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Short Title: Saflufenacil/pyroxasulfone

Interaction of pyroxasulfone and encapsulated saflufenacil applied preemergence to corn

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Abstract

A new formulation of pyroxasulfone + encapsulated saflufenacil has been developed. Combining these two herbicides extends the application window to early postemergence. Pyroxasulfone, saflufenacil (suspension concentrate), and pyroxasulfone + encapsulated saflufenacil (microcapsule suspension) were applied to corn preemergence and evaluated for corn injury, corn yield, and visible weed control; in addition, the interaction (antagonistic, additive, or synergistic) was ascertained for each parameter. Six field trials were conducted at three locations in southwestern Ontario in 2022 and 2023. Pyroxasulfone was applied at 90, 120, and 150 g ai ha^{-1}; saflufenacil was applied at 56, 75, and 95 g ai ha^{-1}; and pyroxasulfone + encapsulated saflufenacil was applied at 146, 195, 245 g ai ha^{-1}, equal to the combined rates of pyroxasulfone and saflufenacil. All pyroxasulfone, encapsulated saflufenacil, and pyroxasulfone + encapsulated saflufenacil treatments caused no corn injury. Weed control varied based on application rate and weed species. Reduced weed interference with pyroxasulfone + encapsulated saflufenacil at 195 and 245 g ai ha^{-1} resulted in corn yield that was similar to the weed-free control and the industry standard of *S*-metolachlor/atrazine/mesotrione/bicyclopyrone. The interaction between pyroxasulfone and encapsulated saflufenacil for weed control was additive.

Nomenclature: Pyroxasulfone; saflufenacil; corn, *Zea mays* L.

Keywords: Additive, antagonistic, corn injury, corn yield, encapsulation, herbicide formulation, interaction, synergistic

Introduction

Corn is the highest-value agronomic crop in Ontario. Weed interference can cause substantial yield losses of 50% if no weed management tactics are implemented (Soltani et al. 2016). The most common method of weed management is the application of herbicides, with 96% of planted corn acres receiving at least one herbicide application (USDA-NASS 2022).

Encapsulated saflufenacil + pyroxasulfone is a new herbicide premix for weed control in corn. Saflufenacil is a Group 14 protoporphyrinogen oxidase inhibitor and pyroxasulfone is a Group 15 very-long-chain fatty acid elongase inhibitor (Shaner 2014). The encapsulated saflufenacil + pyroxasulfone formulation will expand the herbicide application window and increase weed control options for Ontario corn producers. This new herbicide premix provides residual control of small-seeded annual grass and broadleaf weeds. Pyroxasulfone applied at 200 to 300 g ai ha^{-1} provides approximately 4 to 6 wk of residual control of select annual grass and broadleaf weeds (Knezevic et al. 2009). Saflufenacil at 75 g ha^{-1} provides residual control of common lambsquarters (*Chenopodium album* L.), redroot pigweed (*Amaranthus retroflexus* L.), and common ragweed (*Ambrosia artemisiifolia* L.) (Anonymous 2021, 2022; OMAFRA 2021).

Pyroxasulfone and saflufenacil provide primarily annual grass and broadleaf weed control, respectively; therefore, the combination has the potential to control a broader spectrum of weeds (Fillols et al. 2020). Pyroxasulfone controls many small-seeded grass and broadleaf weeds including barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv.], foxtail species (*Setaria* sp.), large crabgrass [*Digitaria sanguinalis* (L.) Scop.], redroot pigweed, velvetleaf (*Abutilon theophrasti* Medik.), and waterhemp [*Amaranthus tuberculatus* (Moq.) J.D. Sauer] (Nurse et al. 2011; OMAFRA 2021; Yamaji et al. 2014). The suspension concentrate formulation of saflufenacil controls many broadleaf weeds such as common lambsquarters, redroot pigweed, Canada fleabane [*Conyza canadensis* (L.) Cronq.], common ragweed, velvetleaf, wild buckwheat (*Polygonum convolvulus* L.), wild mustard (*Sinapis arvensis* L.), and stinkweed (*Thlaspi arvense* L.) (Boydston et al. 2012; Geier et al. 2009; OMAFRA 2021). Pyroxasulfone is used to control many small-seeded grasses and some broadleaf weeds, and saflufenacil is used to control many broadleaf weeds, thus this combination has the potential to control a broader spectrum of weeds than either active ingredient alone.

