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Efficacy of pyroxasulfone + encapsulated saflufenacil applied preemergence with partner herbicides for weed control in corn

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Research Article

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Abstract

A new encapsulated saflufenacil formulation has been developed and premixed as a single product with pyroxasulfone to provide control of small-seeded annual grass and broadleaf weeds and to extend the application window to early postemergence when applied to field corn. Pyroxasulfone + encapsulated saflufenacil applied preemergence alone and in mixtures with other herbicides were examined for crop response and weed control efficacy. We hypothesized that applying pyroxasulfone + encapsulated saflufenacil with a tank-mix partner would expand the spectrum of weed species that can be controlled and improve overall weed control efficacy compared to pyroxasulfone + encapsulated saflufenacil applied alone. Six field experiments were completed at three locations in southwestern Ontario in 2022 and 2023. Pyroxasulfone + encapsulated saflufenacil was applied alone, at 146 g ai ha^{-1} (pyroxasulfone 90 g ai ha^{-1}, saflufenacil 56 g ai ha^{-1}) or 245 g ai ha^{-1} (pyroxasulfone 150, saflufenacil 95 g ai ha^{-1}), and with the following herbicide partners: atrazine, dicamba, or mesotrione + atrazine. All herbicide treatments were applied prior to corn and weed emergence. Weed control, density and biomass, and corn injury and yield were assessed. All pyroxasulfone + encapsulated saflufenacil treatments caused no injury to corn. At 8 wk after emergence (WAE) pyroxasulfone + encapsulated saflufenacil (245 g ai ha^{-1}) controlled common lambsquarters, redroot pigweed, and foxtail species by 42%, 59%, and 41%, respectively. Applications of pyroxasulfone + encapsulated saflufenacil (146 or 245 g ai ha^{-1}) with dicamba or mesotrione + atrazine improved common lambsquarters and redroot pigweed control at 8 WAE compared with pyroxasulfone + encapsulated saflufenacil applied alone. Pyroxasulfone + encapsulated saflufenacil (146 or 245 g ai ha^{-1}) applied with dicamba or mesotrione + atrazine provided similar control of common lambsquarters, redroot pigweed, and foxtail species to that of *S*-metolachlor/atrazine/mesotrione/bicyclopyrone, which is a standard herbicide used to control these weeds. Corn yield for all pyroxasulfone + encapsulated saflufenacil herbicide mixtures was similar to that of the weed-free control and the standard herbicide.

Introduction

In the United States and Canada, approximately 38.1 and 1.5 million ha, respectively, of field corn was planted in 2023 (Statistics Canada 2023; USDA-NASS 2023). A meta-analysis reported that if North American corn producers did not implement any weed management tactics, a 50% yield loss would result (Soltani et al. 2016). Herbicides are the primary strategy used to minimize corn yield loss due to weed interference (USDA-NASS 2022). A new formulation of pyroxasulfone + encapsulated saflufenacil was evaluated for weed management in corn. This preformulated mixture combines pyroxasulfone, a Group 15 herbicide that inhibits very-long-chain fatty acid elongases (VLCFAE), and saflufenacil, a Group 14 herbicide that inhibits protoporphyrinogen oxidase (PPO) (Shaner 2014). (Herbicide groups are categorized by the Herbicide Resistance Action Committee and Weed Science Society of America.) The encapsulation of saflufenacil restricts herbicidal activity until the polymer coating has deteriorated (Armel et al. 2003); consequently, saflufenacil provides primarily residual control rather than control of emerged weeds at the time of application. Moisture is required for the polymer coating to break down and for the herbicide to dissolve in soil water solution so that it can be taken up by the developing weed seedlings (OMAFRA 2021; Yamaji et al. 2014). The efficacy of pyroxasulfone also relies on precipitation and is maximized with more than 12.5 mm of rain or irrigation within 7 d of application and is reduced by 26% when the soil receives less than 6.25 mm (Yamaji et al. 2016). Many Group 14 and Group 15 herbicide combinations include either pyroxasulfone or saflufenacil; these include pyroxasulfone/

Table 1. Year; location; soil characteristics; corn hybrid; planting, emergence, and harvest dates; and herbicide application dates.[a]

