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Control of Rattail Fescue (*Vulpia myuros*) in No-Till Winter Wheat

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Rattail fescue is a problematic weed for small grain producers in the Pacific Northwest when no-till production practices are used. Pyroxsulam and pyroxasulfone are two herbicides not previously evaluated for control of rattail fescue. Pyroxasulfone provided levels of control (> 74%) similar to flufenacet. Pyroxsulam did not consistently control (21 to 71%) rattail fescue. Rattail fescue biomass was reduced by pyroxasulfone and flufenacet compared to the nontreated control. Effective consistent rattail fescue control was only achieved where PRE herbicides were used. When managing rattail fescue, PRE herbicides pyroxasulfone and flufenacet plus metribuzin are essential components of an integrated management strategy.

Nomenclature: Flufenacet; pyroxasulfone; pyroxsulam; rattail fescue, Vulpia myuros (L.) K.C. Gmel., VLPMY; wheat, *Triticum aestivum* L.

Key words: Direct seed, herbicide efficacy, no-till.

Vulpia myuros es una maleza problemática para los productores de granos en el Pacífico Noroeste de Estados Unidos cuando se usan prácticas de producción de labranza cero. Pyroxsulam y pyroxasulfone son dos herbicidas que no han sido evaluados previamente para el control de *V. myuros*. Pyroxasulfone brindó niveles de control (>74%) similares a flufenacet. Pyroxsulam no controló *V. myuros* consistentemente (21 a 71%). La biomasa de *V. myuros* fue reducida por pyroxasulfone y flufenacet al compararse con el testigo sin tratamiento. Un control efectivo y consistente de *V. myuros* se alcanzó solamente donde se usó herbicidas PRE. Al manejar *V. myuros*, los herbicidas PRE pyroxasulfone y flufenacet más metribuzin son componentes esenciales para una estrategia de manejo integrada.

Rattail fescue is an introduced winter annual grass native to Eurasia (Jemmett et al. 2008) with a life cycle similar to downy brome (*Bromus tectorum* L.) and jointed goatgrass (*Aegilops cylindrica* Host) (Ball et al. 2007). Rattail fescue emergence in disturbed soils is poor and it is intolerant of tillage (Ball et al. 2008); however, rattail fescue is well adapted to low-disturbance cropping systems. Rattail fescue forms thick competitive "tufts" in winter wheat that remain after the plant has completed its life cycle (Jemmett et al. 2008). Tufts continue to accumulate in subsequent years, eventually forming residual mats that can interfere with crop establishment and planter operations. In addition to rattail fescue forming a physical barrier to crop establishment, Kato-Noguchi et al. (2010) identified 3-hydroxy-b-ionone and 3-oxo-a-ionol as allelopathic compounds contained in rattail fescue residue. Both compounds inhibit growth in a number of plant species, including Italian ryegrass [*Lolium multiflorum* (Lam.) Husnot], large crabgrass [*Digitaria sanguinalis* (L.) Scop.], and timothy (*Phleum pretense* L.) (Kato-Noguchi et al. 2010).

Rattail fescue usually occurs when growers reduce or eliminate soil disturbance. Surveys of grower practices taken in 1975, 1990, and 2005 have documented adoption of minimal-disturbance production systems increasing from 0% to greater than 60% of growers, depending on precipitation zones, among Pacific Northwest (PNW) wheat growers (Kok 2007). A field study evaluating the agronomics of no-till adoption by Schillinger et al. (2010) compared no-till winter wheat systems to traditional systems of inversion tillage and residue burning. Agronomic benefits from no-till winter wheat production included improved overwinter precipitation storage efficiency, increased soil organic carbon, and increased winter wheat yields compared to traditional inversion tillage (Schillinger et al. 2010). However, new pest problems emerged with adoption of no-till production, including a higher incidence of take-all in wheat and a shift from downy brome to rattail fescue as the predominant weed species (Schillinger et al. 2010). The same study concluded that the severity of rattail fescue

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infestation may require periodic tillage or fallow rotations, which would jeopardize many agronomic benefits of no-till production. Weed control in minimal-disturbance production systems depends on timely glyphosate applications prior to planting. Normally well controlled by tillage, rattail fescue is tolerant to typical use rates of glyphosate (Ball et al. 2007; Jemmett et al. 2008). With the decrease in tillage and the increase in reliance on glyphosate, PNW wheat producers need alternative effective management options for rattail fescue in no-till winter wheat.