With respect to weed control, the interaction between active ingredients can be antagonistic, additive, or synergistic. Weed control interactions with two herbicides are determined by comparing observed and expected control with each active ingredient applied alone with the control of the combination (Akobundu et al. 1975; Green 1989). An antagonistic response is when the observed control is less than expected, an additive response is when the observed control is equal to expected, and a synergistic response is when the observed control is greater than expected. Herbicide interactions are specific to a weed species (Green 1989; Tidemann et al. 2014; Zhang et al. 1995). In previous research, the co-application of other herbicides in groups 14 and 15 has resulted in improved control of common lambsquarters, common ragweed, and green foxtail [*Setaria viridis* (L.) P. Beauv.] (Belfry et al. 2015). Research conducted by Tidemann et al. (2014) established that the interaction between pyroxasulfone (Group 15) and sulfentrazone (Group 14) was additive; however, no previous research has been reported on the interaction between pyroxasulfone and saflufenacil.

Encapsulated saflufenacil + pyroxasulfone is a new herbicide premix, but limited data exist on it its ability to control problematic weeds in southwestern Ontario. The goal of this study was to ascertain the interaction between pyroxasulfone and saflufenacil on visible weed control, density, and biomass of common weed species in southwestern Ontario as well as corn injury and yield.

Materials and Methods

A total of six field trials were conducted over a 2-yr period (2022 and 2023) in southwestern Ontario, Canada. Each year, two trials were established at the University of Guelph Ridgetown Campus, and one at the BASF research farm near Belmont. Trials consisted of 12 treatments set up as a randomized complete block design with four replicated blocks with 2- × 8-m plots. The trials were established using conventional tillage consisting of chisel ploughing in the fall and seedbed preparation in the spring using an S-tine cultivator with rolling basket harrows. Fertilizer was applied based on soil test results and Ontario Ministry of Agriculture, Food and Rural Affairs recommendations. Corn was planted at approximately 80,000 seeds ha^{-1}, approximately 5 cm deep, in rows spaced 75 cm apart. Table 1 contains additional soil and crop information. Herbicide treatments consisted of three rates of pyroxasulfone (90, 120, and 150 g ai ha^{-1}), saflufenacil (56, 75, and 95 g ai ha^{-1}), encapsulated saflufenacil + pyroxasulfone (146, 195, and 245 g ai ha^{-1}), and an industry-standard, *S*-metolachlor/atrazine/mesotrione/bicyclopyrone (2,026 g ai ha $^{-1}$). Treatments were applied preemergence using a CO_2-pressurized backpack sprayer calibrated to deliver 200 L ha^{-1}.

Visible corn injury and weed control ratings were completed on a 0% to 100% scale, with 0% being no visible symptoms and 100% being complete plant death. Visible crop injury assessments were completed at 1, 2, and 4 wk after corn emergence (WAE) and visible weed control at 4 and 8 WAE. Weed density and aboveground biomass data were determined at 8 WAE by counting and collecting each weed species in two 0.25-m^2 quadrats placed at two random locations in each plot. Each weed within the quadrat was cut at the soil surface and placed into separate paper bags by species. The weed biomass was dried in a kiln and the weights were recorded. The natural weeds included common lambsquarters, redroot pigweed, and foxtail species. Corn yield data were collected at harvest maturity using a mechanical small plot combine, and weight and moisture were recorded for each plot. Corn yield was then adjusted to 15.5% moisture before statistical analysis.

Data were analyzed using the GLIMMIX procedure, a mixed model analysis of variance, with SAS software (v.9.4; SAS Institute Inc, Cary, NC). Data from all six site-years were combined for analysis to allow for interpretation across multiple environments. The fixed effect was herbicide treatment and random effects were environment, treatments in different environments, and replications in each environment. One environment was removed for redroot pigweed analysis and three were removed for foxtail species analysis due to low weed density. One outlier, likely due to human error, was removed. Analysis for normality and determination of the best transformation for the data to fit a normal distribution was assessed through distribution plot, residual plots, and a Shapiro-Wilk test. Weed control data used an arcsine transformation, while weed density and biomass used a lognormal transformation. Corn yield was normal, and no transformation was necessary. Least square means and Tukey-Kramer tests were used to establish significance and treatment differences with a P-value of 0.05. All data were back-transformed for presentation of results. Expected visible weed control values were calculated using Colby's equation:

$$E = (X + Y) - (XY)/100 \quad [1]$$

where E is the expected percent control of the herbicide combination, X is the percent control of herbicide 1 at a particular rate, and Y is the percent control of herbicide 2 at a particular rate. A modified version of Colby's equation was used to calculate expected values for density, biomass, and yield data, E = X*Y/untreated control, which are not on a 0 to 100 scale. Expected values were subject to the same transformations according to evaluation type. A *t*-test was performed to establish significance ($P < 0.05$) between observed and expected values.

Results and Discussion

Corn Injury

Pyroxasulfone (90, 120, and 150 g ai ha^{-1}), saflufenacil (56, 75, and 95 g ai ha^{-1}), and encapsulated saflufenacil + pyroxasulfone (146, 195, and 245 g ai ha^{-1}) applied preemergence caused no visible corn injury at 1, 2, and 4 WAE (data not presented). This was not surprising since pyroxasulfone and the suspension concentrate formulation of saflufenacil are registered for application to corn before it emerges (OMAFRA 2021). Previous research on saflufenacil applied preemergence to corn reported minimal corn injury (Soltani et al. 2009) and field corn has excellent tolerance to pyroxasulfone with no, low, or transient corn injury (Geier et al. 2009; Knezevic et al. 2009; Stephenson et al. 2017).

Common Lambsquarters Control

When assessed at 8 WAE, pyroxasulfone applied at 90, 120, and 150 g ai ha^{-1} controlled common lambsquarters by 22%, 23%, and 30%, respectively; while saflufenacil applied at 56, 75, and 95 g ai ha^{-1} controlled the weed by 21%, 31%, and 35%, respectively (Table 2). The premixture of encapsulated saflufenacil + pyroxasulfone applied at 146, 195, and 245 g ai ha^{-1} provided 44%, 52%, and 60% control, respectively. Control at 4 WAE followed a similar trend. Encapsulated saflufenacil + pyroxasulfone at 245 g ai ha^{-1} provided greater common lambsquarters compared to pyroxasulfone (150 g ai ha^{-1}) or saflufenacil (95 g ai ha^{-1}) applied alone. Encapsulated saflufenacil + pyroxasulfone at 195 or 245 g ai ha^{-1} provided greater common lambsquarters control than pyroxasulfone (120 or 150 g ai ha^{-1}) applied alone but similar to that of saflufenacil (75 or 95 g ai ha^{-1}) applied alone at 8 WAE. *S*-metolachlor/atrazine/mesotrione/bicyclopyrone (2,026 g ai ha $^{-1}$) controlled common lambsquarters by 95% and 94% at 4 and 8 WAE, respectively, which is greater than that provided by encapsulated saflufenacil + pyroxasulfone.

Common lambsquarters density and biomass data were variable due to uneven population counts. Pyroxasulfone applied at 90, 120, and 150 g ai ha^{-1} reduced common lambsquarters density by 43%, 59%, and 57%, respectively; while saflufenacil applied at 56, 75, and 95 g ai ha^{-1} reduced common lambsquarters density by 49%, 67%, and 65%, respectively (Table 2). Density was reduced by 80%, 78%, and 80% when encapsulated saflufenacil + pyroxasulfone

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was applied at 146, 195, and 245 g ai ha^{-1}, respectively. Pyroxasulfone applied at 90, 120, and 150 g ai ha^{-1} reduced common lambsquarters biomass by 0%, 0%, and 19%, respectively; while biomass was reduced by 0%, 22%, and 25%, respectively, when saflufenacil was applied at 56, 75, and 95 g ai ha^{-1}. Encapsulated saflufenacil + pyroxasulfone applied at 146, 195, and 245 g ai ha^{-1} reduced the weed biomass by 24%, 51%, and 8%, respectively. *S*-metolachlor/atrazine/mesotrione/bicyclopyrone (2,026 g ai ha $^{-1}$) reduced common lambsquarters density and biomass by 98% and 97%, respectively, which was greater than all evaluated rates of encapsulated saflufenacil + pyroxasulfone.

