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Asiatic dayflower (*Commelina communis*) control in Douglas fir

Jatinder S. Aulakh

Associate Weed Scientist, Connecticut Agricultural Experiment Station, Windsor, CT, USA

Research Article

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Author for correspondence:
Jatinder S. Aulakh, Connecticut Agricultural Experiment Station, Windsor, CT 06095.
(Email: Jatinder.Aulakh@ct.gov)

Abstract

Asiatic dayflower (*Commelina communis* L.) is becoming increasingly invasive in Christmas tree plantations in the U.S. Northeast. Response of *C. communis* to preemergence or postemergence herbicides was evaluated in separate field and greenhouse experiments. The preemergence herbicides consisted of two application rates of flumioxazin (215 and 429 g ai ha^{-1}), hexazinone plus sulfometuron-methyl (316 and 527 g ai ha^{-1}), indaziflam (41 and 82 g ai ha^{-1}), and *S*-metolachlor (2,136 and 4,272 g ai ha^{-1}). The postemergence herbicides were: bentazon at 1,121 g ai ha^{-1}, clopyralid at 280 g ae ha^{-1}, mesotrione at 526 g ai ha^{-1}, topramezone at 294 g ai ha^{-1}, and triclopyr at 842 g ae ha^{-1}. At 16 wk after treatment, higher rates of flumioxazin (429 g ha^{-1}), hexazinone plus sulfometuron-methyl (527 g ha^{-1}), indaziflam (82 g ha^{-1}), and *S*-metolachlor (4,272 ha^{-1}) provided 80% to 92% control and reduced *C. communis* plant density by 84% to 93% compared with the nontreated control. The lower rates of flumioxazin (215 g ha^{-1}), hexazinone plus sulfometuron-methyl (316 g ha^{-1}), and *S*-metolachlor (2,136 ha^{-1}) gave 65% to 72% control and reduced *C. communis* plant density by 27% to 75% compared with the nontreated control. The postemergence application of mesotrione at 526 g ha^{-1}, topramezone at 294 g ha^{-1}, and triclopyr at 842 g ha^{-1} resulted in 76% to 90% control and reduction in dry biomass of 10- to 12-leaf *C. communis* at 28 d after treatment. Bentazon at 1,121 g ha^{-1} and clopyralid at 280 g ha^{-1} applied postemergence were ineffective with <10% control and reduction in *C. communis* dry biomass. This study showed that *C. communis* can be managed effectively with currently registered preemergence and postemergence herbicides in Christmas trees.

Introduction

Asiatic dayflower (*Commelina communis* L.) is an annual, monocotyledonous, C_3 plant in the Commelinaceae family. It is native to northeastern Asia and widely distributed in the temperate zones of the world (Brashier 1966; Faden 1993). Worldwide, there are 40 genera and approximately 600 species in the Commelinaceae family. Several members in *Commelina* genus are troublesome weeds of cotton (*Gossypium hirsutum* L.), peanut (*Arachis hypogaea* L.), and soybean [*Glycine max* (L.) Merr.] in many countries, including the United States (Culpepper et al. 2004; Ulloa and Owen 2009; Webster et al. 2005, 2007). In northeast China, *C. communis* is ranked among the three most troublesome weeds in soybean fields, causing significant reduction in soybean yield and quality. In addition, the Commelinales are also reported as a major weed of apricots (*Prunus armeniaca* L.), bananas (*Musa* spp.), beans (*Phaseolus* spp.), coffee (*Coffea* spp.), oranges [*Citrus* × *sinensis* (L.) Osbeck (pro sp.) *maxima* × *reticulata*], lemons [*Citrus* × *limon* (L.) Burm. f. (pro sp.) *medica* × *aurantifolia*], grapes (*Vitis* spp.), sorghum [*Sorghum bicolor* (L.) Moench], and sugarcane (*Saccharum officinarum* L.) (Isaac et al. 2013).

