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Control of Rattail Fescue (*Vulpia myuros*) in Winter Wheat

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Rattail fescue, a winter annual grass weed, has been increasing in Pacific Northwest (PNW) dryland cereal producing areas. Although rattail fescue is not a new weed species in the PNW, its incidence is expanding rapidly in circumstances where soil disturbances are minimized such as in direct seed systems. Options for effective rattail fescue control in winter wheat cropping systems have not been adequately investigated and need to be developed. Rattail fescue control with herbicide treatments was investigated in imidazolinone-resistant winter wheat using imazamox and other herbicides. Across multiple sites and two growing seasons, crop injury from herbicide treatments was minor to negligible with some exceptions. Treatments containing imazamox or mesosulfuron produced minor, transient winter wheat crop injury at some locations in some years. With the exception of flufenacet applied preemergence (PRE), control of rattail fescue in wheat was variable with single herbicide applications, but improved with sequential herbicide treatments. Rattail fescue biomass was greatly reduced by several treatments especially those containing flufenacet or from sequential herbicide application. Crop yield varied among sites due to growing season precipitation, and in some cases from rattail fescue control or herbicide related crop injury.

Nomenclature: diuron; flufenacet; imazamox; mesosulfuron; pendimethalin; sulfosulfuron; rattail fescue, *Vulpia myuros* (L.) K.C. Gmel. VLPMY; winter wheat, *Triticum aestivum* L. 'ClearFirst'®.

Key words: herbicide efficacy, direct seed, no-till, zero-till, imidazolinone-resistant winter wheat.

Concerns have been increasing among PNW dryland wheat producers about the increasing incidence of rattail fescue in direct seed cropping systems. Rattail fescue is a winter annual grass with a life cycle similar to that of other annual grass weeds of wheat such as downy brome (*Bromus tectorum* L.), and jointed goatgrass (*Aegilops cylindrica* Host). Seed will germinate in autumn under cool soil temperatures and adequate soil moisture. A vernalization requirement must be met before flowering and seed set the following spring (Dillon and Forcella 1984; Wallace 1997). Although rattail fescue has been previously reported as a weed problem in Australian cereal production (Wallace 1997), its prevalence as a problem in PNW cereal production is more recent as hectarage of direct seed cropping systems has increased. Because rattail fescue is shallowly rooted, it tends to be intolerant of tillage. Direct seed cropping systems, sometimes referred to as no-till, are low soil disturbance systems that require no mechanical tillage other than the soil disturbance produced by the seed drilling operation. The substantial reduction in soil disturbance in direct seed systems results in a heavy reliance on glyphosate for weed control. Control of rattail fescue with glyphosate has been difficult in chemical fallow (Jemmett 2006) and prior to establishment of direct seeded spring or winter cereals (Ball et al. 2005) due to an apparent tolerance to typically used glyphosate application rates. The decreased soil disturbance and increased reliance on glyphosate in direct seed systems favors an increased prevalence and severity of rattail fescue infestations (Dillon and Forcella 1984; Dowling 1996; Wallace 1997). In addition, no selective herbicide treatments are currently registered for rattail fescue control in wheat.

Given the increase in direct seeded winter wheat acres in the PNW, the concomitant increase in rattail fescue, and the current lack of effective herbicides for rattail fescue control in that cropping system, research is needed to address this problem. Therefore, the current study was designed to examine potential PRE and postemergence (POST) herbicide treatments, and several sequential herbicide treatments for rattail fescue control in winter wheat over the diverse range of dryland wheat producing environments that exist in the PNW (Douglas et al. 1990).