The low level of common lambsquarters control obtained with pyroxasulfone in this study is similar to the 7% reported by Belfry et al. (2015) at 4 wk after an application of pyroxasulfone at 150 g ai ha^{-1}. Similarly, Yamaji et al. (2014) reported lower common lambsquarters control with pyroxasulfone compared to other small-seeded broadleaf weeds such as redroot pigweed and black nightshade (*Solanum nigrum* L.). Common lambsquarters control with saflufenacil in this study was low, but Boydston et al. (2012), Geier et al. (2009), and OMAFRA (2021) reported control of common lambsquarters with saflufenacil. The encapsulated formulation used in this study may have resulted in reduced control. Control was low with the encapsulated form of saflufenacil + pyroxasulfone used in this study, but previous research with other Group 15 and Group 14 herbicide mixtures reported >80% control (Belfry et al. 2015; Mahoney et al. 2014). Mahoney et al. (2014) studied pyroxasulfone applied preemergence in a mixture with flumioxazin (Group 14) and observed >95% control of common lambsquarters. Another mixture of Group 15 + 14 herbicides, pyroxasulfone + sulfentrazone, applied preemergence, provided 83% to 95% control of the weed (Belfry et al. 2015).

Redroot Pigweed Control

When assessed 4 WAE, pyroxasulfone applied at 90, 120, and 150 g ai ha^{-1} controlled redroot pigweed by 55%, 66%, and 71%, respectively; while saflufenacil applied at 56, 75, and 95 g ai ha^{-1} provided 24%, 33%, and 41% control, respectively (Table 3). Encapsulated saflufenacil + pyroxasulfone applied at 146, 195, 245 g ai ha^{-1} provided 75%, 78%, and 87% control, respectively, at 4 WAE. Among all herbicide treatments evaluated, a numeric decrease in redroot pigweed control was observed at 8 WAE. Encapsulated saflufenacil + pyroxasulfone and pyroxasulfone at the three rates evaluated provided similar redroot pigweed control; however, control with the premix was greater than with saflufenacil applied alone at 4 and 8 WAE. *S*-

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metolachlor/atrazine/mesotrione/bicyclopyrone (2,026 g ai ha^{-1}) provided 98% and 92% control at 4 and 8 WAE, respectively which is similar to that provided by encapsulated saflufenacil + pyroxasulfone at 195 and 245 g ai ha^{-1}.

Redroot pigweed density was reduced by 55%, 70%, and 75%, when pyroxasulfone was applied at 90, 120, and 150 g ai ha^{-1}, respectively; while density was reduced by 55%, 65%, and 80% when saflufenacil was applied at 56, 75, and 95 g ai ha^{-1}, respectively (Table 3). The encapsulated form of saflufenacil + pyroxasulfone applied at 146, 195, and 245 g ai ha^{-1} reduced redroot pigweed density by 85%, 90%, and 95%, respectively. Encapsulated saflufenacil + pyroxasulfone and corresponding rates of pyroxasulfone and saflufenacil applied alone produced similar results in pigweed density. Redroot pigweed biomass was reduced by 31%, 79%, and 85% with applications of pyroxasulfone at 90, 120, and 150 g ai ha^{-1}, respectively; while it was reduced by 43%, 24%, and 49% with applications of saflufenacil at 56, 75, and 95 g ai ha^{-1}, respectively. Encapsulated saflufenacil + pyroxasulfone at 146, 195, and 245 g ai ha^{-1} reduced the weed's biomass by 86%, 90%, and 94%, respectively. *S*-metolachlor/atrazine/mesotrione/bicyclopyrone (2,026 g ai ha^{-1}) reduced both density and biomass by 95% and 99%, respectively, which was similar to that of all rates of encapsulated saflufenacil + pyroxasulfone.