		Soil characteristics				Crop information				Herbicide application date
Year	Location	Texture	OM	pH	CEC	Hybrid	Planting date	Emergence date	Harvest date	
			%							
2022	Ridgetown Campus (A)	Sandy loam	2.9	7.4	8.4	DKC39-97RIB	May 11	May 17	November 4	May 12
	Ridgetown Campus (B)	Clay loam	4.1	7.2	18.0	DKC39-97RIB	May 13	May 23	November 2	May 16
	BASF Research Farm	Loam	2.9	6.6	13.5	DKC48-56RIB	June 14	June 21	November 10	June 16
2023	Ridgetown Campus (A)	Sandy clay loam	4.3	6.6	10.8	DKC39-97RIB	May 11	May 19	October 24	May 12
	Ridgetown Campus (B)	Clay loam	4.9	6.7	15.2	DKC39-97RIB	May 16	May 25	October 25	May 18
	BASF Research Farm	Loam	2.8	7.2	9.6	DKC48-56RIB	May 25	June 2	November 14	May 26

[a]Abbreviations: CEC, cation exchange capacity. OM, organic matter.

carfentrazone, pyroxasulfone/sulfentrazone, and dimethenamid-p/saflufenacil, however the combination of pyroxasulfone + encapsulated saflufenacil is a new product (OMAFRA 2021). Pyroxasulfone primarily controls small-seeded grass weeds and some small-seeded broadleaf weeds (Anonymous 2022b; OMAFRA 2021; Yamaji et al., 2014), whereas saflufenacil provides control of many annual broadleaf weeds (Anonymous 2022a; OMAFRA 2021). Mixtures of herbicides with different modes of action benefit growers by reducing the number of herbicide applications that need to be applied, thereby delaying resistance evolution and controlling a broader spectrum of weed species (Beckie and Reboud 2009; Cloyd [date unknown]). The preformulated mixture of pyroxasulfone + encapsulated saflufenacil was co-applied with atrazine (Group 5), dicamba (Group 4), or mesotrione + atrazine (Groups 27 and 5, respectively) to increase the spectrum of weeds controlled.

Limited research has been conducted on the pyroxasulfone + encapsulated saflufenacil formulation when applied to corn either before or after emergence, and either alone or with a tank-mix partner. Thus, the objective of this study was to determine the effect of pyroxasulfone + encapsulated saflufenacil applied preemergence alone and in combination with atrazine, dicamba, or mesotrione + atrazine. Parameters evaluated included corn injury, corn yield, and weed control efficacy.

Materials and Methods

In 2022 and 2023, six field trials were completed at three locations. Two locations were at the University of Guelph Ridgetown Campus, in Ridgetown, Ontario, and one location at the BASF Research Farm near Belmont, Ontario. Trials consisted of 14 treatments; each treatment occupying a 2-m by 8-m plot and replicated four times in a randomized complete block design. Conventional tillage practices were implemented and consisted of chisel ploughing the previous fall and s-tine cultivation in the spring prior to planting. Fertilizer was applied as recommended by the Ontario Ministry of Agriculture, Food and Rural Affairs based on soil tests. Corn was planted in rows spaced 75 cm apart at a rate of approximately 80,000 seeds ha^{-1} to a depth of 5 cm. Table 1 contains additional soil and crop information. Herbicides were applied after the crop was planted and before either the crop or weeds emerged using a CO_2-powered backpack sprayer that was calibrated to deliver 200 L ha^{-1}. Pyroxasulfone + encapsulated saflufenacil was applied alone, at 146 or 245 g ai ha^{-1}, and with the following herbicide partners: atrazine, dicamba, or mesotrione + atrazine. The weed-free control treatment had an application of a preemergence residual herbicide followed by a postemergence application of glyphosate followed by hand weeding.

Data assessment included visible corn injury, visible weed control, weed density, weed biomass, and corn yield. Corn injury was assessed at 1, 2, and 4 wk after emergence (WAE), and weed control evaluations were completed at 4 and 8 WAE. Weed density and weed biomass data were collected at 8 WAE. Visible corn injury and weed control are based on a 0% to 100% scale, where 0% represents no visible symptoms and 100% represents complete plant death. Weed density and biomass data were collected from two 0.25-m^2 quadrat at random locations in each plot, counting the number of each weed species within each quadrat, cutting the weeds at the soil surface, placing them in paper bags separated by species, drying in a kiln until a constant moisture, and then weighing. Weed species evaluated included natural populations of common lambsquarters, redroot pigweed, and foxtail species. Corn was combined at harvest maturity with a mechanical plot combine, and corn weight and moisture content were recorded. Corn yield was adjusted yield to 15.5% moisture prior to statistical analysis.