Materials and Methods

Study Sites. Five study sites were established in the fall of 2003 and again in the fall of 2004 to evaluate herbicide treatments for rattail fescue control in dryland winter wheat. Study sites were located across a broad range of PNW dryland winter wheat environments and represent wheat growing environments where rattail fescue infestations occur. Crop rotations at study sites consisted of winter wheat followed by summer fallow, or continuous winter wheat. Sites were not necessarily direct seeded but were selected to provide an adequate infestation of rattail fescue for study purposes. In Oregon, studies were established near Corvallis at the Oregon State University Hyslop Field Station in a high-rainfall location (1,109 mm/yr average precipitation), and at a second site near Pendleton at the Columbia Basin Agricultural Research Center in an intermediate rainfall location (429 mm/yr). In Idaho, field studies were established near

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Moscow, at the University of Idaho Parker Research Farm (665 mm/yr), and at the University of Idaho Kambitsch Research Farm near Genesee, ID (521 mm/yr). In Washington, a field location near Pullman at the U.S. Department of Agriculture (USDA) Whitman farm (542 mm/yr average precipitation) was utilized that had a naturally occurring population of rattail fescue. The rattail fescue density was low or nonexistent at the Oregon and Idaho sites, so rattail fescue was broadcast seeded at approximately 2 kg/ha and shallowly incorporated with a spike tooth harrow at all Oregon and Idaho sites prior to seeding wheat. A soft white, imidazolinone-resistant winter wheat, 'ClearFirst', was planted at typical times and seeding rates to approximate commercial seeding practices at each location. This imidazolinone-resistant winter wheat variety grown is adapted to PNW growing conditions and responds as a typical soft white wheat except for the herbicide resistance trait. Imidazolinone-resistant winter wheat was used for studies so that direct comparisons could be made between imazamox treatments and more conventional herbicides.

Herbicide Treatments. The experimental design at all locations was a randomized complete block with four replications in each study year. Plots were 2.5 to 3 m by 9 m at all locations. All herbicide treatments were broadcast applied using CO_2 pressurized, handheld boom, backpack sprayers. Sprayers were calibrated to deliver 94 to 112 L/ha at 240 ± 35 kPa using flat fan spray nozzles. Treatments at each location were applications of pendimethalin or flufenacet applied alone PRE; applications of diuron, flufenacet, imazamox, mesosulfuron, or sulfosulfuron applied alone POST; or various combinations of a PRE herbicide followed by a POST herbicide treatment (Table 1). Postemergence treatments, except diuron, included a nonionic surfactant[1] at 0.5 % v/v. Sulfosulfuron, mesosulfuron, and imazamox treatments also included urea ammonium nitrate (UAN) (32–0–0) at 2.5% v/v (Table 1), as per label recommendations. Crop and rattail fescue growth stages at application dates varied at each site and were dictated by crop growth stage, prevailing weather conditions, and time of year (Table 2). At all Idaho study sites, plots were oversprayed with bromoxynil + MCPA[2] at 1.87 L/ha for broadleaf weed control in the spring of 2004 and 2005. At the Oregon and Washington sites, no weeds other than rattail fescue were present.

Data Collection. Rattail fescue control was visually estimated twice to quantify early- and late-season control using a scale from 0% (no control) to 100% (complete control). Early- and late- season weed control evaluations were highly correlated across all locations, so only late-season control results are presented and discussed. Rattail fescue aboveground biomass was collected at or near seed maturity by clipping and bagging all material from two randomly located 0.25-m^2 quadrats in each plot, combined into a single sample, dried for 48 h at 60 C; and weighed. Winter wheat injury was visually estimated two times at each site to quantify early- and late-season crop injury using a scale from 0% (no injury) to 100% (dead). Winter wheat was harvested in a 1.5 m by 8 m area at crop maturity using a small-plot combine. Harvested grain was cleaned with an Almaco cleaner, weighed, and yields expressed as kilograms per hectare.

Statistical Analysis. Results differed between study sites and years across the PNW due to the broad range of environmental conditions that existed among sites. Site differences existed in annual precipitation, elevation, soils, and crop rotation. This broad range of environmental conditions is typical of wheat producing areas infested with rattail fescue in the PNW. The diverse environments across study sites resulted in a high degree of variability in data collected across locations and years. Homogeneity of variance evaluated using Bartlett's tests revealed significant heterogeneity of variance for all measured variables, thereby preventing pooling of data across sites or years. Therefore, data from

Table 1. Herbicide treatment timing and application rates applied to imidazolinone-resistant winter wheat in 2004 and 2005 to sites in Oregon, Idaho, and Washington.[a]

