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Small-seeded false flax (*Camelina microcarpa*) management in Oklahoma winter wheat

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Research Article

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Abstract

Three herbicide premixes have recently been introduced for weed control in wheat: halauxifen + florasulam, thifensulfuron + fluroxypyr, and bromoxynil + bicyclopyrone. The objective of this study was to evaluate these herbicides along with older products for their control of small-seeded false flax in winter wheat in Oklahoma. Studies took place during the 2017, 2018, and 2020 winter wheat growing seasons. Weed control was visually estimated every 2 wk throughout the growing season, and wheat yield was collected in all 3 yr. Small-seeded false flax diameter was approximately 6 cm at the time of application in all years. Control ranged from 96% to 99% following all treatments with the exception of bicyclopyrone + bromoxynil and dicamba alone, which controlled false flax 90%. All treatments containing an acetolactate synthase (ALS)–inhibiting herbicide achieved adequate control; therefore, resistance is not suspected in this population. Halauxifen + florasulam and thifensulfuron + fluroxypyr effectively controlled small-seeded false flax similarly to other standards recommended for broadleaf weed control in wheat in Oklahoma. Rotational use of these products allows producers flexibility in controlling small-seeded false flax and reduces the potential for development of herbicide resistance in this species.

Introduction

A native to Europe, small-seeded false flax, subsequently referred to as false flax, was first introduced to North America in the 19th century, likely as a contaminant in flax seed (*Linum usitatissimum* L.) and other crops (Francis and Warwick 2009). Since its introduction, it has been a common weed found in agricultural crops but has recently been considered as a potential oilseed crop (Francis and Warwick 2009; Royer and Dickinson 1999). Selective screening for ALS-resistant varieties has even been conducted for this purpose (Walsh et al. 2012). As a pest, it is most commonly found in cool-season crops such as winter wheat but also is found in field pea (*Pisum sativum* L.) and spring wheat in the northern United States and Canada (Francis and Warwick 2009). Though false flax has not been noted by producers in Oklahoma to be of high economic importance, it is still an undesired species competing on a wide geographical area.

False flax can look similar to horseweed [*Conyza canadensis* (L.) Cronq.], a weed that has a considerable impact on agriculture. Much like horseweed, false flax is a winter annual that develops a basal rosette covered in dense hairs. However, the leaves of this rosette are not lobed like horseweed. As false flax matures, it develops an erect stem that is either simple or branched. According to Francis and Warwick (2009), it can reach 1 m in height. Like many species in the Brassicaceae family, it has a raceme inflorescence with a terminal cluster of small, four-petaled, pale-yellow flowers (Francis and Warwick 2009). Once pollinated, these flowers develop into small, round siliques or "pods" with a persistent style (Francis and Warwick 2009). False flax is capable of producing almost 13,000 seeds per plant (Stevens 1957). False flax seeds present at harvest in grain cropping systems could lead to many consequences, including dockage at the elevator.

Other potential reasons for concern about false flax presence outside of crop competition include herbicide resistance and potential outcrossing with other mustard species. Through a whole-plant dose–response study, Hanson et al. (2004) confirmed ALS resistance to metsulfuron and chlorsulfuron occurring naturally in a false flax population in Oregon. This was the result of a single-point mutation within false flax that in other studies has resulted in resistance to four of the five chemical groups that make up the ALS site of action (Hanson et al. 2004; Tranel and Wright 2002). Because ALS-inhibiting herbicides are so commonly used in small grain-producing regions, the continued selection of herbicide-resistant biotypes is of great concern.

Table 1. Agronomic practices at Lahoma, OK, in 2016–2017, 2017–2018, and 2019–2020 winter wheat seasons.

Year	Wheat variety	Planting date	Herbicide application date	Harvest date	Total in-season rainfall[a] mm	30-yr average mm
2017	Endurance	October 14	March 9	June 12	452	634
2018	Spirit Rider	October 2	March 21	June 12	231	–
2020	Iba	October 23	March 21	June 21	363	–

[a]All rainfall data were collected from the Oklahoma Mesonet (www.mesonet.org).