In the United States, *C. communis* is present in at least 40 contiguous states (USDA 2022). It is very aggressive and has invaded many sites in the U.S. Northeast. It prefers moist, fertile soil but also grows well on roadsides and in non-crop areas. *Commelina communis* reproduces by seed and vegetatively through stem cuttings. It is mainly a self-pollinated plant; however, cross-pollination by insects has also been reported (Hardy et al. 2009). *Commelina communis* is becoming increasingly invasive in Christmas tree plantations (Ahrens and Mervosh 2002; Kuhns and Harpster 2002). It usually grows into the lower branches of Christmas trees but may ascend up into the tree using tree branches for support. *Commelina communis* may significantly reduce the growth of newly transplanted trees and disfigure the shape of established trees (Kuhns and Harpster 2002). It is a highly competitive and difficult to control weed, and few herbicides have provided consistent control (Ahrens and Mervosh 2002; Kuhns and Harpster 2002). Furthermore, members of the *Commelinaceae* are highly tolerant to glyphosate. For example, *C. communis*, spreading dayflower (*Commelina diffusa* Burm. f.), and tropical spiderwort (*Commelina benghalensis* L.) have escaped control with glyphosate in glyphosate-tolerant crop systems (Culpepper 2006; Fawcett 2002; Isaac et al. 2007; Tuffi-Santos et al. 2004; Ulloa and Owen 2009; Webster et al. 2005, 2007). Glyphosate tolerance is well documented in several species of the genus *Commelina* (Culpepper et al. 2004; Fawcett 2002; Flanders et al. 2001; Ulloa and

Management Implications

Commelina communis (Asiatic dayflower) is becoming increasingly invasive in Christmas tree plantations in the United States. The present study addressed *C. communis* management strategies involving preemergence or postemergence herbicides. Most preemergence herbicides found effective in this study, such as flumioxazin, indaziflam, and *S*-metolachlor, have already been labeled for weed control in Christmas tree plantations. Hexazinone plus sulfometuron-methyl (Westar®) has recently been de-commercialized, perhaps due to crop safety concerns, and is no longer available. Of the effective postemergence herbicides, only topramezone and triclopyr are registered for use in Christmas tree plantations. This study has clearly demonstrated that Christmas tree growers have a number of preemergence herbicide options for managing *C. communis* invasion. With respect to postemergence control, directed application of either triclopyr or topramezone at tested rates can also provide satisfactory *C. communis* control in the labeled Christmas tree species.

Owen 2009). The known mechanisms of tolerance in *Commelina* species include: reduced uptake due to thick epicuticular waxes, limited translocation, and rapid metabolism (Monquero et al. 2004; Tuffi-Santos et al. 2004). Most Christmas tree growers and ornamental plant producers have failed in selectively controlling *C. communis* (Ahrens and Mervosh 2002; Kuhns and Harpster 2002).

Weed management in Christmas trees largely relies on chemical herbicides. Several preemergence herbicides are registered for use in Christmas tree species such as balsam fir [*Abies balsamea* (L.) Mill. var. *balsamea*], canaan fir (*Abies balsamea* (L.) Mill. var. *phanerolepis* Fernald), Colorado blue spruce (*Picea pungens* Engelm.), Douglas fir [*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*], Fraser fir [*Abies fraseri* (Pursh) Poir.], Nordmann fir [*Abies nordmanniana* (Steven) Spach], Turkish fir [*Abies nordmanniana* subsp. *equi-trojani* (Asch. & Sint. ex Boiss.) Coode & Cullen], Norway spruce [*Picea abies* (L.) Karst.], and white pine (*Pinus strobus* L.). Commonly used preemergence chemistries include: atrazine, dimethenamid, flumioxazin, hexazinone plus sulfometuron-methyl, indaziflam, isoxaben, napropamide, oryzalin, oxadiazon, oxyfluorfen, pendimethalin, prodiamine, simazine, *S*-metolachlor, and trifluralin (Aulakh 2016, 2020). *Commelina communis* has been effectively controlled only by a limited number of preemergence herbicides. Ahrens and Mervosh (2003) found isoxaben ineffective on *C. communis*. They also observed that a simazine plus *S*-metolachlor (1,682 + 3,745 g ai ha^{-1}) tank mixture was effective in the early season, with 83% control of *C. communis* at 4 wk after treatment (WAT). However, control decreased to 60% by 16 WAT, indicating short residual activity of the tank mixture. Flumioxazin applied preemergence was highly effective until 12 WAT in balsam fir with 92% and 100% *C. communis* control at 280 and 561 g ai ha^{-1}, respectively (Ahrens and Mervosh 2002). In the same study, *S*-metolachlor applied preemergence at 3,813 g ai ha^{-1} controlled *C. communis* by 95%, whereas napropamide, oxadiazon, oxyfluorfen, and simazine gave <50% control. In a Pennsylvania study, Kuhns and Harpster (2002) obtained <60% control of *C. communis* 15 wk after preemergence application of flumioxazin at 426 g ai ha^{-1} in Douglas fir. Ulloa and Owen (2009) documented 58% control of *C. communis* by 6 WAT with flumioxazin at 110 g ai ha^{-1}.