Previous research by Ball et al. (2007) evaluated PRE and POST herbicide treatments used alone and sequentially for rattail fescue control at five research sites across the PNW. Control of rattail fescue with flufenacet PRE alone or followed by diuron, imazamox, mesosulfuron, or sulfosulfuron POST was 80% or greater across all locations in the first study year. Control was achieved in the second year at all locations but Pullman, WA (Ball et al. 2007). Rattail fescue was more abundant at the Pullman location in the second year than at all other sites. However, flufenacet applied PRE alone or in combination provided greater control compared to other herbicides and combinations at the Pullman location (Ball et al 2007). Ball et at. (2007) noted that no herbicide was currently registered at the time of publication for control of rattail fescue; although their results suggest flufenacet herbicide programs as a potential management tool for PNW dryland conditions.

Pyroxsulam and pyroxasulfone are new herbicides for grass weed control in wheat, and have not been evaluated for rattail fescue control. Pyroxsulam is a broad-spectrum acetolactate synthase–inhibiting (group 2) herbicide labeled for grass and broadleaf weed control in wheat (Wells 2008). Pyroxsulam controls wild oat (*Avena fatua* L.), bromes (*Bromus* spp. Scoop.), and rigid ryegrass (*Lolium rigidum* Gaudin) as well as the herbicides mesosulfuron, iodosulfuron, and sulfosulfuron (Wells 2008). Pyroxasulfone is a broad-spectrum soil-applied very-long-chain fatty acid elongation-inhibiting (group 15) herbicide for control of several grass and broadleaf weed species. Pyroxasulfone was evaluated for ryegrass control by Hulting et al. (2012) and performed similarly to flufenacet and flufenacet plus metribuzin, and better than diuron. Therefore, two studies were conducted to evaluate pyroxsulam and pyroxasulfone for rattail fescue control. The objectives of the first study were to evaluate pyroxsulam timing when applied alone or used in sequential herbicide treatments, and to evaluate the use of ammonium sulfate (AMS) as an adjuvant with pyroxsulam. The objective of the second study was to determine the optimal rate for pyroxasulfone used alone or as a sequential herbicide treatment, and compare pyroxasulfone efficacy to flufenacet applied in the fall and pyroxsulam applied in the spring.

Methods and Materials

Field studies were established to evaluate pyroxsulam and pyroxasulfone for rattail fescue control in no-till winter wheat. Studies were located at the Palouse Conservation Field Station near Pullman, WA. A natural infestation of rattail fescue was present at the study location and the site had been managed using no-till practices for the past 12 seasons. Both studies were randomized complete block design with four replications. Plot dimensions were 2.4 m by 9.1 m. Wheat was planted on 25.4-cm rows using a direct-seed drill with a hoe opener at 112 kg ha^{-1}. Seeds were placed 4 cm below the soil surface. Studies planted in 2009 and 2010 were planted with the soft white wheat variety ‘Madsen’, and studies planted in 2011 were planted with the soft white wheat variety ‘AP 700CL’. In all study years, seed was treated with thiamethoxam for wireworm control and, mefenoxam and difenoconazole for control of fungal diseases. Herbicides were applied utilizing a backpack sprayer calibrated to deliver 140 L ha^{-1} at 165 kPa using 11002 nozzles (TeeJet®, Springfield, IL). Rattail fescue was not yet emerged when fall application were made. Rattail fescue varied in height from 2 to 5 cm at the timing of the first spring application, and from 4 to 8 cm in height when the second spring application was made. In all years, rattail fescue was between one and three tillers and in the vegetative growth stage when spring applications were made.