There are numerous reports that pyroxasulfone provides control of redroot pigweed (Nurse et al. 2011; OMAFRA 2021; Yamaji et al. 2014). Yamaji et al. (2014) reported ≥95% redroot pigweed control at rates ≥32 g ai ha^{-1}, while the results of this study demonstrated much lower levels of control. Nurse et al. (2011) reported that the required dose of pyroxasulfone to achieve a 90% reduction in redroot pigweed biomass was 93 g ai ha^{-1}. At the highest rate of pyroxasulfone (150 g ai ha^{-1}) evaluated in this study a 90% reduction in redroot pigweed biomass was not achieved. Saflufenacil also controls redroot pigweed (Boydston et al. 2012; Geier et al. 2009; OMAFRA 2021), but in this study, the encapsulated formulation may have reduced its activity. Pigweed species control provided by saflufenacil + pyroxasulfone applied preemergence at ≥80 g ai ha^{-1} was 100% at 4 wk after application (Mahoney et al. 2014). In this study, encapsulated saflufenacil + pyroxasulfone provided 75% to 87% redroot pigweed control 4 WAE.

Foxtail Species Control

When assessed at 4 WAE, pyroxasulfone applied at 90, 120, and 150 g ai ha^{-1} controlled foxtail species by 28%, 33%, and 51%, respectively; while saflufenacil applied at 56, 75, and 95 g ai ha^{-1} provided 10%, 12%, and 12% control, respectively (Table 4). Encapsulated saflufenacil + pyroxasulfone applied at 146, 195, 245 g ai ha^{-1} provided 35%, 43%, and 45% control, respectively. There was a numeric decrease in foxtail species control at 8 WAE among all herbicide treatments. Encapsulated saflufenacil + pyroxasulfone and pyroxasulfone at the three corresponding rates provided similar foxtail species control; however, control with the premix was generally greater both at 4 and 8 WAE than with saflufenacil applied alone. *S*-metolachlor/atrazine/mesotrione/bicyclopyrone (2,026 g ai ha^{-1}) provided 47% and 25% control of foxtail species at 4 and 8 WAE, respectively, which was similar to that of encapsulated saflufenacil + pyroxasulfone at all rates.

Pyroxasulfone applied at 90, 120, and 150 g ai ha^{-1} reduced foxtail species density by 70%, 85%, and 81%, respectively; while saflufenacil applied at 56, 75, and 95 g ai ha^{-1} reduced foxtail species density by 55%, 59%, and 47%, respectively (Table 4). Encapsulated saflufenacil + pyroxasulfone applied at 146, 195, and 245 g ai ha^{-1} reduced density by 74%, 62%, and 78%, respectively. Pyroxasulfone applied at 90, 120, and 150 g ai ha^{-1} provided biomass reductions of 27%, 68%, and 55%, respectively; while saflufenacil applied at 56, 75, and 95 g ai ha^{-1} provided reductions of 23%, 12%, and 4%, respectively. Encapsulated saflufenacil + pyroxasulfone applied at 146, 195, and 245 g ai ha^{-1} reduced biomass by 20%, 4%, and 58%, respectively. *S*-metolachlor/atrazine/mesotrione/bicyclopyrone (2,026 g ai ha^{-1}) reduced density and biomass 64% and 11%, respectively. All rates of encapsulated saflufenacil + pyroxasulfone provided reductions in density and biomass that were similar to those of *S*-metolachlor/atrazine/mesotrione/bicyclopyrone.

Control of foxtail species at 8 WAE in this study was 15% to 36% when pyroxasulfone was used (Table 4); in contrast, Nurse et al. (2011), Yamaji et al. (2014), and OMAFRA (2021) reported >80% control when pyroxasulfone was applied at similar rates. This may be due to rainfall and weed density variability between the two experimental sites in our study. Saflufenacil is known to provide limited control of grass weeds, including foxtail species (Boydston et al. 2012; Jhala et al. 2013; OMAFRA 2021), which supports the data reported in this study. Saflufenacil + pyroxasulfone applied preemergence at 240 g ai ha^{-1} provided 98%

control of green foxtail control at 4 wk after application (Mahoney et al. 2014), whereas encapsulated saflufenacil + pyroxasulfone applied at a similar rate (245 g ai ha^{-1}) provided 44% control at 4 WAE in the current study (Table 4).