Postemergence herbicides are used frequently for grassy weed control in Christmas tree plantations. There are limited chemical options for selective postemergence control of broadleaf weeds and sedges. Commonly used herbicides for postemergence broadleaf weed control in Christmas trees include: bentazon, clopyralid, glyphosate, oxyfluorfen, and triclopyr (Ahrens and Bennett 2011). Bentazon as an over-the-top application is safe on white pine. However, a fully directed application is recommended in other Christmas tree species. Clopyralid, a selective broadleaf herbicide usually safe on most Christmas trees, has sometimes resulted in temporary needle curling and leader twisting. Clopyralid controls a limited number of broadleaf weeds, and its efficacy also varies with weed size. Nonselective herbicides such as glyphosate and triclopyr are rarely used in actively growing Christmas trees because of high risk for tree injury. Occasionally, a fully directed or shielded application has resulted in tree injury. Both glyphosate and triclopyr are safe in dormant Christmas trees, including Douglas fir when applied as a semi-directed spray after hardening of new growth in the fall. Generally, most true firs and spruces are tolerant to semi-directed application of glyphosate or triclopyr around mid-September. Douglas fir and white pine are tolerant around the end of September. Topramezone and mesotrione are two Group 27 herbicides. These herbicides inhibit 4-hydroxyphenylpyruvate dioxygenase, a key enzyme in the biosynthesis of prenylquinones (e.g., plastoquinone) and tocopherols. This results in bleaching or whitening of susceptible plant species, due to oxidative degradation of chlorophyll and photosynthetic membranes, followed by necrosis and eventual plant death within 14 d (Grossmann and Ehrhardt 2007). Topramezone was recently registered for preemergence and postemergence control of many grassy and broadleaf weeds in Christmas trees (Anonymous 2022a). Mesotrione has been found to be safe on many Christmas trees, including Douglas fir, but is not yet available for weed control in a Christmas trees (Ahrens and Mervosh 2009; Anonymous 2022b).

There are limited postemergence herbicide efficacy results for *C. communis* control. The bentazon herbicide label indicates effectiveness on 15-cm-tall *Commelina* species, yet *C. communis* control was not satisfactory in the field trials (Fawcett 2002). Ahrens and Mervosh (2003) found clopyralid and oxyfluorfen ineffective on 2.5-cm-tall *C. communis* with less than 50% control. Kuhns and Harpster (2004) observed ≥80% *C. communis* control with cloransulam and imazaquin without any injury to Douglas fir. However, neither of these two herbicides is currently registered for use in Christmas tree plantations. A few studies addressed *C. communis* management strategies involving preemergence and/or postemergence herbicides, mainly in agronomic crops. To date, there is no published scientific research that compared efficacy of different preemergence or postemergence herbicides for *C. communis* control in Christmas trees. Therefore, a study was conducted for *C. communis* control in Douglas fir with the objective to evaluate response of *C. communis* to preemergence and postemergence herbicides commonly used for weed management in Christmas tree plantations.

