	3 f	100 a	100 a	99 a
Oxyfluorfen + penoxsulam	Pindar™ GT	Dow	4.5 pt	PRE	9 d	10 f	18 def	100 a	100 a	88 ab
Oxyfluorfen + penoxsulam	Pindar™ GT	Dow	6 pt	PRE	11 d	10 f	11 ef	100 a	100 a	96 a
Oxyfluorfen + penoxsulam	Pindar™ GT	Dow	9 pt	PRE	40 c	35 e	39 cde	100 a	100 a	85 abc
Pyroxasulfone	Zidua®	BASF	1.25 oz	PRE	71 a	50 cde	20 def	100 a	95 abc	84 abc
Saflufenacil	Treevix®	BASF	1 oz	PRE	51 bc	58 bcd	60 abc	99 ab	95 abc	68 bc
Saflufenacil	Treevix®	BASF	2 oz	PRE	66 ab	80 a	83 a	98 ab	89 abc	60 c
Mesotrione	Tenacity®	Syngenta	5 fl oz	POST	—	8 f	0 f	—	86 abc	94 ab
Mesotrione	Tenacity®	Syngenta	7 fl oz	POST	—	10 f	1 f	—	95 abc	91 ab
Triclopyr	Garlon 3A®	Dow	3 pt	POST	—	45 cde	44 bcd	—	84 c	75 abc
Triclopyr	Garlon 3A®	Dow	5 pt	POST	—	74 ab	70 ab	—	91 abc	83 abc
Nontreated	—	—	—	—	0 d	0 f	0 f	0 c	0 d	0 d

[a] Flazasulfuron treatments were mixed with nonionic surfactant at 0.25%, volume/volume prior to application.

[b] PRE = preemergence, applied May 15, 2015 (4 days after transplanting); POST = postemergence, applied June 15, 2015.

Notes: Means within a column followed by the same letter or with no letters are not statistically different ($P \leq 0.05$). 1 fl oz = 29.6 ml; 1 pint = 0.47 L.

oz/ac, and oxyfluorfen plus penoxsulam at 4.5 pt/ac. The industry-standard product oxyfluorfen at 6 pt/ac also provided excellent weed control with low crop injury. Flazasulfuron, saflufenacil, triclopyr, and pyroxasulfone may have potential for use in conifer nursery production for other tree species, or if applied prior to transplanting Douglas-fir seedlings.

Yellow Fieldcress Trial

Initial injury to yellow fieldcress was greatest with imazapyr alone or in tank mixtures (table 3). Weed cover was reduced from an average of 20 percent to 2 percent by September 9 (2 months after treatment) in plots treated with that herbicide. No other plots differed significantly from the nontreated control, although sulfometuron and triclopyr treatments showed a trend of reduced yellow fieldcress cover (table 3). Plots were tilled shortly after the September 2015 evaluation and were observed to be essentially weed-free on January 20, 2016 (data not shown).

Fraser and noble fir seedlings were sensitive to soil residuals of imazapyr at 14 months after treatment and 4 months after outplanting (table 3). Fraser fir was more sensitive (25 to 40 percent injury) than noble fir (15 to 26 percent injury), although both species sustained unacceptably high injury. Common groundsel was

Table 2. Douglas-fir tree measurements at time of lifting after treatment with several herbicides (2016).

