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...
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 ≤ 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 1. Yellow fieldcress in flower. This weed is particularly damaging problematic in forest tree nurseries. (Photo by Tim Miller, 2011)](image1)

![Figure 2. Yellow fieldcress infesting a bed of Douglas-fir seedlings. (Photo by Tim Miller, 2011)](image2)
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 ≤ 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
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>
<thead>
<tr>
<th>Chemical name</th>
<th>Trade name</th>
<th>Manufacturer</th>
<th>Rate (product/ac)</th>
<th>Timing</th>
<th>Douglas-fir injury (%)</th>
<th>Weed control (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dithiopyr</td>
<td>Dimension® Dow</td>
<td>8 fl oz</td>
<td>PRE</td>
<td></td>
<td>0 d 0 f 1 f</td>
<td>95 b 88 abc 88 ab</td>
</tr>
<tr>
<td>Dithiopyr</td>
<td>Dimension® Dow</td>
<td>12 fl oz</td>
<td>PRE</td>
<td></td>
<td>0 d 4 f 3 f</td>
<td>98 ab 85 bc 89 ab</td>
</tr>
<tr>
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<td>PRE</td>
<td>63 ab</td>
<td>36 de 14 f</td>
<td>99 ab 98 abc 79 abc</td>
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<td>Mission® ISK</td>
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<td>66 abc 29 def</td>
<td>99 ab 99 ab 80 abc</td>
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<td>Alion® Bayer</td>
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<td>PRE</td>
<td>0 d</td>
<td>3 f 1 f</td>
<td>100 a 100 a 100 a</td>
</tr>
<tr>
<td>Indaziflam</td>
<td>Alion® Bayer</td>
<td>5 fl oz</td>
<td>PRE</td>
<td>1 d</td>
<td>3 f 0 f</td>
<td>99 ab 98 abc 98 a</td>
</tr>
<tr>
<td>Isoxaben</td>
<td>Gallery® Dow</td>
<td>8 oz</td>
<td>PRE</td>
<td>1 d</td>
<td>1 f 0 f</td>
<td>99 ab 95 abc 94 ab</td>
</tr>
<tr>
<td>Isoxaben</td>
<td>Gallery® Dow</td>
<td>11 oz</td>
<td>PRE</td>
<td>3 d</td>
<td>3 f 0 f</td>
<td>98 ab 89 abc 91 ab</td>
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<td>GoalTender® Dow</td>
<td>3 pt</td>
<td>PRE</td>
<td>0 d</td>
<td>1 f 0 f</td>
<td>100 a 100 a 98 a</td>
</tr>
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<td>Oxyfluorfen</td>
<td>GoalTender® Dow</td>
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<td>PRE</td>
<td>1 d</td>
<td>2 f 0 f</td>
<td>100 a 100 a 99 a</td>
</tr>
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<td>Oxyfluorfen + penoxsulam</td>
<td>Pindar™ GT Dow</td>
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<td>PRE</td>
<td>1 d</td>
<td>0 f</td>
<td>3 f</td>
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<td>PRE</td>
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<td>10 f</td>
<td>18 def</td>
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<td>Pindar™ GT Dow</td>
<td>6 pt</td>
<td>PRE</td>
<td>11 d</td>
<td>10 f</td>
<td>11 ef</td>
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<td>PRE</td>
<td>40 c</td>
<td>35 e</td>
<td>39 cde</td>
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<td>Pyroxasulfone</td>
<td>Zidua® BASF</td>
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<td>50 cde 20 def</td>
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<td>PRE</td>
<td>51 bc</td>
<td>58 bcd 60 abc</td>
<td>99 ab 95 abc 68 bc</td>
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<td>2 oz</td>
<td>PRE</td>
<td>66 ab</td>
<td>80 a 83 a</td>
<td>98 ab 89 abc 60 c</td>
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<tr>
<td>Mesotrione</td>
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<td>—</td>
<td>8 f</td>
<td>0 f</td>
</tr>
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<td>Mesotrione</td>
<td>Tenacity® Syngenta</td>
<td>7 fl oz</td>
<td>POST</td>
<td>—</td>
<td>10 f</td>
<td>1 f</td>
</tr>
<tr>
<td>Triclopyr</td>
<td>Garlon 3A® Dow</td>
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<td>POST</td>
<td>—</td>
<td>45 cde 44 bcd</td>
<td>84 c 75 abc</td>
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<td>Triclopyr</td>
<td>Garlon 3A® Dow</td>
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<td>POST</td>
<td>—</td>
<td>74 ab 70 ab</td>
<td>91 abc 83 abc</td>
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<td>—</td>
<td>—</td>
<td>—</td>
<td>0 d</td>
<td>0 f</td>
<td>0 f</td>
</tr>
</tbody>
</table>