Materials and Methods

Field Experiment

A field experiment was conducted at a commercial Christmas tree farm in Sheldon, CT (41°19.51.2N, 72°10.16.5W) in 2017 and

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Table 1. Preemergence herbicides used in the field study at Shelton, CT, during 2017 and 2018.

Common name	Trade name	Rate	Manufacturer
		—g ai ha^{-1}—	
1. Flumioxazin	Sureguard®	215	Valent U.S.A. Corporation, Walnut Creek, CA 94596-8025
		429	
2. Hexazinone + sulfometuron-methyl	Westar®	289 + 27	Bayer Environmental Science, Research Triangle Park, NC 27709
		480 + 47	
3. Indaziflam	Marengo®	41	Bayer Environmental Science
		82	
4. *S*-metolachlor	Pennant magnum®	2,136	Syngenta Crop Protection, Inc., Greensboro, NC 27
		4,372	

Table 2. Postemergence herbicides used in the greenhouse study at Windsor, CT, during 2021 and 2022.

Common name	Trade name	Rate	Manufacturer
		—g ai/ae ha^{-1}—	
1. Bentazon	Basagran® T&O	1,121	BASF Corporation, Research Triangle Park, NC 27709
2. Clopyralid	Stinger®	280	Corteva Agriscience LLC, Indianapolis, IN 46268
3. Mesotrione	Tenacity®	526	Syngenta Crop Protection, Inc., Greensboro, NC 27419-8300
4. Topramezone	Frequency®	294	BASF Corporation
5. Triclopyr	Garlon® 3A	842	Corteva Agriscience LLC

2018. The soil at the experiment site was a Hollis-Chatfield-Rock outcrop (loamy, mixed, superactive, mesic Lithic Dystrudepts), gravelly fine sandy loam with 63% sand, 29% sand, 8% clay, 2.5% organic matter, and pH 5.5. The experiment site was a mixed stand of Douglas fir plants of different ages. Douglas fir seedlings (2+1) were transplanted 150-cm apart in 180-cm-apart rows in the spring of 2011 and again in 2013. Therefore, trees varied in age from 6 to 8 yr. The experimental design was a randomized complete block with four replications. Each experimental unit (7.6 by 1.8 m) consisted of two rows of five Douglas fir plants each. The preemergence treatments consisted of factorial combinations of four preemergence herbicides and two application rates (Table 1). The preemergence treatments were applied before bud break, in a 90-cm band, with a compressed CO_2 backpack sprayer delivering 187 L ha^{-1} at 207 kPa and 3.5 kph through a single off-center flat-spray OC-2 nozzle (TeeJet® Technologies, Springfield, IL). Herbicides were applied as a semi-directed treatment allowing contact with the lower 20 to 30 cm of all trees. Both sides of each row and row middles were treated on April 18, 2017, and April 24, 2018. To control emerged *C. communis* and other weeds, glyphosate (Roundup Pro®, 841 g ae ha^{-1}; Bayer CropScience, St Louis, MO) was tank-mixed with all preemergence treatments without additional surfactant. The soil was moist, relative humidity was around 62%, and average air temperature was 16 C at the time of preemergence treatment application during both years. *Commelina communis* control and Christmas tree injury were assessed visually at 4, 8, 12, and 16 WAT using a scale ranging from 0% (no control) to 100% (complete control) for *C. communis* control and a scale of 0 (no injury) to 10 (dead plant) for injury. *Commelina communis* control estimates were based on chlorosis, necrosis, and stunting of *C. communis* compared with the nontreated control plots. Douglas fir injury estimates were based on chlorosis, necrosis, and stunting of the new growth compared with the trees in the nontreated control plots. *Commelina communis* plant density was determined at 4 and 16 WAT by counting the number of plants within two 0.5-m^2 quadrats randomly placed over the treated row. Douglas fir leader length was recorded at 16 WAT.