Corn Yield

Weed interference reduced corn yield by 45% in this study (Table 5). Corn yield was reduced by 30% to 38% and by 34% to 37%, when pyroxasulfone and saflufenacil, respectively, similar to that of the untreated control. Corn yield was also reduced by 24%, 22%, and 18% after preemergence applications of encapsulated saflufenacil + pyroxasulfone at 146, 195, and 245 g ai ha^{-1}, respectively, compared with the weed-free control. Applications of *S*-metolachlor/atrazine/mesotrione/bicyclopyrone to manage weed interference resulted in a 6% decrease in corn yield. Corn yields after applications of pyroxasulfone, saflufenacil, and encapsulated saflufenacil + pyroxasulfone were similar, and corn yields were similar after applications of encapsulated saflufenacil + pyroxasulfone and *S*-metolachlor/atrazine/mesotrione/bicyclopyrone. Corn yields were similar to that of the untreated control with applications of pyroxasulfone (90, 120, and 15 g ai ha^{-1}), saflufenacil (56, 75, and 95 g ai ha^{-1}), and encapsulated saflufenacil + pyroxasulfone (146 and 195 g ai ha^{-1}). Reduced weed interference after applications of encapsulated saflufenacil + pyroxasulfone (195 and 245 g ai ha^{-1}) and *S*-metolachlor/atrazine/mesotrione/bicyclopyrone resulted in corn yields that were similar to those of the weed-free control.

Interaction of Pyroxasulfone and Encapsulated Saflufenacil

When assessing the interaction between pyroxasulfone and saflufenacil, nonsignificant results indicate an additive interaction, while significant results indicate a synergistic response if the observed value is greater than expected, or antagonistic if the observed value is less than expected. Visible control data showed the interaction of encapsulated saflufenacil + pyroxasulfone was additive for controlling common lambsquarters, redroot pigweed, and foxtail species with two exceptions. Redroot pigweed control at 8 WAE had a synergistic response when encapsulated saflufenacil + pyroxasulfone was applied at 146 g ai ha^{-1} (Table 3) and one instance of antagonism was recorded at 4 WAE for visible foxtail species control when encapsulated saflufenacil + pyroxasulfone was applied at 245 g ai ha^{-1} (Table 4). Density and biomass data indicated an additive interaction with only one exception, an antagonistic response by foxtail species when encapsulated saflufenacil + pyroxasulfone was applied at 195 g ai ha^{-1}.

The interaction of pyroxasulfone and saflufenacil on yield was additive at all rates (146, 195, and 245 g ai ha^{-1}) of encapsulated saflufenacil + pyroxasulfone (Table 5).

Even though there were some contradictions, the over interaction between encapsulated saflufenacil + pyroxasulfone is additive. All synergistic or antagonistic responses for density and biomass can be attributed to experimental variability. Previous research conducted by Tidemann et al. (2014) and Ferrier et al. (2022) established the interaction between the Group 15 + 14 herbicide combinations of pyroxasulfone + sulfentrazone and pyroxasulfone + flumioxazin, respectively, as an additive, thereby supporting the findings of this study.

In conclusion, differences in control of weeds with pyroxasulfone, saflufenacil, and encapsulated saflufenacil + pyroxasulfone were specific to the weed species and herbicide rate. Common lambsquarters control was improved when encapsulated saflufenacil + pyroxasulfone was applied at 245 g ai ha^{-1} over either pyroxasulfone (150 g ai ha^{-1}) or saflufenacil (95 g ai ha^{-1}) applied alone. Redroot pigweed and foxtail species control was improved with applications of encapsulated saflufenacil + pyroxasulfone (146, 195, 245 g ai ha^{-1}) compared to corresponding rates of saflufenacil (56, 75, 95 g ai ha^{-1}). Corn yields were similar for each active ingredient, pyroxasulfone and saflufenacil, applied alone and in combination. Weed control, density, biomass, and corn yield data indicated an additive interaction between pyroxasulfone and saflufenacil, with a few indications of synergism and antagonism.

Practical Implications

Weed control differences with pyroxasulfone, saflufenacil, and the encapsulated saflufenacil + pyroxasulfone formulation were dependent on the specific weed species present and herbicide application rates. Data on weed control, density, and biomass, and corn yield showed an additive interaction between pyroxasulfone and saflufenacil, with occasional indications of synergistic and antagonistic effects. The new formulation of encapsulated saflufenacil + pyroxasulfone offers another weed option in corn production. The combination of these two herbicides provides control of a broader spectrum of weeds without causing corn injury. Additionally, the additive interaction between saflufenacil and pyroxasulfone suggests that the co-application of these herbicides can enhance weed control, resulting in corn yields that are comparable to those when the current industry standard herbicide is used. This formulation could be a valuable tool for farmers seeking to improve weed management while maintaining high crop productivity, especially in areas with diverse weed populations.