Perhaps even more concerning is that the alleles that confer ALS resistance are dominant over the susceptible when exposure to an ALS-inhibiting herbicide occurs. According to Tranel and Wright (2002), even under heterozygous conditions, the resistant alleles are still selected for. Thus, the resistant alleles can spread through both seed and pollen (Tranel and Wright 2002). A close relative of false flax, known as gold of pleasure or largeseed false flax [*Camelina sativa* (L.) Crantz], can effectively cross-pollinate and produce seeds with false flax (Seguin-Swartz, et al. 2011). This species can also fertilize and produce viable seed with flat-seeded false flax [*Camelina alyssum* (Mill.) Thell]. Thus, if ALS resistance is not already present, these species can inherit this resistance from false flax (Seguin-Swartz, et al. 2011). Both of these species have been recorded in North America (Francis and Warwick 2009; Frankton and Mulligan 1987).

False flax management in grain-producing grass crops can be accomplished in several ways. Control of many broadleaf weeds in grass crops is achieved most commonly by the use of either ALS-inhibiting herbicides, synthetic auxin herbicides, or mixtures of the two sites of action; however, few studies have evaluated false flax response to various herbicides. If not resistant, Group 2 herbicides including metsulfuron and chlorsulfuron effectively control false flax. According to an extension fact sheet by Oklahoma State University, metsulfuron, imazamox, propoxycarbazone, sulfosulfuron, pyroxsulam, and premixes of halauxifen + florasulam, metsulfuron + chlorsulfuron, and thifensulfuron + fluroxypyr are all effective at controlling false flax that is not ALS resistant (Lofton et al. 2017). Other herbicide options include Group 4 herbicides like dicamba, MCPA, 2,4-D, or 4-hydroxyphenylpyruvate dioxygenase/photosystem II premixes of pyrasulfotole + bromoxynil or bicyclopyrone + bromoxynil (Lofton et al. 2017). False flax is a growing concern to Oklahoma winter wheat producers; thus, evaluation of its control with available products has become important. A primary objective of this study was therefore to determine the efficacy of several common herbicides for false flax management in winter wheat in Oklahoma.

Materials and Methods

Field experiments were conducted at Lahoma, OK (36.39° N, 98.11° W, elevation 380 m) during the 2016–2017, 2017–2018, and 2019–2020 winter wheat growing seasons (October to June). Field seasons are referred to as the year harvest occurred. All fields were planted using a grain drill with 19-cm row spacing. Soil was primarily composed of a Grant silt loam (fine-silty, mixed, superactive, thermic Udic Argiustolls). Lahoma received 452, 231, and 363 mm of rain during the 2017, 2018, and 2020 growing seasons, respectively. A normal 30-yr precipitation average for this location during the winter wheat growing season is 634 mm (Table 1) (Oklahoma Mesonet 2018).

All studies were arranged in a randomized complete block design with three to four replications. Individual plots were 2.1 m wide by 7.6 or 9.1 m in length. Herbicide applications were made using a CO_2-pressurized backpack sprayer calibrated to deliver 93 L ha^{-1}. All treatments were applied postemergence. Herbicides used consisted of three newer premixes labeled for use in wheat: Quelex® (halauxifen + florasulam), Sentrallas® (thifensulfuron + fluroxypyr), and Talinor® (bicyclopyrone + bromoxynil). Along with these, several other products labeled in wheat for broadleaf weed control were included for comparison purposes. All herbicide treatments were applied using water as the carrier except for two treatments that were also applied in 28% urea-ammonium nitrate (UAN). Treatments applied in UAN included haluxifen + florasulam alone or tank-mixed with MCPA. All treatments containing an ALS-inhibiting herbicide included a nonionic surfactant at 0.25% vol/vol in the spray mixture. It is also important to note that the bicyclopyrone + bromoxynil treatment should have included a crop oil concentrate at 1% vol/vol (Anonymous 2016), but it was inadvertently omitted in 2017. In 2018 and 2020, an additional treatment of bicyclopyrone + bromoxynil + crop oil concentrate was included. No increase in percent crop injury or weed control was recorded compared to the same treatment without crop oil (data not shown). Herbicides and application rates are listed in Table 2, and specific herbicide treatments are listed in Table 3. Fertilization and disease control were standard for grain-only wheat production in the southern Great Plains (Hunger and Marburger 2018; Raun and Zhang 2006).

Visual control estimates were recorded approximately every 2 wk beginning at 14 d after treatment up to 56 d after treatment using a scale of 0 to 100%, where 0 equals no weed control and 100% equals complete control. Wheat injury was also evaluated using a scale of 0 to 100, where 0 equals no injury and 100% equals wheat death. Regarding wheat growth stage, all herbicides were applied within the recommended timing per their label, and no injury was observed. Wheat was harvested with a Wintersteiger (Wintersteiger Inc., Salt Lake City, UT) small-plot combine on June 12, 2017, June 12, 2018, and June 21, 2020.