Greenhouse Experiment

Commelina communis response to the postemergence herbicides was evaluated in the greenhouse at the Connecticut Agricultural Experiment Station in Windsor, CT. *Commelina communis* plants were propagated vegetatively from 5-cm stem sections with 2-cm-long preset nodal roots, two partially expanded leaves, and an axillary leaf bud. Each stem section was transplanted in 10-cm-diameter plastic pots containing Sunshine® propagation mix no. 5 (Sun Gro Horticulture, Agawam, MA). The plants were supplied with water and nutrients and kept in a greenhouse maintained at a 32/27 C day/night temperature regimen with a 16-h photoperiod supplemented by overhead sodium-halide lamps. The study was conducted in a completely randomized design with five plants for each tested herbicide. The experiment was conducted twice in 2021 and 2022 under similar greenhouse conditions. *Commelina communis* plants were treated at the 10- to 12-leaf growth stage with postemergence herbicides at 5 wk after transplanting (Table 2). A nontreated control was included for comparison. Herbicide treatments were applied outside the greenhouse with a compressed CO_2 backpack sprayer through a single flat-fan spray nozzle AIXR 8002 (TeeJet®; Spraying Systems, Wheaton, IL) calibrated to deliver 187 L ha^{-1} spray volume at 207 kPa and 3.5 kph. Each herbicide treatment was prepared in distilled water. A crop oil concentrate (Agri-Dex®; Helena Chemical, Collierville, TN) was added at 1% vol/vol to bentazon solution and a nonionic surfactant (Induce®; Helena Chemical) at 0.25% vol/vol with all other herbicide treatments. Approximately 4 h after herbicide application, plants were moved back into the greenhouse. Visual estimates of *C. communis* control were recorded at 28 d after treatment (DAT) based on a scale of 0% (no control) to 100% (plant death). Plants were harvested at 28 DAT and oven-dried for 4 d at 65 C, after which aboveground dry weight was determined. The biomass data were converted into percent biomass reduction compared with the nontreated control (Wortman 2014) as shown in Equation 1:

$$\text{Biomass reduction } (\%) = \frac{(\bar{C} - B)}{\bar{C}} \times 100 \quad [1]$$

where $\bar{C}$ is the mean biomass of the nontreated control and B is the biomass of an individual treated plant.

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Table 3. *Commelina communis* control and plant density under different preemergence treatments at Shelton, CT.[a]

Herbicide	Rate	Control[b] 4 WAT	Control[b] 8 WAT	Control[b] 16 WAT	Plant density[b] 4 WAT	Plant density[b] 16 WAT
	—g ai ha^{-1}—	%			plants m^{-2}	
Nontreated		0	0	0	187 a	63 a
Flumioxazin	215	82 bc	77 bc	72 bc	27 de	19 c
Flumioxazin	429	95 ab	90 ab	88 a	13 de	9 de
Hexazinone + sulfometuron-methyl	289 + 27	85 abc	82 abc	70 bc	21 de	16 cd
Hexazinone + sulfometuron-methyl	480 + 47	98 a	97 a	92 a	5 e	4 e
Indaziflam	41	45 d	42 e	35 e	83 b	46 b
Indaziflam	82	85 abc	80 bc	80 ab	24 de	10 de
S-metolachlor	2,136	72 c	68 cd	65 c	41 cd	21 c
S-metolachlor	4,272	90 ab	86 ab	81 ab	14 de	9 de

[a]Abbreviation: WAT, weeks after treatment.
[b]Means averaged over 2 yr. Means within a column followed by the same letter are not significantly different according to the "Adj = simulate" option in SAS PROC. GLIMMIX at P = 0.05.