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Competing Interests

Chris Budd is senior biologist with BASF Canada Inc. The other authors declare they have no conflicts of interest.

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

		Soil characteristics				Crop information				
Year	Location	Texture	OM	pH	CEC	Hybrid	Planting date	Emergence date	Harvest date	Herbicide application 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	June 2
	BASF Research Farm	Loam	2.8	7.2	9.6	DKC48-56RIB	May 25	June 2	November 15	June 9

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

[b]Six trials were conducted in Ontario, Canada, in 2022 and 2023.

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Table 2. Influence of encapsulated saflufenacil + pyroxasulfone on common lambsquarters control at 4 and 8 wk after application, and density and biomass of corn.[a–e]

Herbicide treatment	Rate	Weed control								Density				Biomass			
		4 WAE				8 WAE											
	g ai ha^{-1}	------------------ % ------------------								No. plants m^{-2}				g m^{-2}			
		Observed		Expected		Observed		Expected		Observed		Expected		Observed		Expected	
Untreated control		0				0				49	e			83.8	b		
Weed-free control		100				100				0	a			0	a		
Pyroxasulfone	90	33	D			22	d			28	de			90.1	b		
Pyroxasulfone	120	38	Cd			23	d			20	bcd			121.8	b		
Pyroxasulfone	150	44	Cd			30	cd			21	bcd			68.1	b		
Saflufenacil	56	31	D			21	d			25	cde			91.3	b		
Saflufenacil	75	36	Cd			31	cd			16	bcd			65.3	b		
Saflufenacil	95	42	Cd			35	bcd			17	bcd			62.5	b		
Pyroxasulfone/saflufenacil	146	50	Bcd	54	a	44	bcd	40	b	10	bc	20	b	63.8	b	162.9	a
Pyroxasulfone/saflufenacil	195	58	Bc	59	b	52	bc	50	a	11	b	9	a	41.4	b	157.8	a
Pyroxasulfone/saflufenacil	245	69	B	67	b	60	b	58	a	10	b	12	ab	77.5	b	119.9	a
S-metolachlor/atrazine/ mesotrione/bicyclopyrone	2,026	95	A			94	a			1	a			2.3	a		

[a]Abbreviation: WAE, weeks after emergence.

[b]Means followed by the same letter are not significantly different according to the Tukey-Kramer multiple range test ($P < 0.05$).

[c]Expected values were calculated using Colby's equation.

[d]Control data were back-transformed from arcsine transformation; density and biomass data were back-transformed from log transformation.

[e]Values in bold indicate a significant interaction of $P < 0.05$ (synergism when observed > expected; antagonism when observed < expected).

Table 3. Influence of encapsulated saflufenacil + pyroxasulfone on redroot pigweed control (4 and 8 wk after application) and density and biomass of corn.[a–e]

		Weed control							
Herbicide treatment	Rate	4 WAE		8 WAE		Density		Biomass	
	g ai ha^{-1}	------------------ % ------------------				No. plants m^{-2}		g m^{-2}	
		Observed	Expected	Observed	Expected	Observed	Expected	Observed	Expected
Untreated control		0		0		20 e		91.2 e	
Weed-free control		100		100		0 a		0 a	
Pyroxasulfone	90	55 Bcde		39 cde		9 cd		62.7 bcde	
Pyroxasulfone	120	66 Bcd		47 bcd		6 abcd		18.8 abcd	
Pyroxasulfone	150	71 Bc		58 bcd		5 abcd		13.4 abc	
Saflufenacil	56	24 E		11 e		9 de		51.9 de	
Saflufenacil	75	33 De		15 e		7 de		68.9 cde	
Saflufenacil	95	41 Cde		27 de		4 bcd		46.7 de	
Pyroxasulfone/saflufenacil	146	75 Bc	67 b	**61 bc**	**45 b**	3 abcd	8 b	13.0 abc	308.2 a
Pyroxasulfone/saflufenacil	195	78 Ab	77 a	67 abc	57 ab	2 abc	5 ab	9.4 ab	65.8 a
Pyroxasulfone/saflufenacil	245	87 Ab	81 a	74 ab	70 a	1 ab	2 a	5.6 a	25.0 a
S-metolachlor/atrazine/ mesotrione/bicyclopyrone	2,026	98 A		92 a		1 a		1.2 a	

[a]Abbreviations: WAE, weeks after emergence.