Statistical analysis was completed using the GLIMMIX procedure, a mixed model analysis of variance, using SAS software (v.9.4; SAS Institute Inc., Cary, NC). Data from the 2022 and 2023 sites were combined for analysis (Tables 1–5). The fixed effect was herbicide treatment, and random effects included environment, replications in each environment, and treatments in different environments. Each was analyzed for its effect on corn injury and yield, weed control, density, and biomass. Two environments were removed for foxtail species analysis due to low weed density. Distribution plots, residual plots, and a Shapiro-Wilk test were used to analyze normality and determine which distribution fit the data the best. Arcsine transformation was used for visible weed control assessments, lognormal for density and biomass data, and normal for yield. All arcsine and log-transformed data are presented following back-transformation using the appropriate procedures. Least square means and a Tukey-Kramer test were used to establish significance and treatment differences with a P-value of 0.05.

Results and Discussion

Crop Response

Pyroxasulfone + encapsulated saflufenacil (146 or 245 g ai ha^{-1}) applied alone or in combination with atrazine, dicamba, or mesotrione + atrazine caused no visible corn injury at 1, 2, and 4 WAE (data not presented). Soltani et al. (2009) observed minimal to no corn injury when saflufenacil was applied preemergence, and field corn has excellent tolerance to pyroxasulfone applied preemergence, with numerous reports indicating little to no or only transient injury (Geier et al. 2006; Knezevic et al. 2009; Stephenson et al. 2017). All tank-mix partners are labeled for

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Table 2. Effect of pyroxasulfone + encapsulated saflufenacil applied alone or in mixtures on common lambsquarters control (at 4 and 8 wk after emergence), density, and biomass when applied to corn.[a,b]

Herbicide treatment	Rate	Control[c] 4 WAE	Control[c] 8 WAE	Density	Biomass
	g ai ha^{-1}	------- % ------		No. plants m^{-2}	g m^{-2}
Nontreated control		0	0	42 e	64.1 d
Weed-free control		100	100	0 a	0.0 a
Pyroxasulfone + encapsulated saflufenacil	146	40 d	28 f	15 de	36.0 cd
Pyroxasulfone + encapsulated saflufenacil	245	50 cd	42 def	11 d	27.8 c
Atrazine	1,000	38 d	32 ef	12 de	24.0 cd
Dicamba	600	84 ab	82 abc	10 d	3.4 ab
Mesotrione + atrazine	144 + 1,000	92 ab	89 ab	1 ab	3.0 a
Pyroxasulfone + encapsulated saflufenacil + atrazine	146 + 1,000	56 cd	59 cde	8 cd	16.5 bc
Pyroxasulfone + encapsulated saflufenacil + atrazine	245 + 1,000	76 bc	69 bcd	7 bcd	14.6 bc
Pyroxasulfone + encapsulated saflufenacil + dicamba	146 + 600	92 ab	94 a	1 abc	0.9 a
Pyroxasulfone + encapsulated saflufenacil + dicamba	245 + 600	96 a	96 a	1 a	0.7 a
Pyroxasulfone + encapsulated saflufenacil + mesotrione + atrazine	146 + 144 + 1,000	92 ab	92 a	1 a	2.4 a
Pyroxasulfone + encapsulated saflufenacil + mesotrione + atrazine	245 + 144 + 1,000	93 ab	89 ab	1 abc	2.9 a
S-metolachlor/atrazine/mesotrione/bicyclopyrone	2,026	96 a	93 a	1 a	1.5 a

[a]Abbreviation: WAE, weeks after corn emergence.
[b]Means followed by the same letter are not significantly different according to the Tukey-Kramer multiple range test ($P < 0.05$).
[c]Visible control data were back-transformed from arcsine transformation; density and biomass data were back-transformed from log transformation.