Statistical Analyses

Data were subjected to ANOVA using the PROC GLIMMIX procedure in SAS v. 9.4 (SAS Institute, Cary, NC). For *C. communis* preemergence control, *C. communis* plant density, and Douglas fir leader length data from the field experiment, year, herbicide, and application rate were treated as fixed effects, whereas replication and its interactions with fixed effect factors were considered as random effects. For *C. communis* postemergence control and dry biomass data from the greenhouse study, experiment year and herbicide were treated as fixed effects, whereas replication and its interactions with fixed effect factors were considered as random effects. When the year or experiment year main effects or interactions with fixed effect factors were not significant ($P > 0.05$), data were combined over the years. Residuals were analyzed individually for each variable using the UNIVARIATE procedure for normality, homogeneity of variance, and independence of errors. *Commelina communis* preemergence control data were arcsine square-root transformed to improve the normality and homogeneity of variance assumptions, but the nontransformed means are presented in the tables. *Commelina communis* plant density data were analyzed using a log-normal distribution function, and back-transformed means are reported. No data transformation was needed for Douglas fir leader length from the field experiment and *Commelina communis* postemergence control and dry biomass data from the greenhouse study. Multiple means comparisons of significant effects were made using the Adj = simulate option in SAS PROC GLIMMIX at the 5% significance level.

Results and Discussion

The mean weekly air temperature and cumulative weekly rainfall data, based on the nearest weather station (located in Hamden, CT, 18 km from the experiment site), indicated similar weather conditions during each experimental year. Mean weekly air temperatures from April to August were in the range of 8 to 24 C during each year. There was a significant variation in the seasonal amount and pattern of rainfall distribution between the two study years. The cumulative rainfall from April through August was around 38 cm in 2017 and 44 cm in 2018.

Field Experiment

Douglas Fir Injury

None of the preemergence herbicide treatments caused perceptible injury to Douglas fir in either study year. However, the year effect for leader length was significant ($P = 0.012$). Leader length was higher in 2018 because of a relatively favorable moisture regime due to higher and well-distributed rainfall compared with 2017. The average leader length of Douglas fir was 34- and 46-cm in 2017 and 2018, respectively. Previous researchers also reported no injury in balsam fir, Douglas fir, and Fraser fir with comparable rates of flumioxazin, hexazinone plus sulfometuron-methyl, indaziflam, and *S*-metolachlor (Ahrens 2007; Ahrens and Mervosh 2002, 2003, 2013; Kuhns and Harpster 2003).

Commelina communis Preemergence Control

The year effect was not significant ($P = 0.0627$). Therefore, *C. communis* preemergence control data were combined over years after a nonsignificant *F*-test. A herbicide by application rate interaction was highly significant at 4, 8, and 16 WAT ($P < 0.001$). This suggests that *C. communis* control varied with herbicide and application rate. At 4 WAT, *C. communis* control was similar with flumioxazin and hexazinone plus sulfometuron-methyl regardless of application rate, whereas indaziflam and *S*-metolachlor were effective at higher application rates tested in this study (Table 3). *Commelina communis* was controlled 82% to 98% with flumioxazin at ≥215 g ha^{-1}, hexazinone plus sulfometuron-methyl at ≥316 g ha^{-1}, indaziflam at 82 g ha^{-1}, and *S*-metolachlor at 4,272 ha^{-1}. With low rates of indaziflam (41 g ha^{-1}) and *S*-metolachlor (2,136 g ha^{-1}), control was 45% and 72%, respectively. Similar treatment differences were observed at 8 WAT with 77% to 97% *C. communis* control with all treatments, except with low rates of both indaziflam and *S*-metolachlor (Table 3). Ahrens and Mervosh (2002) reported >95% *C. communis* control at 8 WAT in balsam fir with flumioxazin (≥280 g ai ha^{-1}) and *S*-metolachlor plus simazine (4,261 plus 3,364 g ai ha^{-1}). In Georgia and North Carolina cotton fields, *C. benghalensis* was controlled >90% at 6 WAT with *S*-metolachlor preemergence at 1,070 g ai ha^{-1} (Webster et al. 2006). In the same study, flumioxazin preemergence at 72 g ai ha^{-1}, which was three to six times lower than flumioxazin rates tested in current study, gave 54% control of *C. communis*.