	Treatment[b]	Rate	Timing[c]
		g ai/ha	
1	Nontreated check	—	—
2	Pendimethalin	840	PRE
3	Flufenacet	403	PRE
4	Flufenacet + NIS	403	POST
5	Sulfosulfuron + NIS + UAN	35	POST
6	Mesosulfuron + NIS + UAN	15	POST
7	Diuron	1,120	POST
8	Imazamox + NIS + UAN	53	POST
9	Flufenacet/sulfosulfuron + NIS + UAN	403/35	PRE/POST
10	Flufenacet/mesosulfuron + NIS + UAN	403/15	PRE/POST
11	Flufenacet/diuron	403/1,120	PRE/POST
12	Flufenacet/imazamox + NIS + UAN	403/53	PRE/POST
13	Pendimethalin/flufenacet + NIS	840/403	PRE/POST
14	Pendimethalin/sulfosulfuron + NIS + UAN	840/35	PRE/POST
15	Pendimethalin/mesosulfuron + NIS + UAN	840/15	PRE/POST
16	Pendimethalin/diuron	840/1,120	PRE/POST
17	Pendimethalin/imazamox + NIS + UAN	840/53	PRE/POST

[a] Abbreviations: NIS, nonionic surfactant; UAN, urea ammonium nitrate; PRE, preemergence; POST, postemergence.

[b] NIS applied at 0.5 % v/v and 32% nitrogen (UAN) applied at 2.5% v/v.

[c] PRE and POST application timing.

Table 2. Crop and rattail fescue growth stages at postemergence treatment application at test sites in Oregon, Idaho and Washington in 2003–2004 and 2004–2005 winter wheat growing seasons.

Location	Application date	Crop stage leaf	Rattail stage leaf
Pendleton, OR	March 29, 2004	5 to 7	6 to 8
Pendleton, OR	February 1, 2005	5 to 7	5 to 6
Corvallis, OR	October 29, 2003	2	2
Corvallis, OR	December 10, 2004	7	7
Genesee, ID	April 13, 2004	6 to 7	3 to 5
Genesee, ID	April 7, 2005	5 to 7	6
Moscow, ID	April 12, 2004	5 to 7	2 to 3
Moscow, ID	April 6, 2005	5 to 6	6
Pullman, WA	April 10, 2004	5 to 7	2 to 3
Pullman, WA	April 29, 2005	7 to 8	6 to 8

individual study sites and years were analyzed using ANOVA procedures and discussed separately. Percent weed control and crop injury data were arcsine transformed prior to ANOVA procedures and back transformed for tabular presentation.

Results and Discussion

Rattail Fescue Response to Herbicide Treatments. Late-season rattail fescue control by flufenacet PRE alone was 94 to 100% at all site-years except Pullman in 2005 (Figures 1 and 2). As would be expected, sequential treatments of flufenacet PRE followed by a POST herbicide also provided high levels of control at all site-years except Pullman in 2005 (Figure 2). Control by any treatment at Pullman in 2005 did not exceed 74% due to the high rattail fescue population density that year and the fact that the infestation occurred naturally rather than being introduced by broadcast seeding as at the other sites. However, the flufenacet treatments did provide 60 to 74% late-season control which almost always was better than the 0 to 48% late-season control by any other treatment (Figure 2). Conversely, at the Moscow site in 2004, all treatments with the exception of diuron POST, gave control ratings from 92 to 100% due to a very light rattail fescue density.

Pendimethalin PRE alone provided 10 to 99% control depending on site-year. In 2004, control with pendimethalin PRE followed by a POST treatment was improved to 81 to 100%, except for the 2004 Pullman site (Figure 1). In 2005, pendimethalin PRE followed by a POST treatment ranged from 71 to 95% except at Pullman where control ranged from 3 to 48% (Figure 2). Again, rattail fescue control at Pullman was reduced due to a dense, natural rattail fescue population.

