Sunflower Tolerance and Weed Control from Pyroxasulfone

Rich Zollinger[1*], Phillip W. Stahlman[6], Brian Jenks[2], Michael Moechnig[3], Brian Olson[4], Dallas E. Peterson[5], and Curtis R. Thompson[7]

[1]North Dakota State University, Fargo, ND, 58108 USA, r.zollinger@ndsu.edu
[2]Kansas State University, Hays, KS, 67601 USA, stahlman@ksu.edu
[3]North Dakota State University, Minot, ND, 58701 USA, brian.jenks@ndsu.edu
[4]South Dakota State, Brookings, SD, 57006 USA, michael.moechnig@sdstate.edu
[5]Kansas State University, Colby, KS, 67701 USA, bolson@ksu.edu
[6]Kansas State University, Manhattan, KS, 66506 USA, dpeterso@ksu.edu
[7]Kansas State University, Garden City/Manhattan, KS, 67846 USA, cthompso@ksu.edu
[1]Corresponding author: r.zollinger@ndsul.edu

Abstract
Pyroxasulfone (KIH-485) is a soil-applied, seedling growth-inhibiting herbicide developed by Kumiai America that has the potential to control weeds in several crops, including sunflower. The U.S. E.P.A. registration is expected in 2012 on corn, soybean, and winter wheat. Selectivity to other crops and interaction with various soil types and environments are under investigation. Pyroxasulfone has activity on small-seeded grass and broadleaf species but not large-seed broadleaf species, including wild sunflower (*Helianthus annuus*), hence possible herbicide selectivity to the cultivate crop. The objective of this 3-year, multi-location research project was to evaluate sunflower tolerance and weed control with pyroxasulfone applied at various rates, with and without sulfentrazone herbicide.

Studies were conducted across the sunflower production area of the U.S. Studies were conducted in 2006-2007 to evaluate sunflower response to pyroxasulfone applied preemergence at 0, 166, 210, or 332 g ai ha^{-1}. In 2008, pyroxasulfone was applied with sulfentrazone at 105 and 140 g ai ha^{-1}.

In eight locations in 2006, less than 10% injury was observed from pyroxasulfone. Sunflower injury at one location was 24% but injury at the highest rate was much less and yield was greater than measurements at the standard rate so the injury was assumed to be caused by other factors. In 2007, no sunflower injury was observed with any rate of pyroxasulfone at any location except Highmore, SD, where sunflower injury was 17%, 4 wk after treatment (WAT) with 332 g ha^{-1}. There was no reduction in yield or sunflower population. In 2008, pyroxasulfone was applied alone and in tank mixture with sulfentrazone. Sunflower injury ranged from 0 to 4% for all treatments. Adding sulfentrazone did not increase injury. Sunflower yield was only reduced in treatments in which weeds were not effectively controlled. Sunflower yield did not differ among the other treatments of pyroxasulfone or sulfentrazone applied alone or in combination.

Sunflower tolerance to pyroxasulfone applied alone or in combination with sulfentrazone is adequate. Pyroxasulfon at rates three to eight times lower than comparable products gave 60 to 99% control of many annual species of *Setaria, Digitaria, Kochia, Amaranthus, Salsola, Abutilon, Ambrosia, Tribulus, Chenopodium, Solanum, Brassica, and Polygonum.* This is significant since drought conditions caused other soil-applied herbicides to fail from lack of activating moisture. The addition of sulfentrazone to pyroxasulfone improved control of *Hordeum, Amaranthus, Polygonum,* and *Iva* species; did not improve control of *Digitaria* or *Setaria* species; and did not reduce control of any weed species evaluated.

There are few herbicides registered on sunflower. Lack of broad-spectrum weed control is a major problem in sunflower production. Pyroxasulfone can control many annual grass and broadleaf weeds contributing to full sunflower yield potential and effective weed management. Pyroxasulfone can control many weeds that have developed resistance to herbicides of several modes of action, including *kochia scoparia* L. and *amaranthus tuberculatus* (Moq.) Sauer.

Keywords: herbicide, weed control, pyroxasulfone.