At 16 WAT, *C. communis* control differed with application rate even for flumioxazin and hexazinone plus sulfometuron-methyl (Table 3). The higher rates of flumioxazin (429 g ha^{-1}), hexazinone plus sulfometuron-methyl (527 g ha^{-1}), indaziflam (82 g ha^{-1}), and S-metolachlor (4,272 ha^{-1}) were similar, with 80% to 92% control, whereas, the lower rates of flumioxazin (215 g ha^{-1}), hexazinone plus sulfometuron-methyl (316 g ha^{-1}), and *S*-metolachlor

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(2,136 ha^{-1}) provided 65% to 72% control. *Commelina communis* control was the lowest (35%) with indaziflam at 41 g ha^{-1}. Results of this study are consistent with the findings of Ahrens and Mervosh (2002), who reported >95% control 16 WAT with preemergence application of flumioxazin at 280 g ai ha^{-1} and *S*-metolachlor at 4,261 g ai ha^{-1}. Furthermore, Ahrens and Mervosh (2002, 2003) documented ≥80% *C. communis* control at 12 WAT with sulfometuron-methyl preemergence at 27 g ai ha^{-1} in balsam fir and Fraser fir nursery beds. Sulfometuron-methyl rate (27 g ai ha^{-1}) in their study was similar to the sulfometuron-methyl rate in hexazinone plus sulfometuron-methyl at 316 g ha^{-1} used in the current study. In another study, *C. communis* was controlled only 57% with sulfometuron-methyl preemergence at 41 g ai ha^{-1} in a 1-yr-old Douglas fir plantation (Kuhns and Harpster 2002). Indaziflam efficacy on *C. communis* had not been reported before the present study.

Commelina communis Plant Density

A herbicide by application rate interaction was highly significant for *C. communis* plant density at 4 and 16 WAT ($P < 0.001$). Reduction in *C. communis* plant density at both evaluations closely followed the control data in the corresponding treatments. At 4 WAT, *C. communis* plant density in the nontreated control plots averaged 187 plants m^{-2} (Table 3). Hexazinone plus sulfometuron-methyl (527 g ha^{-1}) reduced *C. communis* plant density by 97% compared with the nontreated control. This was similar to >85% reduction with flumioxazin at both rates tested, hexazinone plus sulfometuron-methyl at 316 g ha^{-1}, indaziflam at 82 g ha^{-1}, and *S*-metolachlor at 4,272 g ha^{-1}. Indaziflam at 41 g ha^{-1} and *S*-metolachlor at 2,136 ha^{-1} reduced *C. communis* plant density by 56% and 78%, respectively. Previously, Ulloa and Owen (2009) reported 34% and 56% reduction at 6 WAT in *C. communis* plant density in soybean with preemergence application of flumioxazin at 110 g ai ha^{-1} and *S*-metolachlor at 2,140 g ai ha^{-1}. The flumioxazin rates in their study were two to four times lower than the flumioxazin rates tested in the current study, whereas the *S*-metolachlor rate in their study matched with the lower rates tested in the current study. Kuhns and Harpster (2004) also observed 75% to 92% reduction in *C. communis* plant cover by 9 WAT with flumioxazin applied preemergence at 280 g ai ha^{-1} and 560 g ai ha^{-1}. At 16 WAT, *C. communis* plant density averaged 63 plants m^{-2} in the nontreated control, probably due to inter- as well as intraspecific competition for resources. Flumioxazin at 429 g ha^{-1}, hexazinone plus sulfometuron-methyl at 527 g ha^{-1}, indaziflam at 82 g ha^{-1}, and *S*-metolachlor at 4,272 g ha^{-1} were similar, with 84% to 93% reduction compared with the nontreated control. Furthermore, flumioxazin at 215 g ha^{-1}, hexazinone plus sulfometuron-methyl at 316 g ha^{-1}, and *S*-metolachlor at 2,136 g ha^{-1} resulted in 66% to 75% reduction compared with the nontreated control. Indaziflam at 41 g ha^{-1} reduced *C. communis* plant density by only 27%.