Table 3. Effect of pyroxasulfone + encapsulated saflufenacil applied alone or in mixtures on redroot pigweed control (4 and 8 wk after emergence), density, and biomass when applied to corn.[a,b]

Herbicide treatment	Rate	Control[c] 4 WAE	Control[c] 8 WAE	Density	Biomass
	g ai ha^{-1}	------- % -------		No. plants m^{-2}	g m^{-2}
Nontreated control		0	0	29 e	151.4 d
Weed-free control		100	100	0 a	0.0 a
Pyroxasulfone + encapsulated saflufenacil	146	44 cd	40 d	6 bcd	53.9 cd
Pyroxasulfone + encapsulated saflufenacil	245	65 bcd	59 cd	2 abcd	7.5 abc
Atrazine	1,000	37 d	36 d	5 cd	26.3 bcd
Dicamba	600	79 abc	76 abc	12 de	6.0 abc
Mesotrione + atrazine	144 + 1,000	90 ab	85 abc	1 abc	5.1 abc
Pyroxasulfone + encapsulated saflufenacil + atrazine	146 + 1,000	66 bcd	62 bcd	3 abcd	23.7 abc
Pyroxasulfone + encapsulated saflufenacil + atrazine	245 + 1,000	81 ab	82 abc	1 abc	2.8 ab
Pyroxasulfone + encapsulated saflufenacil + dicamba	146 + 600	94 ab	94 a	1 abc	0.5 a
Pyroxasulfone + encapsulated saflufenacil + dicamba	245 + 600	98 a	97 a	0 a	0.6 a
Pyroxasulfone + encapsulated saflufenacil + mesotrione + atrazine	146 + 144 + 1,000	92 ab	89 ab	1 abc	8.3 abc
Pyroxasulfone + encapsulated saflufenacil + mesotrione + atrazine	245 + 144 + 1,000	93 ab	88 ab	1 abc	2.0 a
S-metolachlor/atrazine/mesotrione/bicyclopyrone	2,026	98 a	95 a	0 ab	1.8 a

[a]Abbreviations: WAE, weeks after corn emergence.
[b]Means followed by the same letter are not significantly different according to the Tukey-Kramer multiple range test ($P<0.05$).
[c]Visible control data presented was back-transformed from arcsine transformation; density and biomass data presented was back-transformed from log transformation

preemergence application to corn, and no injury was anticipated from the solo application of atrazine, dicamba, or mesotrione + atrazine (OMAFRA 2021).

Weed interference reduced corn yield 50% in this study (Table 5). Reduced weed interference with all herbicide treatments evaluated in this study, except pyroxasulfone + encapsulated saflufenacil (146 g ai ha^{-1}) applied alone, and atrazine applied alone, resulted in corn yield that was similar to that of the weed-free control. Application of pyroxasulfone + encapsulated saflufenacil with atrazine, dicamba, or mesotrione + atrazine did not improve corn yield when compared to yield after encapsulated saflufenacil + pyroxasulfone was applied alone (Table 5).

Common Lambsquarters Control

Pyroxasulfone + encapsulated saflufenacil applied at 146 or 245 g ai ha^{-1} controlled common lambsquarters by 40% and 50%, respectively, at 4 WAE, and by 28% and 42% at 8 WAE (Table 2). Adding atrazine to encapsulated saflufenacil + pyroxasulfone did not result in greater control at 4 WAE compared to pyroxasulfone + encapsulated saflufenacil applied alone. In contrast, atrazine added to pyroxasulfone + encapsulated saflufenacil (146 g ai ha^{-1}) increased control by 31% at 8 WAE. Addition of dicamba or mesotrione + atrazine to pyroxasulfone + encapsulated saflufenacil applied at 146 or 245 g ai ha^{-1} increased common lambsquarters control to ≥89% at both 4 and 8 WAE. Pyroxasulfone + encapsulated saflufenacil applied at 146 or 245 g ai ha^{-1} reduced the weed's density by 64% and 74%, respectively. A co-application of dicamba or mesotrione + atrazine with pyroxasulfone + encapsulated saflufenacil resulted in a 98% decrease in common lambsquarters density; however, there was no decrease in density when atrazine was applied with pyroxasulfone + encapsulated saflufenacil. Pyroxasulfone + encapsulated saflufenacil applied at 146 or 245 g ai ha^{-1} reduced common