A univariate analysis was performed on all responses to test for stable variance (Version 9.4, SAS Institute Inc., SAS Campus Drive, NC). No data sets were transformed, as transformation did not increase stabilization. Data sets were analyzed using PROC MIXED with the pdmix 800 macro described by Saxton (1998) and treatments were separated by Fisher's Protected LSD at an alpha level of $P < 0.05$. In the model, fixed effects included year and herbicide treatment, and random effects included replication. False flax control and wheat yield estimates for 2017, 2018, and 2020 were averaged over years, as there was no significant year-by-treatment effect ($P > 0.05$).

Results and Discussion

Weed Control and Wheat Yield

Averaged across years, false flax control was 90% or greater for all treatments (Table 3). All treatments achieved 96% to 99% control of false flax, with the exception of bromoxynil + bicyclopyrone and

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Table 2. Common and trade names and manufacturer of herbicides used in experiments conducted during 2016–2017, 2017–2018, and 2019–2020 trials at Lahoma, OK.

Common name	Trade name	Manufacturer
2,4-D Ester	2, 4-D Ester LV 6	WinField United, St. Paul, MN, http://www.winfieldunited.com
Bicyclopyrone + bromoxynil	Talinor®	Syngenta Crop Protection, Greensboro, NC, http://www.syngenta.com
Dicamba	Banvel®	Arysta LifeScience, Cary, NC, https://www.arystalifescience.com/eng-us/global-products.html
Halauxifen + florasulam [a]	Quelex®	Corteva Agriscience, Indianapolis, IN, http://www.corteva.com
MCPA Ester	MCPA Ester 4	Albaugh, Ankeny, IA, https://www.albaughllc.com/
Metsulfuron	Ally XP®	DuPont, Wilmington, DE; http://www.dupont.com
Metsulfuron + chlorsulfuron	Finesse® Cereal and Fallow	FMC Agricultural Solutions, Philadelphia, PA, http://www.fmc.com
Pyroxsulam	PowerFlex HL®	Corteva Agriscience, Indianapolis, IN
Thifensulfuron + fluroxypyr	Sentrallas®	FMC Agricultural Solutions

[a]Nonionic surfactant at 0.25% vol/vol was included with all treatments that contained an acetolactate synthase herbicide.

Table 3. Control of small-seeded false flax following application of various herbicide treatments. Treatments were applied to small-seeded false flax of 6 cm diam. Wheat yield for each treatment regimen is also shown. Evaluation was conducted 7–8 wk after application near Lahoma, OK, during the 2016–2017, 2017–2018, and 2019–2020 winter wheat growing seasons.

Herbicide treatment [a]	Rate	Control [b], [c]	Wheat yield
	g ha^{-1}	%	kg ha^{-1}
Nontreated	–	–	2,440
2,4-D	524	99 a	2,260
Bromoxynil + bicyclopyrone	233 + 48	90 b	2,430
Dicamba	140	90 b	2,190
Chlorsulfuron + metsulfuron + dicamba + NIS [d]	17.3 + 3.5 + 140	99 a	2,500
Chlorsulfuron + metsulfuron + MCPA + NIS	17.3 + 3.5 + 560	99 a	2,380
Halauxifen + florasulam + NIS	5.25 + 5.25	96 a	2,410
Halauxifen + florasulam + NIS + 28% UAN [e]	5.25 + 5.25	97 a	2,440
Halauxifen + florasulam + 2,4-D + NIS	5.25 + 5.25 + 280	99 a	2,330
Halauxifen + florasulam + dicamba + NIS	5.25 + 5.25 + 70	97 a	2,270
Halauxifen + florasulam + MCPA + NIS + 28% UAN	5.25 + 5.25 + 350	99 a	2,600
Halauxifen + florasulam + MCPA + NIS	5.25 + 5.25 + 350	99 a	2,280
Halauxifen + florasulam + pyroxsulam + NIS	5.25 + 5.25 + 18.4	99 a	2,820
Metsulfuron + 2,4-D + NIS	4.2 + 280	99 a	2,220
Metsulfuron + dicamba + NIS	4.2 + 70	98 a	2,290
Thifensulfuron + fluroxypyr + dicamba + NIS	22 + 114 + 140	97 a	2,410
Thifensulfuron + fluroxypyr + MCPA + NIS	22 + 114 + 560	99 a	2,360
P value	–	0.003	0.99