INTRODUCTION

Pyroxasulfone (code name KIH-485) is pyrazole-based herbicide being developed for use in major field crops such as maize, soybean, wheat, and several other crops. It has pre-emergence activity and inhibits shoot elongation of susceptible seedling plants by inhibiting the biosynthesis of very-long-chain fatty acids (Tanetani *et al.* 2009). Both the mechanism of action and probable use patterns for pyroxasulfone is similar to those of metolachlor. Synthesis and early development of pyroxasulfone was done by Japan-based Kumiai Chemical Industry Co., Ltd. Kumiai has entered into development and distribution agreements with multiple companies for specific uses (crops and premixed products) of pyroxasulfone for other major world markets.

Extensive research in several countries has shown that pyroxasulfone selectively controls many common annual grass and broadleaf weed species at lower use rates than other acetanilide herbicides. Geier *et al*. (2006) reported the effective use rates of pyroxasulfone were approximately 12% of *S*-metolachlor use rates (125 to 500 g/ha versus 1,070 to 4,260 g/ha, respectively). Dose-response curves showed pyroxasulfone at 200 to 300 g ai/ha provided excellent control of most grasses and certain broadleaf species in maize for at least the first 4 weeks of the growing season on soils with up to 3% organic matter (Knezevic *et al.* 2009).

Most early development research has focused on maize and soybean with lesser efforts in other crops. Limited testing in 2004 and 2005 indicated sunflower exhibited sufficient tolerance to pyroxasulfone to warrant expanded testing to refine use rates and evaluate herbicide combinations for broader spectrum weed control. Sulfentrazone is widely used in sunflower in the U.S. for control of broadleaf weeds but it has little activity on grass weeds and is usually tank mixed with *S*-metolachlor or pendimethalin for broad spectrum weed control. Thus, sulfentrazone is a prime candidate to tank mix with pyroxasulfone. In 2006 to 2008, the (U.S.) National Sunflower Association provided partial funding to evaluate weed control efficacy and sunflower tolerance to pyroxasulfone applied pre-emergence alone and in combination with sulfentrazone at several sites in central and northern regions of the U.S. Great Plains.

MATERIAL AND METHODS

Field trials were conducted at eight rainfed sites from Kansas (KS) to North Dakota (ND) in 2006, 2007, and 2008 using standardized protocols. Experiments were randomized complete blocks with three or four treatment replications. Depending on year, treatments consisted of pyroxasulfone at three or four rates based on soil texture at each site, sulfentrazone at two rates, and combinations of the two herbicides at those rates plus one or more commercial standard treatments and an untreated check. Treatments were replicated three or four times. Herbicides were applied pre-emergence to crop and weeds using tractor-mounted or backpack research sprayers. Plots were 3 ± 1 by 8 ± 1 m. Soil types ranged from silt loam to clay loam with 1.6 to 3.8% organic matter and pH 5.5 to 8.3. Agronomic practices for sunflower production were typical for the areas. Sunflower were sown at rates of 42,000 to 59,000 seed/ha with higher populations in wetter environments. Seldom was the same sunflower hybrid grown at more than one site.

Weed control and crop response were visually rated multiple times using a scale of 0 = no weed control or crop injury to 100 = complete weed control or crop mortality. The two middle rows of individual plots in most trials were machine harvested and seed yields adjusted to 10% moisture. Seed yields were not determined in four experiments for various reasons. All data were subjected to analysis of variance with mean separation at the 5% level of probability.

RESULTS

Pyroxasulfone caused no visible crop injury at six of eight sites in 2006 and no visible injury at any site at expected use rates of 166 to 332 g/ha in 2007 or 2008 (data not shown). In ND in 2006, pyroxasulfone at rates of 286 to 358 g/ha injured sunflower 17 to 24%, but yield was not reduced (Zollinger *et al.* 2007). Over the three-year period, 2X pyroxasulfone use rates caused <10% injury in 5 of 24 experiments and 17% injury in one experiment at 4 weeks after treatment. However, the sunflower recovered fully and seed yield was not reduced. In the large majority of trials, tank mixing sulfentrazone with pyroxasulfone did not increase risk of crop injury.