Pyroxsulam Study. The first study evaluating pyroxsulam was established during the 2009 to 2010 growing season and repeated the following two seasons. Fall applications consisted of a prepackaged mixture (Table 1) of flufenacet (304 g ai ha^{-1}) and metribuzin (76 g ai ha^{-1}) (Table 2). Early POST spring and late POST spring applica-

Table 1. Herbicide trade and common names.

Trade name	Formulation	Common name	% Weight	Manufacturer	Location	Website
AXIOM®	DF[a]	Flufenacet	54.4	Bayer Crop Science	RTP, NC	http://www.cropscience.bayer.com
		Metribuzin	13.6			
GoldSky®	OD	Florasulam	0.2	Dow AgroSciences LLC	Indianapolis, IN	http://www.dowagro.com
		Fluroxypyr	11.57			
		Pyroxsulam	1.2			
Osprey®	WG	Mesosulfuron-methyl	4.5	Bayer Crop Science	RTP, NC	http://www.cropscience.bayer.com
PowerFlex®	WG	Pyroxsulam	7.5	Dow AgroSciences LLC	Indianapolis, IN	http://www.dowagro.com
Zidua®	WG	Pyroxasulfone	85.0	BASF	RTP, NC	http://www.agro.basf.com

[a] Abbreviations: DF, dry flowable; ODoil dispersionWG, water-dispensed granule; RTP, Research Triangle Park.

tions consisted of pyroxsulam (18 g ai ha^{-1}); mesosulfuron-methyl (15 g ai ha^{-1}); or a prepackaged mixture of florasulam (2.5 g ai ha^{-1}), fluroxypyr (100 g ae ha^{-1}), and pyroxsulam (15 g ai ha^{-1}) (Table 2). Sequential treatments included a prepackaged mixture of flufenacet and metribuzin followed by a late spring application of pyroxsulam; mesosulfuron-methyl; or a prepackaged mixture of florasulam, fluroxypyr, and pyroxsulam. Nonsequential early and late spring pyroxsulam applications alone or as a prepackaged mix were applied with and without AMS (1.7 kg ha^{-1}) (Table 2). When pyroxsulam, either alone or as a prepackaged mixture, was applied sequentially following flufenacet in the fall, AMS (1.7 kg ha^{-1}) was included as an adjuvant. Nonionic surfactant (NIS) was used as an adjuvant at 0.5% v/v in all pyroxsulam and mesosulfuron applications.

Pyroxasulfone Study. The study to evaluate pyroxasulfone was established during the 2010 to 2011 growing season and repeated the following season. Treatments consisted of fall pyroxasulfone (60, 80, 100, 160, or 220 g ai ha^{-1}) applications and a prepackaged mixture of flufenacet (Table 1) (304 g ha^{-1}) and metribuzin (76 g ha^{-1}). An early POST spring pyroxsulam (18 g ha^{-1}) application also was included. Sequential applications consisted of a fall application of either pyroxasulfone (80 or 100 g ha^{-1}) or a prepackaged mixture of flufenacet and metribuzin followed by late spring pyroxsulam application (Table 3). NIS was used as an adjuvant at 0.5% v/v in all pyroxsulam applications.

Assessments. Visual assessment of rattail fescue control was rated on a percentage basis ranging from 0 to 100% and was conducted in all years of

Table 2. Pyroxsulam application rates and timing for rattail fescue control.