[b]Means followed by the same letter are not significantly different according to the Tukey-Kramer multiple range test ($P<0.05$).

[c]Expected values calculated with Colby’s equation.

[d]Control data presented was back-transformed from arcsine transformation; density and biomass data presented was back-transformed from log transformation.

[e]Values in bold indicate a significant interaction of $P < 0.05$ (synergism when observed > expected; antagonism when observed < expected).

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Table 4. Influence of encapsulated saflufenacil + pyroxasulfone applied preemergence on foxtail species control (4 and 8 weeks after application), density, and biomass in corn from six trials conducted in Ontario, Canada in 2022 and 2023.

		Weed control[c]							
Herbicide treatment	Rate	4 WAE[ad]		8 WAE		Density		Biomass	
	g ai ha^{-1}	------------------ % ------------------				No. plants m^{-2}		g m^{-2}	
		Observed	Expected[b]	Observed	Expected	Observed	Expected	Observed	Expected
Untreated control		0		0		73 e		45.5 bc	
Weed-free control		100		100		0 a		0 a	
Pyroxasulfone	90	28 abc		15 ab		22 bcde		33.4 bc	
Pyroxasulfone	120	33 ab		32 a		11 b		14.5 b	
Pyroxasulfone	150	51 a		36 a		14 bc		20.5 b	
Saflufenacil	56	10 c		3 b		33 de		35.1 c	
Saflufenacil	75	12 bc		3 b		30 cde		40.0 bc	
Saflufenacil	95	12 bc		3 b		39 de		43.9 bc	
Pyroxasulfone/saflufenacil	146	35 ab	34 B	23 a	17 B	19 bcd	24 a	36.4 bc	27.7 a
Pyroxasulfone/saflufenacil	195	43 a	41 ab	36 a	34 ab	**28 bcde**	**6 a**	43.6 bc	22.9 a
Pyroxasulfone/saflufenacil	245	**45 a**	**56 a**	43 a	38 A	16 bcd	18 a	19.0 bc	33.1 a
S-metolachlor/atrazine/ mesotrione/bicyclopyrone	2,026	47 a		25 a		26 bcde		40.4 bc	

[a]Abbreviations: WAE, weeks after emergence.

[b]Means followed by the same letter are not significantly different according to the Tukey-Kramer multiple range test ($P<0.05$).

[c]Expected values calculated with Colby's equation.

[d]Control data presented was back-transformed from arcsine transformation; density and biomass data presented were back-transformed from log transformation.

[e]Values in bold indicate a significant interaction of $P < 0.05$ (synergism when observed > expected; antagonism when observed < expected).

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Table 5. Influence of encapsulated saflufenacil + pyroxasulfone herbicide mixtures on corn yield.[a,b,c]

Herbicide treatment	Rate	Yield			
	g ai ha^{-1}	T ha^{-1}			
		Observed		Expected	
Untreated control		6.3	d		
Weed-free control		11.4	a		
Pyroxasulfone	90	7.1	cd		
Pyroxasulfone	120	7.9	cd		
Pyroxasulfone	150	8.0	bcd		
Saflufenacil	56	7.5	cd		
Saflufenacil	75	7.2	cd		
Saflufenacil	95	7.5	cd		
Pyroxasulfone/saflufenacil	146	8.7	bcd	10.9	a
Pyroxasulfone/saflufenacil	195	8.9	abcd	13.2	a
Pyroxasulfone/saflufenacil	245	9.3	abc	15.1	a
S-metolachlor/atrazine/mesotrione/bicyclopyrone	2,026	10.7	ab		

[a]Means followed by the same letter are not significantly different according to the Tukey-Kramer multiple range test ($P < 0.05$).

[b]Expected values calculated using Colby's equation.

[c]Values in bold indicate a significant interaction of $P < 0.05$ (synergism when observed > expected; antagonism when observed < expected).

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