Greenhouse Experiment

Commelina communis Postemergence Control

The year effect was not significant ($P = 0.1191$). Therefore, *C. communis* preemergence control data were combined over years. A herbicide main effect was significant ($P = 0.019$) for *C. communis* postemergence control. At 28 DAT, *C. communis* control was ≥85% with mesotrione at 526 g ha^{-1} and topramezone at 294 g ha^{-1}, which was higher than 76% control with triclopyr at 842 g ae ha^{-1} (Table 4). Both mesotrione and topramezone injury on *C. communis* progressed from growth retardation to bleaching of leaves and stems, eventually followed by necrosis or plant death, whereas the triclopyr herbicide injury symptoms comprised chlorosis, necrosis, curling of leaves and stems, and stunted growth. Both bentazon at 1,121 g ha^{-1} and clopyralid at 280 g ae ha^{-1} had little effect on *C. communis*. *Commelina communis* dry biomass data at 28 DAT conformed to the control estimates (Table 4). Efficacy of mesotrione, topramezone, and triclopyr in controlling *C. communis* was not known before this work. However, less than 50% control of 2.5-cm-tall *C. communis* was reported with clopyralid at 140 g ha^{-1} and oxyfluorfen at 561 g ai ha^{-1} in balsam fir and Douglas fir (Ahrens and Mervosh 2002; Kuhns and Harpster 2002). *Commelina communis* in those studies was only in the 2- to 3-leaf stage compared with the 10- to 12-leaf stage in the current study.

Table 4. *Commelina communis* control and dry biomass reduction 28 d after treatment under different postemergence herbicides.

Herbicide	Rate	Control	Biomass reduction[a]
	—g ai/ae ha^{-1}—	%[b]	
Bentazon	215	0	6 c
Clopyralid	429	0	0 c
Mesotrione	316	88 a	90 a
Topramezone	527	85 a	89 a
Triclopyr	841	76 b	78 b

[a]Percent biomass reduction was calculated using the following equation: Biomass reduction $(\%) = [(\bar{C} - B)/\bar{C}\} \times 100$, where $\bar{C}$ is the mean dry biomass of the nontreated control and B is the dry biomass of an individual treated plant.
[b]Means averaged over 2 yr. Means within a column followed by the same letter are not significantly different according to the “Adj = simulate” option in SAS PROC. GLIMMIX at $P = 0.05$.

Mesotrione over-the-top application at 280 g ai ha^{-1} was found to be safe on many actively growing Christmas tree species, including Douglas fir (Ahrens and Mervosh 2010). This was 2-fold less than the mesotrione rate used in the current study. Douglas fir is also listed as a tolerant Christmas species on the topramezone herbicide label, which allows directed application in several Christmas tree species (Anonymous 2022a). Triclopyr is a selective broadleaf herbicide for broadleaf weed control in Christmas tree row middles planted to desirable grasses (Ahrens and Bennett 2011). It is also used as fully directed spot treatment for controlling tough broadleaf weeds within the Christmas tree rows in the summer or as semi-directed treatment for controlling woody perennials in the fall (Ahrens and Bennett 2011).

In this study, *C. communis* was satisfactorily controlled with certain preemergence or postemergence treatments. For example, hexazinone plus sulfometuron-methyl at 527 g ha^{-1} was most effective throughout the season, with ≥92% *C. communis* control and plant density reduction. Flumioxazin at 429 g ha^{-1}, indaziflam at 82 g ha^{-1}, and *S*-metolachlor at 4,272 g ha^{-1}, all resulted in ≥80% control and almost similar reductions in plant density. With lower rates of flumioxazin (215 g ha^{-1}), hexazinone plus sulfometuron-methyl (316 g ha^{-1}), and *S*-metolachlor (2,136 g ha^{-1}), *C. communis* control and plant density reduction ranged from 65% to 72%. Indaziflam at 41 g ha^{-1} was ineffective (≤35% control) on *C. communis.* Of the postemergence herbicides, mesotrione at 526 g ha^{-1}, topramezone at 294 g ai ha^{-1}, and triclopyr at 842 g ae ha^{-1} controlled 10- to 12-leaf *C. communis* ≥ 76% at 14 DAT. This study has clearly demonstrated that Christmas tree growers have PRE as well as POST herbicide options for managing *C. communis* invasion without risk for injury to the labelled Christmas tree species.

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