Treatment	Rate	Timing
	g ai or ae ha^{-1}	
Nontreated	—	—
Pyroxsulam	18 ai	Early spring
Pyroxsulam (+ AMS[a])	18 ai (+ 1,700)	Early spring
Pyroxsulam + florasulam + fluroxypyr	15 ai + 2.5 ai + 100 ae	Early spring
Pyroxsulam + florasulam + fluroxypyr (+ AMS)	15 ai + 2.5 ai + 100 ae (+ 1,700)	Early spring
Mesosulfuron	15 ai	Early spring
Pyroxsulam	18 ai	Late spring
Pyroxsulam (+ AMS)	18 ai (+ 1,700)	Late spring
Pyroxsulam + florasulam + fluroxypyr	15 ai + 2.5 ai + 100 ae	Late spring
Pyroxsulam + florasulam + fluroxypyr (+ AMS)	15 ai + 2.5 ai + 100 ae (+ 1,700)	Late spring
Mesosulfuron	15 ai	Late spring
Flufenacet + metribuzin	304 ai + 76 ai	Fall
Flufenacet + metribuzin fb pyroxsulam	304 ai + 76 ai fb 18 ai	Fall fb late spring
Flufenacet + metribuzin fb pyroxsulam + florasulam + fluroxypyr	304 ai + 76 ai fb 11 ai + 2 ai + 105 ae	Fall fb late spring
Flufenacet + metribuzin fb mesosulfuron	304 ai + 76 ai fb 15 ai	Fall fb late spring

[a] Abbrevations: AMS, ammonium sulfate; fb, followed by.

Table 3. Pyroxasulfone rates and application timing for rattail fescue control.

Treatment	Rate	Timing
	g ai ha^{-1}	
Nontreated	—	—
Pyroxsulam	18	Early spring
Pyroxasulfone	60	Fall
Pyroxasulfone	80	Fall
Pyroxasulfone	100	Fall
Pyroxasulfone	160	Fall
Pyroxasulfone	200	Fall
Flufenacet + metribuzin	304 + 76	Fall
Pyroxasulfone fb[a] pyroxsulam	80 fb 18	Fall fb late spring
Pyroxasulfone fb pyroxsulam	100 fb 18	Fall fb late spring
Flufenacet + metribuzin fb pyroxsulam	304 + 76 fb 18	Fall fb late spring

[a] Abbrevation: fb, followed by.

Table 4. Timing of field operations and treatment applications, and seasonal precipitation.

Field operations	2009–2010	2010–2011	2011–2012
Planting	October 28	October 10	October 14
Fall applications	November 4	October 28	November 7
Early spring applications	March 16	April 12	April 23
Late spring applications	April 19	May 11	May 7
Injury ratings	July 1	July 7	June 27
Weed biomass sampling	September 3	September 1	Augu 10
Grain harvest	September 3	September 21	Augu 15
Season precipitation[a]	44 cm	55 cm	55 cm

[a] Seasonal precipitation; October 1 until harvest date.

both studies in the first week of July (Table 4). Rattail fescue aboveground biomass and grain yield were collected in all years of the pyroxsulam and pyroxasulfone study. Rattail fescue aboveground biomass was measured prior to grain harvest by collecting two 0.1-m^2 samples per plot. Biomass values from each plot were averaged together prior to analysis. Grain was harvested each year of the pyroxsulam study, and at the conclusion of the 2011 to 2012 season of the pyroxasulfone study. Grain was not harvested during the 2010 to 2011 season due to the presence of jointed goatgrass that would cause combine contamination. Although the density of jointed goatgrass did prevent harvesting of grain, it did not affect rattail fescue density. Grain was harvested from a 1.5- by 8-m area in each plot using a small-plot combine. Yield per plot was recorded with the Classic Grain Gauge combine mounted plot harvest data system (Juniper Systems, Inc., Logan UT).

Statistical Analysis. ANOVA was conducted using the analysis of variance) function in R to test for significance of herbicide treatment and trial year (R Development Core Team, version 3.0.2, R Foundation for Statistical Computing, Vienna, Austria). Fixed effects consisted of herbicide treatment, year, interaction of treatment by year, and block. Response variables consisted of rattail fescue control, rattail fescue biomass, and grain yield. All ANOVA models were checked for linearity, homoscedasticity, and normality. Significant results ($\alpha = 0.05$) underwent post-hoc analysis with Fisher's protected LSD using the LSD test function in the agricolae package in R (Agricolae R package version 1.1–4, Felipe de Mendiburu, Lima, Peru).