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Table 4. Effect of pyroxasulfone + encapsulated saflufenacil applied alone or in mixtures on foxtail species control (4 and 8 wk after emergence), density, and biomass when applied to corn.[a,b]

Herbicide treatment	Rate	Control[c] 4 WAE	8 WAE	Density	Biomass
	g ai ha^{-1}	------- % -------		No. plants m^{-2}	g m^{-2}
Nontreated control		0	0	36 b	53.7 ab
Weed-free control		100	100	0 a	0.0 a
Pyroxasulfone + encapsulated saflufenacil	146	34 bcd	27 bcd	12 ab	11.5 a
Pyroxasulfone + encapsulated saflufenacil	245	58 abc	41 abc	13 ab	10.8 a
Atrazine	1,000	8 d	4 de	26 ab	31.2 ab
Dicamba	600	32 bcd	13 cde	20 ab	13.9 ab
Mesotrione + atrazine	144 + 1,000	26 cd	0 e	17 b	30.8 b
Pyroxasulfone + encapsulated saflufenacil + atrazine	146 + 1,000	45 abcd	42 abc	18 ab	21.1 ab
Pyroxasulfone + encapsulated saflufenacil + atrazine	245 + 1,000	57 abc	57 ab	20 ab	24.1 ab
Pyroxasulfone + encapsulated saflufenacil + dicamba	146 + 600	74 ab	62 ab	10 ab	11.5 a
Pyroxasulfone + encapsulated saflufenacil + dicamba	245 + 600	79 a	75 a	7 a	5.8 a
Pyroxasulfone + encapsulated saflufenacil + mesotrione + atrazine	146 + 144 + 1,000	58 abc	43 abc	23 ab	31.9 ab
Pyroxasulfone + encapsulated saflufenacil + mesotrione + atrazine	245 + 144 + 1,000	56 abc	61 ab	17 ab	22.8 ab
S-metolachlor/atrazine/mesotrione/bicyclopyrone	2,026	61 abc	58 ab	9 ab	12.8 a

[a]Abbreviation: WAE, weeks after corn emergence.
[b]Means followed by the same letter are not significantly different according to the Tukey-Kramer multiple range test ($P < 0.05$).
[c]Visible control data presented was back-transformed from arcsine transformation; density and biomass data presented was back-transformed from log transformation

Table 5. Effect of pyroxasulfone + encapsulated saflufenacil applied alone or in mixtures on corn yield.[a,b]

Herbicide treatment[c,d]	Rate	Yield
	g ai ha^{-1}	kg ha^{-1}
Nontreated control		5,900 c
Weed-free control		11,700 a
Pyroxasulfone + encapsulated saflufenacil	146	8,600 bc
Pyroxasulfone + encapsulated saflufenacil	245	9,300 ab
Atrazine	1,000	8,800 b
Dicamba	600	10,100 ab
Mesotrione + atrazine	144 + 1,000	10,300 ab
Pyroxasulfone + encapsulated saflufenacil + atrazine	146 + 1,000	9,500 ab
Pyroxasulfone + encapsulated saflufenacil + atrazine	245 + 1,000	10,300 ab
Pyroxasulfone + encapsulated saflufenacil + dicamba	146 + 600	10,400 ab
Pyroxasulfone + encapsulated saflufenacil + dicamba	245 + 600	10,300 ab
Pyroxasulfone + encapsulated saflufenacil + mesotrione + atrazine	146 + 144 + 1,000	10,000 ab
Pyroxasulfone + encapsulated saflufenacil + mesotrione + atrazine	245 + 144 + 1,000	10,300 ab
S-metolachlor/atrazine/mesotrione/bicyclopyrone[e]	2,026	10,800 ab

[a]Means followed by the same letter are not significantly different according to the Tukey-Kramer multiple range test ($P < 0.05$).
[b]Control data were back-transformed from arcsine transformation; density and biomass data were back-transformed from log transformation.
[c]Glyphosate at 900 g ai ha^{-1} added to all herbicide treatments.
[d]Dicamba/diflufenzopyr includes the safener isoxadifen.
[e]*S*-metolachlor/atrazine/mesotrione/bicyclopyrone includes the safener benoxacor.