In western KS in 2006, pyroxasulfone at 166 g/ha controlled green foxtail (*Seterai viridis* L.), Russian thistle (*Salsola tragus* L.), puncturevine (*Tribulus terrestris* L.), redroot pigweed (*Amaranthus retroflexus* L.) and tumble pigweed (*Amaranthus albus* L.) by 83% or greater, but pyroxasulfone at rates as high as 418 g/ha did not control kochia [*Kochia scoparia* (L.) Roth] by more than 70% (Table 1). At least 210 g/ha of pyroxasulfone was needed to control Russian thistle and green foxtail more than 90%. Nearly doubling pyroxasulfone rate from 210 to 418 g/ha did not significantly increase control of any weed species except kochia in one of the two trials shown in Table 1. The lowest rate of pyroxasulfone tested controlled most species as well or better than common use rates of *S*-metolachlor or pendimethalin. This finding is consistent with results of other trials not shown. Kochia is a major broadleaf weed in sunflower, thus an effective broadleaf herbicide must be mixed with pyroxasulfone to achieve a level of acceptable control.

Table 1. Mid-season percentage weed control in sunflower at two sites in the central Great Plains in 2006.

		Tribune, KS					Hays, KS			
Herb[a]	Rate	Ruth[b]	Koch[b]	Tupw[b]	Rrpw[b]	Puvi[b]	Grft[b]	Koch[b]	Tupw[b]	Rrpw[b]
	g ai/ha	%								
Pyro	166	83	65	93	92	86	83	38	95	93
Pyro	210	91	70	97	92	91	94	53	99	95
Pyro	332	94	63	97	94	91	93	62	98	99
Pyro	418	93	70	99	99	92	94	73	98	99
Meto	1410	70	41	84	74	80	95	43	96	99
Pend	1400	65	46	66	65	81	91	53	99	65
LSD 0.05		15	21	17	17	10	10	18	ns	20

[a] Pyro, pyroxasulfone; meto, *S*-metolachlor; pend, pendimethalin

[b] Grft = green foxtail, *Setaria viridis*; Koch = kochia, *Kochia scoparia*; Puvi = puncturevine, *Tribulus terrestris*; Rrpw = redroot pigweed, *Amaranthus retroflexus*; Tupw, tumble pigweed, *Amaranthus albus*

In the northern Great Plains, there was a general trend of increasing weed control as pyroxasulfone rate was increased from 166 to 332 g/ha with the majority of increased control occurring when rate was increased from 166 to 210 g/ha (Table 2). Yellow foxtail [*Setaria pumila* (Poir.) Roem. & Schult.] and redroot pigweed control at Prosper, ND in 2006, marsh elder (*Iva frutescens* L.) control at Valley City, ND in 2007, and green foxtail control at Highmore, South Dakota (SD) in 2007 increased further as rate was increased from 210 to 250 g/ha. There was little or no benefit gained from increasing pyroxasulfone rate to 298 g/ha. A tank mixture of 166 g/ha of pyroxasulfone and 105 g/ha of sulfentrazone controlled redroot pigweed, common lambsquarters (*Chenopodium album* L.), marsh elder, and green foxtail better than either herbicide alone at those rates.

Table 2. Mid-season percentage weed control in sunflower at three sites in the northern Great Plains in 2006 and 2007.

Prosper, ND 2006	Valley City, ND	Highmore, SD

Herb[a]	Rate	Yeft[b]	Rrpw[b]	Colq[b]	Hans[b]	Mael[b]-06	Mael-07	Grft[b]-06	Grft-07	Grft-08
	g ai/ha	%								
Pyro	166	75	70	77	80	83	50	85	90	75
Pyro	210	78	91	92	88	91	60	88	91	83
Pyro	250	88	96	96	91	92	85	93	98	90
Pyro	298	86	96	97	94	-	-	94	97	-
Pyro + sulf	166 + 105	83	97	97	76	94	99	-	93	86
LSD 0.05		11	4	8	9	7	20	7	3	6