Assessment of pyroxasulfone trials using ANOVA and Fisher's protected LSD was restricted to fall-applied pyroxasulfone at 80 or 100 g ai ha^{-1}, fall-applied flufenacet and metribuzin as a prepackaged mixture, spring-applied pyroxsulam, and sequential treatments. Other treatments were considered subsidiary. Nonlinear regression was conducted with pyroxasulfone treatments at 0, 60, 80, 100, 160, and 220 g ai ha^{-1} to determine the effect of rate on control and biomass of rattail fescue and wheat yield. A three-parameter log-logistic regression model (Equation 1) described by Seefeldt et al. (1995) was fit using the drc package in R (Ritz and Streibig 2005; DRC R package version 2.3-96):

$$f(x) = d/\Big(1 + exp\{b[\log(x) - \log(e)]\}\Big)$$

where e is the dose required to induce a 50% response, b is the relative slope at point e, d is the upper limit of the model, and x is the rate of pyroxasulfone.

Results and Discussion

Pyroxsulam. Results from the ANOVA performed on all three seasons of the pyroxsulam study indicated a significant influence of year with rattail fescue control, biomass, and grain yield (for clarity, all studies will be referred to by the year the study was harvested in the Results and Discussion section). When the 2010 season was analyzed

Table 5. Rattail fescue response to pyroxsulam application rates, timing, and other herbicides.

		Rattail fescue control (%)	
Treatment	Timing	2010	2011 and 2012
Non-treated		—	—
Pyroxsulam	Early spring	25	48
Pyroxsulam (+ AMS[a])	Early spring	25	65
Pyroxsulam + florasulam + fluroxypyr	Early spring	22	60
Pyroxsulam + florasulam + fluroxypyr (+ AMS)	Early spring	29	63
Mesosulfuron	Early spring	22	45
Pyroxsulam	Late spring	24	56
Pyroxsulam (+ AMS)	Late spring	26	71
Pyroxsulam + florasulam + fluroxypyr	Late spring	21	67
Pyroxsulam + florasulam + fluroxypyr (+ AMS)	Late spring	27	51
Mesosulfuron	Late spring	21	56
Flufenacet + metribuzin	Fall	84	73
Flufenacet + metribuzin fb pyroxsulam	Fall fb late spring	75	82
Flufenacet + metribuzin fb pyroxsulam + florasulam + fluroxypyr	Fall fb late spring	87	81
Flufenacet + metribuzin fb mesosulfuron	Fall fb late spring	84	83
	LSD (0.05)	7	15

[a] Abbrevations: AMS, ammonium sulfate; fb, followed by.

separately from the 2011 and 2012 seasons, there was no significant influence of year. Differing response between the 2010 and later seasons is likely due to late planting in 2009 that resulted in poor crop establishment (Table 4). Treatment effects on rattail fescue control, biomass, and grain yield were significant for 2010 alone and the combined years. Mean separation using Fischer's protected LSD ($\alpha = 0.05$) was performed on rattail fescue control, biomass, and grain yield through all seasons. The 2011 and 2012 seasons were combined for post-hoc analysis for control of rattail fescue, rattail fescue biomass, and grain yield.

In 2010, all POST spring applications failed to provide control greater than 30% control (Table 5). In the 2011 and 2012 seasons, spring-applied herbicides provided greater control (48 to 71%) than in the 2010 season. There was no difference in rattail fescue control due to timing of spring applications during the 2011 and 2012 seasons (Table 5). Addition of AMS only improved rattail fescue control when pyroxsulam was applied alone in the early spring. Treatments receiving a fall application of flufenacet plus metribuzin had the highest control (73 to 87%) of rattail fescue across all years. In all study years, fall applications followed by late spring applications did not significantly improved rattail fescue control compared to flufenacet plus metribuzin applied alone (Table 5).