lambsquarters biomass by 44% and 57%, respectively. Adding dicamba or mesotrione + atrazine to pyroxasulfone + encapsulated saflufenacil (146 or 245 g ai ha^{-1}) decreased the biomass by 96% to 99%. In contrast, biomass was not reduced when atrazine was added to pyroxasulfone + encapsulated saflufenacil. The industry standard herbicide for this study, *S*-metolachlor/atrazine/mesotrione/bicyclopyrone, provided greater common lambsquarters control, and reduced density and biomass more than pyroxasulfone + encapsulated saflufenacil (146 or 245 g ai ha^{-1}) applied alone; however, the addition of dicamba or mesotrione + atrazine controlled and reduced both density and biomass of the weed similar to that of the industry standard.

The results of this study build on previous research that investigated pyroxasulfone and saflufenacil applied alone. Although pyroxasulfone is known to provide control (>80%) of some small-seeded broadleaf weeds, common lambsquarters control is not achieved at rates <63 g ai ha^{-1} (OMAFRA 2021; Yamaji et al. 2014), while saflufenacil (50 to 100 g ai ha^{-1}) provides control of many broadleaf weeds including common lambsquarters (Anonymous 2022a; OMAFRA 2021). Preemergence application of other Group 15 and Group 14 herbicide mixtures such as pyroxasulfone/flumioxazin (Mahoney et al. 2014) and pyroxasulfone + sulfentrazone (Belfry et al. 2015) provided ≥95% and ≥83% control of common lambsquarters, respectively. However, in this study pyroxasulfone + encapsulated saflufenacil applied at 146 or 245 g ai ha^{-1} did not achieve acceptable control (≥80%) of common lambsquarters without the addition of dicamba or mesotrione + atrazine. When dicamba was applied alone in this study >80% residual control of common lambsquarters was achieved at 8 WAE, which is supported by Johnson et al. (2010) who achieved >90% control at numerous locations.

Redroot Pigweed Control

Pyroxasulfone + encapsulated saflufenacil applied at 146 or 245 g ai ha^{-1} controlled redroot pigweed by 44% and 65%, respectively, at

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4 WAE, and by 40% and 59% at 8 WAE(Table 3). Compared to pyroxasulfone + encapsulated saflufenacil (146 or 245 g ai ha^{-1}) applied alone, adding atrazine to pyroxasulfone + encapsulated saflufenacil did not improve redroot pigweed control, whereas at 8 WAE, control increased to ≥88% with the addition of dicamba or mesotrione + atrazine. Pyroxasulfone + encapsulated saflufenacil applied at 146 or 245 g ai ha^{-1} reduced redroot pigweed density by 79% and 93%, respectively. Compared to pyroxasulfone + encapsulated saflufenacil applied alone, the addition of atrazine, dicamba, or mesotrione + atrazine with 146 or 245 g ai ha^{-1} of pyroxasulfone + encapsulated saflufenacil did not further reduce the redroot pigweed density. Pyroxasulfone + encapsulated saflufenacil applied at 146 or 245 g ai ha^{-1} reduced redroot pigweed biomass by 64% and 95%, respectively. Only dicamba tank-mixed with pyroxasulfone + encapsulated saflufenacil (146 g ai ha^{-1}) provided a further decrease (>99%) in biomass compared to pyroxasulfone + encapsulated saflufenacil applied alone; all other mixtures with pyroxasulfone + encapsulated saflufenacil did not further reduce redroot pigweed biomass. The co-application of pyroxasulfone + encapsulated saflufenacil applied at 146 or 245 g ai ha^{-1} with dicamba or mesotrione + atrazine provided similar control and a similar decrease in redroot pigweed density and biomass to that of *S*-metolachlor/atrazine/mesotrione/bicyclopyrone.

Previous research indicates that both pyroxasulfone (Yamaji et al. 2014) and saflufenacil (Geier et al. 2009; OMAFRA 2021) provide control of redroot pigweed. In this study, acceptable control (≥80%) was not achieved when pyroxasulfone + encapsulated saflufenacil was applied alone, but the addition of dicamba or mesotrione raised control efficacy to acceptable levels. We speculate that the reduced efficacy observed in this study may be due to the encapsulated formulation of saflufenacil.