Of the POST alone treatments, sulfosulfuron or imazamox often provided acceptable rattail fescue control, but was variable depending on site-year. Control with single sulfosulfuron POST treatment ranged from 30 to 95%, and the single imazamox POST treatment ranged from 13 to 98% (Figures 1 and 2). Mesosulfuron POST alone control ranged from 5 to 85%, and diuron POST control ranged from 0 to 97%. Again, rattail fescue control was related to the weed population density.

Evaluation of late-season biomass in the nontreated checks provided indications as to why percent control varied across sites and years (Table 3). Even though rattail fescue density and resulting biomass was relatively high at Corvallis, especially in 2004, flufenacet applied PRE alone or followed by a POST herbicide reduced rattail fescue biomass compared with the nontreated biomass at that, and every other site-year except Pullman in 2005. The pendimethalin PRE treatments followed by a POST reduced biomass at every site except Pullman in 2004 and 2005. As previously mentioned, control of the naturally occurring, high density rattail fescue population at Pullman was less than 75% in 2005. At Pullman in 2005, no treatment reduced biomass compared with the nontreated control biomass, however, flufenacet treatments did reduce biomass numerically compared with the nontreated control biomass. Conversely, weed biomass was very low at both Idaho sites in both years, thereby contributing to the greater degree of rattail fescue control among treatments. The Corvallis sites in both years also had high amounts of rattail fescue biomass, but weed control was very effective from several treatments, possibly due to the higher amount of growing season precipitation common at this location (1,109 mm/yr average precipitation), which resulted in a higher yielding and more competitive wheat crop. The most consistently effective herbicide treatments were those containing flufenacet PRE, alone or in a sequential treatment. These treatments greatly reduced rattail fescue biomass compared to the nontreated check at all sites and years (Table 3).

Imidazolinone-Resistant Winter Wheat Response to Rattail Fescue Control Treatments. Arcsine transformed crop injury data were subjected to ANOVA and presented separately due to heterogeneity of variance across site-years. Significant levels of crop injury occurred at all sites in 2004 except Pullman, and with the exception of Corvallis (data not shown), only was evident at time of early-season evaluation (Table 4). No significant crop injury greater than 5% occurred at any site in 2005, except at Corvallis (data not shown). In 2004, the three treatments including imazamox POST were the only ones causing significant early-season crop injury at Pendleton and ranged from 19 to 24% (Table 4). At Genesee and Moscow in 2004, imazamox POST containing treatments (4 to 15%) and treatments including mesosulfuron POST (3 to 9%) were the only ones causing injury.

At Corvallis in 2004, all treatments except pendimethalin PRE alone and diuron POST alone caused early-season injury ranging from 4 to 17%. At Corvallis in 2005, only those treatments containing flufenacet PRE alone or in combination with POST treatments caused early-season crop injury ranging from 13 to 18% (data not shown). This site received more than twice the annual precipitation of the other sites, which could have affected the crop response to herbicide treatments, including flufenacet. Wheat crop injury from PRE flufenacet treatment at Corvallis has been previously reported when winter wheat is shallowly seeded (Affeldt et al. 2005). Flufenacet is considered to have a low (Rouchaud et al. 1999) to moderate (Vasilakoglou et al. 2001) soil mobility depending on soil properties. Crop injury at Corvallis from flufenacet, and possibly other treatments, may have resulted from shallow wheat seeding depth made possible by the higher precipitation growing region. Wheat is typically seeded deeper at drier locations so that seed is placed into soil moisture adequate for seed germination. Shallow seeding (< 5 cm) at Corvallis exposed seed to greater concentrations of herbicide. The extremely low mobility of pendimethalin likely contributed to the lack of crop injury observed at the Corvallis and other sites (Ismail and Kalithasan 1997).

Winter wheat yields varied across sites, primarily due to differences in growing season precipitation, therefore yield data could not be combined across sites, years, or years within sites. Differences in wheat grain yield due to herbicide treatment were observed at five of the nine site-years where yield was measured (Table 5). Wheat grain yields were not taken at Corvallis in 2005 due to severe lodging and rodent damage.