Late POST spring applications of mesosulfuron and pyroxsulam as part of a prepackaged mixture failed to reduce rattail fescue biomass compared to nontreated plots in 2010 (Table 6). During the 2011 and 2012 seasons, early spring applications of pyroxsulam applied without AMS and mesosulfuron did not reduce rattail fescue biomass compared to nontreated control. Of the late spring applications made during the 2011 and 2012 seasons, only pyroxsulam applied alone with AMS reduced rattail fescue biomass compared to the nontreated plots (Table 6). In 2010, early spring applications of pyroxsulam applied as part of a prepackaged mixture significantly reduced rattail fescue biomass and increased grain yield compared to late spring applications. In the 2011 and 2012 seasons, only prepackaged pyroxsulam treatments applied with AMS significantly reduced rattail fescue biomass and increased grain yield when applied in the early spring compared to late spring applications. There was no decrease in rattail fescue biomass or increase in grain yield when a fall application of flufenacet and metribuzin was followed by a sequential spring application.

Ball et al. (2007) reported mesosulfuron alone provided 5 to 85% rattail fescue control across five locations over 2 yr, and flufenacet treatments provided 60 to 74% control of rattail fescue at a site near Pullman, WA. The results of the pyroxsulam study are similar to the range of rattail fescue

Table 6. Rattail fescue biomass and grain yield response to pyroxsulam application rates, timing, and other herbicides.

		Rattail fescue biomass		Grain yield	
Treatment	Timing	2010	2011 and 2012	2010	2011 and 2012
		$g\ m^{-2}$		$kg\ ha^{-1}$	
Non-treated		202	135	1,510	2,670
Pyroxsulam	Early spring	70	89	2,290	3,110
Pyroxsulam (+ AMS[a])	Early spring	57	50	2,330	4,070
Pyroxsulam + florasulam + fluroxypyr	Early spring	89	91	2,380	4,230
Pyroxsulam + florasulam + fluroxypyr (+ AMS)	Early spring	58	35	2,560	4,260
Mesosulfuron	Early spring	106	71	2,280	3,300
Pyroxsulam	Late spring	89	115	2,070	3,560
Pyroxsulam (+ AMS)	Late spring	89	34	1,950	3,310
Pyroxsulam + florasulam + fluroxypyr	Late spring	177	80	1,670	3,980
Pyroxsulam + florasulam + fluroxypyr (+ AMS)	Late spring	185	100	1,820	2,980
Mesosulfuron	Late spring	122	75	2,140	3,710
Flufenacet + metribuzin	Fall	42	33	2,320	3,290
Flufenacet + metribuzin fb pyroxsulam	Fall fb late spring	17	37	2,680	4,010
Flufenacet + metribuzin fb pyroxsulam + florasulam + fluroxypyr	Fall fb late spring	51	30	2,680	3,640
Flufenacet + metribuzin fb mesosulfuron	Fall fb late spring	28	23	2,730	4,230
	LSD (0.05)	82	69	580	1,060

[a] Abbrevations: AMS, ammonium sulfate; fb, followed by.

control values reported by Ball et al. (2007) for single spring POST applications, whereas greater levels of rattail fescue control were observed with flufenacet treatments. Mesosulfuron alone controlled rattail fescue 21 to 56% and flufenacet treatments controlled rattail fescue 73 to 84%. Pyroxsulam appears to have activity on rattail fescue, but that activity is inconsistent, as observed by the variable control between the first and latter two seasons. The inconsistent control with spring-applied pyroxsulam is mainly attributed to late planting of winter wheat in 2009 allowing for a more competitive rattail fescue population at the time of spring applications. Chemical management of rattail fescue will require other inputs in addition to pyroxsulam.

Pyroxasulfone. Rattail fescue control was combined for both years since there was no significant interaction of year by treatment (Table 7). Rattail fescue biomass interaction was significant between years and was separated by year (Table 7). Rattail fescue control with fall-applied herbicide treatments was greater than with spring-applied pyroxsulam alone (Table 7). Pyroxasulfone applied alone provided similar control as a prepackaged mixture of flufenacet and metribuzin. Control was improved when pyroxasulfone was applied alone at 100 g ha^{-1} compared with 80 g ha^{-1} (Table 7). Following a fall application of either pyroxasulfone or flufenacet and metribuzin with a spring application of pyroxsulam only improved control when pyroxasulfone was applied at 80 g ha^{-1} (Table 7).