[a]Abbreviations: NIS, nonionic surfactant; UAN, urea–ammonium nitrate.
[b]Control and wheat yield averaged over 2016–2017, 2017–2018, and 2019–2020 growing seasons.
[c]Means within a column followed by a common letter were similar according to Fisher's Protected LSD at $P < 0.05$.
[d]NIS at 0.25% vol/vol was included with all acetolactate synthase herbicides.
[e]UAN (28%) was used as the sole carrier for treatments having UAN listed as a component. For all other treatments, water was used as the carrier.

dicamba alone, which resulted in the lowest control (90%). Herbicide treatment, averaged across years, did not affect grain yield (Table 3). The average yield across all years and treatments was 2,390 kg ha^{-1}. Record yields were recorded across Oklahoma in 2020 as a result of timely rains. Similar trends were observed in the Oklahoma State Wheat Variety Trials conducted at Lahoma in 2017, 2018, and 2020; however, weed-free conditions in those trials meant that yields were higher than those observed in this study. The mean yield across varieties tested in the variety trials at Lahoma was 3,970, 2,150, and 6,050 kg ha^{-1} in 2017, 2018, and 2020, respectively, with an average yield across all 3 yr of 4,060 kg ha^{-1} (Oklahoma State University 2021). Although false flax may not have had a significant influence on wheat yield in our study, interest by producers in controlling this species is still likely due to other economic impacts. Examples of these include dockage at the elevator, green material at harvest leading to mold, or impacts on rotation options, especially soybean [*Glycine max* (L.) Merr.] or sorghum [*Sorghum bicolor* (L.) Moench] following wheat in double-crop systems.

A major benefit from the relatively high level of false flax control provided by all herbicide treatments is that producers battling false flax have several options. They also have options with a relatively wide range in price, as 2,4-D alone, for example, can cost less than US$5 ha^{-1} for the herbicide. The high efficacy of the treatments tested allows winter wheat producers the opportunity to rotate through herbicides with multiple sites of action to control false flax and thus reduce the potential to select for herbicide resistance in this species. Additionally, because of the high efficacy of all treatments containing an ALS-inhibiting herbicide, herbicide resistance is not suspected in this population, in contrast to what Hanson et al. (2004) found in a population in Oregon.

As there has been little work done on the management of false flax, it is necessary to compare studies performed on similar species. A study in wheat by Geier et al. (2011) found that pyroxsulam at 18 g ai ha^{-1} was 95% effective at controlling blue mustard [*Chorispora tenella* (Pall.) DC] at the fall postemergence timing; however, control was lowered to 77% at the spring postemergence timing. The use of bromoxynil + bicyclopyrone has not been

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recorded in the literature on any mustard species; however, volunteer canola (*Brassica napus* L.), field pennycress (*Thlaspi arvense* L.), flixweed [*Descurainia sophia* (L.) Webb ex Prantl.], London rocket (*Sisymbrium irio* L.), blue mustard, tumble mustard (*Sisymbrium altissimum* L.), wild mustard (*Sinapsis arvensis* L.), shepherd's-purse [*Capsella bursa-pastoris* (L.) Medik], and tansymustard [*Descurainia pinnata* (Walter) Britton] are all listed as controlled by the highest rate on the product label (Anonymous 2018). Similar mustard plant species are listed as controlled when the highest labeled rate of thifensulfuron + fluroxypyr is applied (Anonymous 2015–2016). The label for bromoxynil + bicyclopyrone also lists horseweed (rosettes < 8 cm) as a controlled species when the highest rate is applied, but in a previous study evaluating similar treatments, bromoxynil + bicyclopyrone performed poorly on horseweed (Crose et al. 2019). Although bicyclopyrone + bromoxynil did not perform as poorly on small-seeded false flax as was observed in the Crose et al. (2019) horseweed study, it was in the group of lower performing treatments in this study.

Relative to other options previously available to producers in Oklahoma for control of false flax, halauxifen + florasulam and thifensulfuron + fluroxypyr provided similar control of this species. Although the efficacy of these herbicides on false flax is now known, further work looking specifically at control of other mustard species and economically important broadleaves using these newer products is needed to offer best management practices to Oklahoma wheat growers.

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