Treatment	Trade name	Manufacturer	Rate (product/ac)	Timing [b]	Tree height[c] (cm)	Stem diameter[c] (mm)	Root biomass[c] (g)	Shoot biomass[c] (g)
Dithiopyr	Dimension®	Dow	8 fl oz	PRE	43.1 a	8 ab	34 abc	35 ab
Dithiopyr	Dimension®	Dow	12 fl oz	PRE	38.0 abc	8 ab	36 ab	31 abc
Flazasulfuron[a]	Mission®	ISK	1 oz	PRE	38.3 abc	8 ab	40 ab	24 a–f
Flazasulfuron[a]	Mission®	ISK	2 oz	PRE	31.8 abc	8 ab	20 abc	18 b–f
Indaziflam	Alion®	Bayer	3 fl oz	PRE	43.9 a	9 ab	42 a	39 a
Indaziflam	Alion®	Bayer	5 fl oz	PRE	41.0 abc	9 a	33 abc	31 a–d
Isoxaben	Gallery®	Dow	8 oz	PRE	39.9 abc	9 ab	28 abc	28 a–e
Isoxaben	Gallery®	Dow	11 oz	PRE	42.8 a	8 ab	19 abc	26 a–e
Oxyfluorfen	GoalTender®	Dow	3 pt	PRE	42.3 ab	8 ab	36 ab	33 abc
Oxyfluorfen	GoalTender®	Dow	6 pt	PRE	41.8 abc	8 ab	24 abc	27 a–e
Oxyfluorfen + penoxulam	Pindar™ GT	Dow	3 pt	PRE	37.7 abc	9 ab	26 abc	28 a–e
Oxyfluorfen + penoxulam	Pindar™ GT	Dow	4.5 pt	PRE	33.9 abc	8 ab	22 abc	26 a–e
Oxyfluorfen + penoxulam	Pindar™ GT	Dow	6 pt	PRE	31.0 abc	7 ab	17 abc	17 b–f
Oxyfluorfen + penoxulam	Pindar™ GT	Dow	9 pt	PRE	28.8 abc	7 ab	11 bc	17 b–f
Pyroxasulfone	Zidua®	BASF	1.25 oz	PRE	40.6 abc	8 ab	34 abc	26 a–e
Saflufenacil	Treevix®	BASF	1 oz	PRE	42.7 a	6 abc	13 abc	12 ef
Saflufenacil	Treevix®	BASF	2 oz	PRE	20.8 c	4 c	5 c	6 f
Mesotrione	Tenacity®	Syngenta	5 fl oz	POST	40.4 abc	8 ab	24 abc	26 a–e
Mesotrione	Tenacity®	Syngenta	7 fl oz	POST	44.3 a	8 ab	27 abc	30 a–e
Triclopyr	Garlon 3A®	Dow	3 pt	POST	24.9 abc	6 abc	16 abc	16 c–f
Triclopyr	Garlon 3A®	Dow	5 pt	POST	20.9 bc	6 bc	11 bc	12 def
Nontreated	—	—	—	—	36.0 abc	8 ab	25 abc	23 a–f

[a] Flazasulfuron treatments were mixed with nonionic surfactant at 0.25%, volume/volume prior to application.

[b] PRE = preemergence, applied May 15, 2015 (4 days after transplanting); POST = postemergence, applied June 15, 2015.

[c] Trees lifted January 20, 2016.

Notes: Means within a column followed by the same letter or with no letters are not statistically different ($P \leq 0.05$). 1 fl oz = 29.6 ml; 1 pint = 0.47 L.

found in most plots in September 2016, and control did not differ among treatments (data not shown). Because yellow fieldcress had been removed by hand-weeding crews, ultimate control of this species from herbicide treatment followed by fumigation was not estimable.

Based on these data, sulfometuron alone or in combination with glyphosate applied in the summer prior to soil fumigation is recommended for control of yellow fieldcress in forest tree nurseries. Although it provided excellent initial control of yellow fieldcress, imazapyr persisted in the soil and injured fir seedlings transplanted into treated soil. It is not known if other conifer species would be less sensitive to residual imazapyr.

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Table 3. Yellow fieldcress control in a forest tree nursery before and after application of several herbicides and percent injury to noble fir and Fraser fir (4 months after planting and 14 months after herbicide application).

Treatment[a]	Trade name	Manufacturer	Rate (product/ac)	Yellow fieldcress cover		Noble fir injury[b]	Fraser fir injury[b]
				Pre-treat (Jul 1) (%)	Sep 9, 2015 (%)	(%)	(%)
Glyphosate	Roundup Pro®	Monsanto	1 qt	25	70 a	0 c	0 c
Glyphosate	Roundup Pro®	Monsanto	2 qt	20	60 ab	0 c	0 c
Glyphosate	Roundup Pro®	Monsanto	3 qt	19	64 ab	0 c	0 c
Imazapyr	Arsenal®	BASF	3 pt	18	3 c	19 ab	20 b
Imazapyr	Arsenal®	BASF	6 pt	20	0 c	15 b	40 a
Sulfometuron	Oust® XP	Bayer	2 oz	18	23 bc	1 c	0 c
Sulfometuron	Oust® XP	Bayer	4 oz	15	14 c	0 c	0 c
Triclopyr	Garlon 3A®	Dow	1 gal	23	39 abc	1 c	0 c
Triclopyr	Garlon 3A®	Dow	2 gal	25	29 abc	0 c	0 c
Glyphosate + imazapyr	Roundup + Arsenal	—	1 qt + 6 pt	24	4 c	26 a	40 a
Glyphosate + imazapyr	Roundup + Arsenal	—	2 qt + 3 pt	18	0 c	19 ab	25 ab
Glyphosate + sulfometuron	Roundup + Oust	—	2 qt + 2 oz	21	26 bc	0 c	0 c
Nontreated	—		—	20	58 ab	0 c	0 c

[a] Treatments were applied July 1, 2015; Imazapyr and Sulfometuron treatments were mixed with methylated seed oil at 1%, volume/volume prior to application.

[b] Tree injury evaluated September 7, 2016.

Notes: Means within a column followed by the same letter or with no letters are not statistically different ($P \leq 0.05$). 1 fl oz = 29.6 ml; 1 pint = 0.47 L; 1 qt = 0.95 L.

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