Foxtail Species Control

Pyroxasulfone + encapsulated saflufenacil applied at 146 or 245 g ai ha^{-1} controlled foxtail species by 34% and 58%, respectively, at 4 WAE, and by 27% and 41% at 8 WAE (Table 4). Application of pyroxasulfone + encapsulated saflufenacil with atrazine, dicamba, or mesotrione + atrazine did not increase control of foxtail species compared to pyroxasulfone + encapsulated saflufenacil applied alone. Pyroxasulfone + encapsulated saflufenacil applied at 146 and 245 g ai ha^{-1} reduced density by 67% and 64%, and biomass by 79% and 80%, respectively. Compared to pyroxasulfone + encapsulated saflufenacil applied alone, adding atrazine, dicamba, or mesotrione + atrazine to pyroxasulfone + encapsulated saflufenacil did not decrease density or biomass. Pyroxasulfone + encapsulated saflufenacil (146 or 245 g ai ha^{-1}) applied alone or with atrazine, dicamba, or mesotrione + atrazine provided similar reductions in foxtail species control, density, and biomass as *S*-metolachlor/atrazine/mesotrione/bicyclopyrone.

Pyroxasulfone primarily controls small-seed annual grasses with excellent activity against foxtail species (Yamaji et al. 2014), while saflufenacil has some effect on annual broadleaf weeds but limited effect on grass species (Jhala et al. 2013). All tank mixtures evaluated in this study demonstrated some control of broadleaf weeds. Previous research indicating a lack of grass control with atrazine, dicamba, or mesotrione + atrazine supports the results from this study, with no improvement in foxtail species control when co-applied with pyroxasulfone + encapsulated saflufenacil.

In conclusion, pyroxasulfone + encapsulated saflufenacil applied alone or with atrazine, dicamba, or mesotrione + atrazine resulted in no corn injury. The effectiveness of the herbicide mixtures varied depending on the weed species, with addition of dicamba or mesotrione + atrazine providing better control and reductions in density and biomass of common lambsquarters. For redroot pigweed, the efficacy of pyroxasulfone + encapsulated saflufenacil was influenced by the application rate and the choice of herbicide partner, making it important to consider these factors for optimal weed control. However, the addition of atrazine, dicamba, or mesotrione + atrazine did not improve control of foxtail species when used in combination with pyroxasulfone + encapsulated saflufenacil. Pyroxasulfone + encapsulated saflufenacil (146 or 245 g ai ha^{-1}) applied with dicamba or mesotrione + atrazine provided similar control of common lambsquarters, redroot pigweed, and foxtail species as the standard herbicide, *S*-metolachlor/atrazine/mesotrione/bicyclopyrone. Previous research on other Group 15 and Group 14 herbicides, pyroxasulfone + sulfentrazone (Belfry et al. 2015) or dimethenamid-P + saflufenacil (Moran et al. 2011), applied preemergence controlled common lambsquarters, pigweed species, and green foxtail. Corn yield after all herbicide treatments was similar to that when the industry standard herbicide was applied. Based on the results of this study, applying pyroxasulfone + encapsulated saflufenacil in a mixture with another herbicide is recommended depending on the application rate of pyroxasulfone + encapsulated saflufenacil, herbicide partner, and which weed species are present.

Practical Implications

The results of this study conclude that the combination of pyroxasulfone + encapsulated saflufenacil, applied preemergence either alone or in combination with atrazine, dicamba, or mesotrione + atrazine, has an adequate margin of crop safety for weed management in field corn. Additionally, the effectiveness of the herbicide mixtures varied depending on the weed species. Pyroxasulfone + encapsulated saflufenacil in combination with dicamba or mesotrione + atrazine was comparable to that of the standard herbicide, S-metolachlor/atrazine/mesotrione/bicyclopyrone, which is used to control common lambsquarters, redroot pigweed, and foxtail species. When applied alone, the herbicide combination of pyroxasulfone + encapsulated saflufenacil did not provide adequate control of these species. Therefore, for effective weed control in field corn, especially common lambsquarters and redroot pigweed, we recommend that pyroxasulfone + encapsulated saflufenacil be applied with another herbicide.

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