Rattail fescue biomass was significantly reduced in all treatments compared to the nontreated plots in both seasons (Table 7). There was no difference in rattail fescue biomass among nonsequential fall-applied herbicide treatments or between sequential fall-applied herbicides and spring-applied pyroxsulam. Following a fall-applied herbicide with a spring-applied pyroxsulam application significantly reduced biomass when pyroxasulfone was applied at 220 g ai ha^{-1} in the 2011 growing season. In the 2012 growing season all herbicide treatments reduced rattail fescue biomass compared to the nontreated plots. No differences in grain yield were observed in the 2012 season (Table 7).

Based upon the results of nonlinear stepwise regression, study year was combined for both response variables for log-logistic regression analysis. Log-logistic regression analysis of rattail fescue control (Figure 1) returned an estimated effective dose for 50% control (ED_{50}) of 87.8 g ai ha^{-1} for control with pyroxasulfone (Table 8). Log-logistic regression analysis of rattail fescue biomass (Figure 1) returned an estimated effective dose for 50%

Table 7. Rattail fescue control and biomass, and wheat grain yield response to pyroxasulfone and other herbicides.

Treatment	Rate	Timing	Control 2011 and 2012	Biomass 2011	Biomass 2012	Yield 2012
	g ai ha^{-1}		%	g m^{-2}	g m^{-2}	kg ha^{-1}
Nontreated	—	—	—	199	165	3,760
Pyroxsulam	18	Early spring	63	95	41	3,320
Pyroxasulfone	80	Fall	74	81	0	3,540
Pyroxasulfone	100	Fall	85	44	0	3,580
Fluflufenacet + metribuzin	304 + 76	Fall	83	47	0	3,010
Pyroxasulfone fb[a] pyroxsulam	80 fb 18	Fall fb late spring	91	27	0	3,800
Pyroxasulfone fb pyroxsulam	100 fb 18	Fall fb late spring	93	22	0	3,040
Flufenacet + metribuzin fb pyroxsulam	304 + 76 fb 18	Fall fb late spring	91	30	1	3,310
		LSD (0.05)	10	53	52	NS

[a] Abbreviation: fb, followed by.

reduction in biomass (ED_{50}) of 162 g ai ha^{-1} for reduction in biomass with pyroxasulfone (Table 8).

Ball et al. (2007) reported flufenacet applied in the fall alone or followed by spring-applied diuron, imazamox, mesosulfuron, or sulfosulfuron provided greater than 80% control in all but one study location. Results from pyroxsulam and pyroxasulfone studies presented here agree with the findings of Ball et al. (2007): single fall applications of flufenacet (73 to 84% control) and fall flufenacet applications followed by spring-applied herbicides (75 to 91% control) are effective for control of rattail fescue.