[a] Pyro, pyroxasulfone; sulf, sulfentrazone

[b] Colq = common lambsquarters, *Chenopodium album*; Grft = green foxtail, *Setaria viridis*; Hans = hairy nightshade, *Solanum sarrachoides*; Mael = marsh elder, *Iva frutescens*; Rrpw = redroot pigweed, *Amaranthus retroflexus*; Yeft = yellow foxtail, *Setaria lutescens*

Tank mixtures of pyroxasulfone at 166 g/ha and sulfentrazone at 105 g/ha seldom provided improved control of most weed species compared to either herbicide alone at those rates in the central Great Plains in 2008 (Table 3), but the same tank mixture often provided better control of the species evaluated than either herbicide alone in the northern Great Plains (Table 4). The data clearly show, however, that sulfentrazone is necessary for acceptable kochia control and sulfentrazone improves the control of other important broadleaf weed species.

DISCUSSION

Results of these and other similar field trials not shown here indicate pyroxasulfone when activated by rain or irrigation controls many annual grass and broadleaf weeds as well or better at rates three to eight-times lower than herbicides currently registered for use in sunflower. Tank mixing pyroxasulfone with sulfentrazone broadens the spectrum of weeds controlled and improves the control of certain species. Sunflower has demonstrated excellent tolerance to pyroxasulfone with only occasional injury that did not reduce seed yield. Collectively, these studies conducted over a wide range of soil and environmental conditions indicate pyroxasulfone has potential for pre-emergence weed control in sunflower. However, additional trials are needed to determine whether mixtures of pyroxasulfone and sulfentrazone or other herbicides will consistently provide improved broad spectrum weed control compared to the herbicides currently available to U.S. sunflower growers.

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Table 3. Mid-season percentage weed control in sunflower at two sites in the central Great Plains in 2008.

		Garden City, KS			Hays, KS			
Herbicides	Rate	Koch[a]	Rrpw[a]	Puvi[a]	Tupw[a]	Puvi	Lcgr[a]	Stgr[a]
	g/ha	%						
Pyroxasulfone	166	74	80	35	71	63	58	70
	210	83	85	35	58	64	55	63
	332	88	91	50	99	82	70	99
Sulfentrazone	105	99	99	51	63	44	23	28

	140	99	99	63	74	63	55	50
Pyro + sulf	166+105	99	99	73	91	60	50	63
	166+140	99	99	76	89	61	65	65
	210+105	99	99	74	99	50	58	85
	210+140	99	99	79	98	74	65	93
	332+105	99	99	84	91	63	53	88
	332+140	99	99	90	88	47	65	65
LSD 0.05		5	6	21	23	ns	18	27

[a] Koch = kochia, *Kochia scoparia*; Lcgr = large crabgrass, *Digitaria sanguinalis*; Puvi = puncturevine, *Tribulus terrestris;* Rrpw = redroot pigweed, *Amaranthus retroflexus*; Tupw = tumble pigweed, *Amaranthus albus*; Stgr = stinkgrass, *Eragrostis cilianensis*

Table 4. Mid-season percentage weed control in sunflower at three sites in the northern Great Plains in 2008.

		Minot, ND		Valley City, ND		Brookings, SD	
Herbicides	Rate	Prpw[a]	Wibw[a]	Ftba[a]	Mael[a]	Grft[a]	Wibw[a]
	g/ha	%					
Pyroxasulfone	166	67	47	40	43	75	67
	210	71	58	50	53	83	68
	332	81	70	75	85	90	80
Sulfentrazone	105	80	90	30	27	50	63
	140	84	92	47	58	65	75
Pyro + sulf	166+105	93	86	67	73	86	81
	166+140	95	90	53	65	90	83
	210+105	98	95	72	77	92	83
	210+140	99	97	72	81	88	85
	332+105	98	96	50	67	88	85
	332+140	97	92	72	89	93	65
LSD 0.05		13	12	6	10	8	12

[a] Ftba = foxtail barley, *Hordeum jubatum*; Grft, green foxtail, *Setaria viridis*; Mael = annual marsh elder, *Iva frutescens*; Prpw = prostrate pigweed, *Amaranthus blitoides*; Wibw = wild buckwheat, *Polygonum convolvulus*

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