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

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

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Trade name</th>
<th>Manufacturer</th>
<th>Rate (product/ac)</th>
<th>Timing</th>
<th>Tree height (cm)</th>
<th>Stem diameter (mm)</th>
<th>Root biomass (g)</th>
<th>Shoot biomass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dithiopyr</td>
<td>Dimension®</td>
<td>Dow</td>
<td>8 fl oz PRE</td>
<td>43.1 a</td>
<td>8 ab</td>
<td>34 abc</td>
<td>35 ab</td>
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<tr>
<td>Dithiopyr</td>
<td>Dimension®</td>
<td>Dow</td>
<td>12 fl oz PRE</td>
<td>38.0 abc</td>
<td>8 ab</td>
<td>36 ab</td>
<td>31 ab</td>
<td></td>
</tr>
<tr>
<td>Flazasulfuron</td>
<td>Mission®</td>
<td>ISK</td>
<td>1 oz PRE</td>
<td>38.3 abc</td>
<td>8 ab</td>
<td>40 ab</td>
<td>24 a–f</td>
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</tr>
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<td>Flazasulfuron</td>
<td>Mission®</td>
<td>ISK</td>
<td>2 oz PRE</td>
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<td>8 ab</td>
<td>20 abc</td>
<td>18 b–f</td>
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<tr>
<td>Indaziflam</td>
<td>Alion®</td>
<td>Bayer</td>
<td>3 fl oz PRE</td>
<td>43.9 a</td>
<td>9 ab</td>
<td>42 a</td>
<td>39 a</td>
<td></td>
</tr>
<tr>
<td>Indaziflam</td>
<td>Alion®</td>
<td>Bayer</td>
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<td>9 a</td>
<td>33 abc</td>
<td>31 a–d</td>
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<td>Dow</td>
<td>8 oz PRE</td>
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<td>9 ab</td>
<td>28 abc</td>
<td>28 a–e</td>
<td></td>
</tr>
<tr>
<td>Isoxaben</td>
<td>Gallery®</td>
<td>Dow</td>
<td>11 oz PRE</td>
<td>42.8 a</td>
<td>8 ab</td>
<td>19 abc</td>
<td>26 a–e</td>
<td></td>
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<td>Oxyfluorfen</td>
<td>GoalTender®</td>
<td>Dow</td>
<td>3 pt PRE</td>
<td>42.3 ab</td>
<td>8 ab</td>
<td>36 ab</td>
<td>33 abc</td>
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<td>Dow</td>
<td>6 pt PRE</td>
<td>41.8 abc</td>
<td>8 ab</td>
<td>24 abc</td>
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<td>BASF</td>
<td>2 oz PRE</td>
<td>20.8 c</td>
<td>4 c</td>
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<td>Syngenta</td>
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<td>40.4 abc</td>
<td>8 ab</td>
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<td>26 a–e</td>
<td></td>
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<tr>
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<td>Syngenta</td>
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<td>8 ab</td>
<td>27 abc</td>
<td>30 a–e</td>
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<td>Dow</td>
<td>3 pt POST</td>
<td>24.9 abc</td>
<td>6 ab</td>
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<td>16 c–f</td>
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<td>Triclopyr</td>
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<td>Dow</td>
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<td>20.9 bc</td>
<td>6 bc</td>
<td>11 bc</td>
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<tr>
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<td>—</td>
<td>—</td>
<td>36.0 abc</td>
<td>8 ab</td>
<td>25 abc</td>
<td>23 a–f</td>
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Notes: Means within a column followed by the same letter or with no letters are not statistically different (P ≤ 0.05). 1 fl oz = 29.6 ml; 1 pint = 0.47 L.

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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.
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).

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

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 ≤ 0.05). 1 fl oz = 29.6 ml; 1 pint = 0.47 L; 1 qt = 0.95 L.

REFERENCES