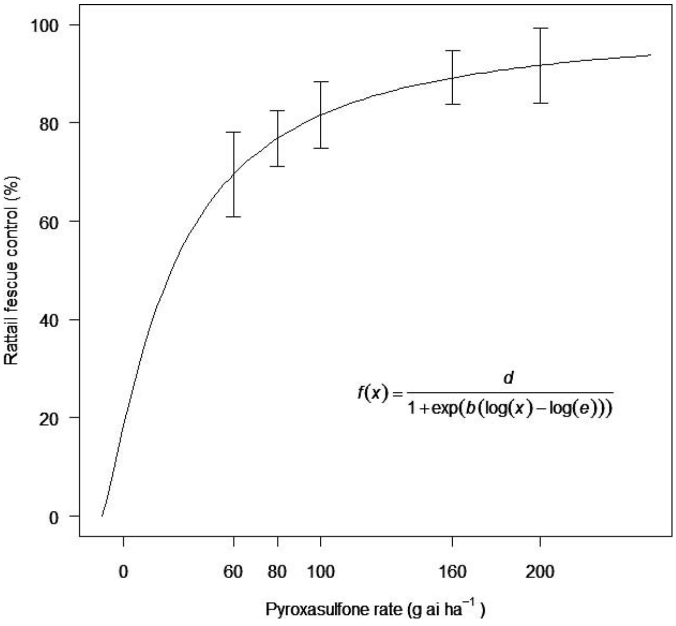

Figure 1. Rattail fescue control with fall-applied pyroxasulfone.

Fall-applied pyroxasulfone and flufenacet plus metribuzin resulted in greater levels of rattail fescue control ($>$ 74%) compared to spring-applied pyroxsulam and mesosulfuron (21 to 71%) and reduced rattail fescue biomass compared with nontreated plots (135 to 202 g m^{-2} vs. 0 to 51 g m^{-2}). Significance varied year to year, along with the performance of spring-applied pyroxsulam and mesosulfuron. Spring-applied POST herbicides did not consistently control rattail fescue. However, fall-applied flufenacet plus metribuzin and pyroxasulfone were consistent year to year. Addition of a sequential spring-applied POST herbicide treatment to a fall-applied herbicide treatment only improved rattail fescue control when pyroxasulfone was applied in the fall at a low dose. There was little utility of using spring-applied treatments when pyroxasulfone was used at high rates for control of rattail fescue. AMS improved the performance of pyroxsulam in only limited years and only when pyroxsulam was applied in the early spring. However pyroxsulam, with or without AMS, did not provide adequate or consistent rattail fescue control. In both studies evaluating pyroxsulam and pyroxasulfone, rattail fescue biomass largely reflected patterns observed with control ratings. The use

Table 8. Log-logistic regression parameters.

Response variable	Parameter estimate (SE)[a] b	d	e
Control (%)	−1.29 (1.56)	100 (24.8)	31.9 (11)
Biomass (g m^{-2})	1.63 (0.709)	199 (22)	58.9 (15.4)

[a] Abbreviations: *e*, the dose required to induce a 50% response, *b*, the relative slope at point *e*, *d*, the upper limit of the model.

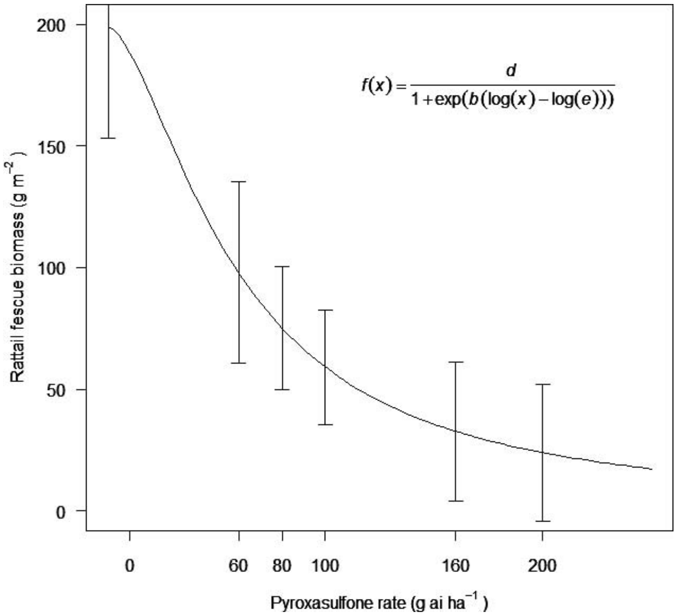

Figure 2. Rattail fescue biomass as influenced by fall-applied pyroxasulfone.

of PRE herbicides in the PNW is not a common practice. However, effective consistent rattail fescue control was only achieved where PRE herbicides were used. When managing rattail fescue, PRE herbicides pyroxasulfone and flufenacet plus metribuzin are essential components of an integrated management strategy.

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