At Pendleton in 2004, yields resulting from flufenacet PRE alone or followed by a POST herbicide were greater than the nontreated control yield. These treatments provided 97 to

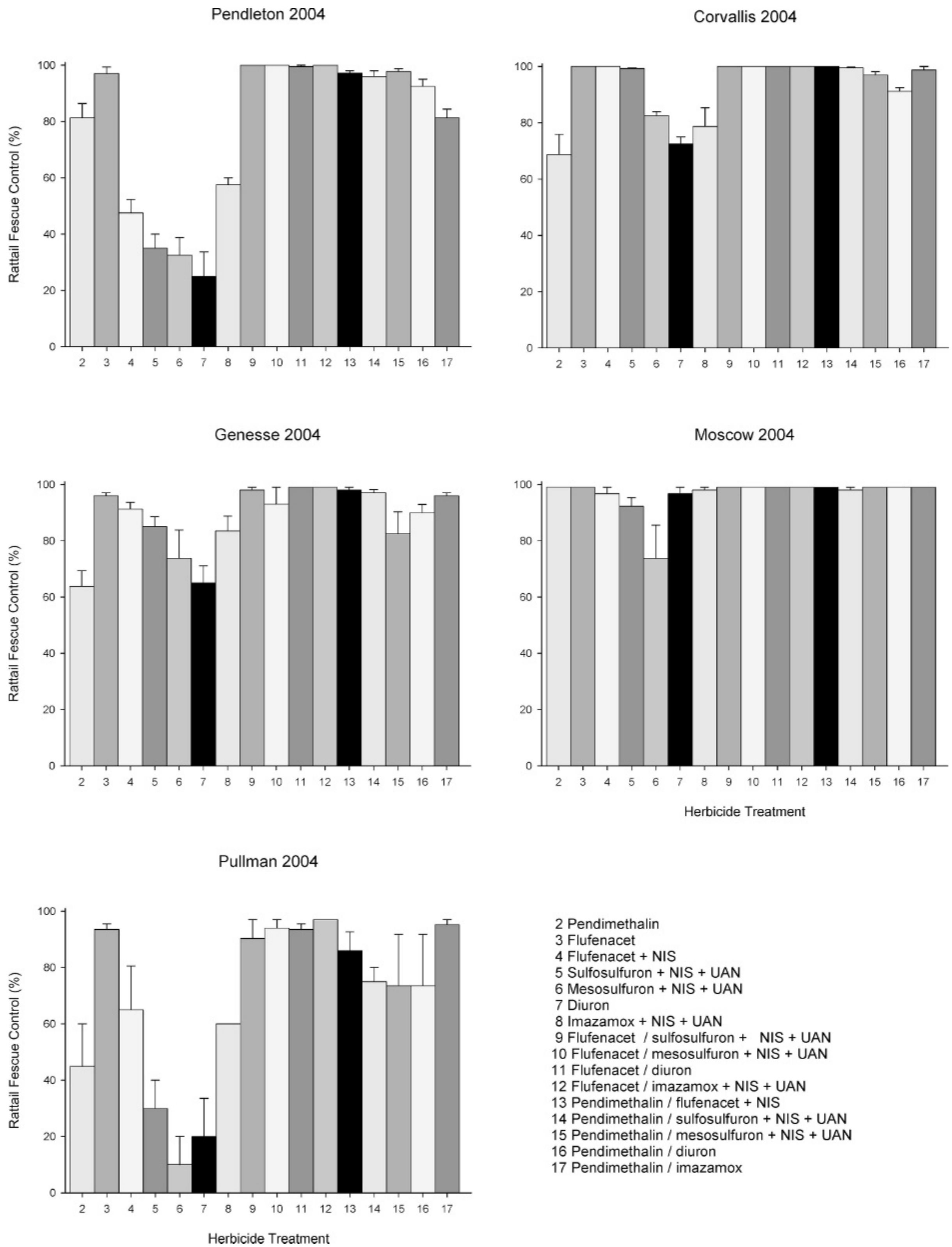

Figure 1. Late-season rattail fescue control (%) ratings with standard errors at five sites in 2004.

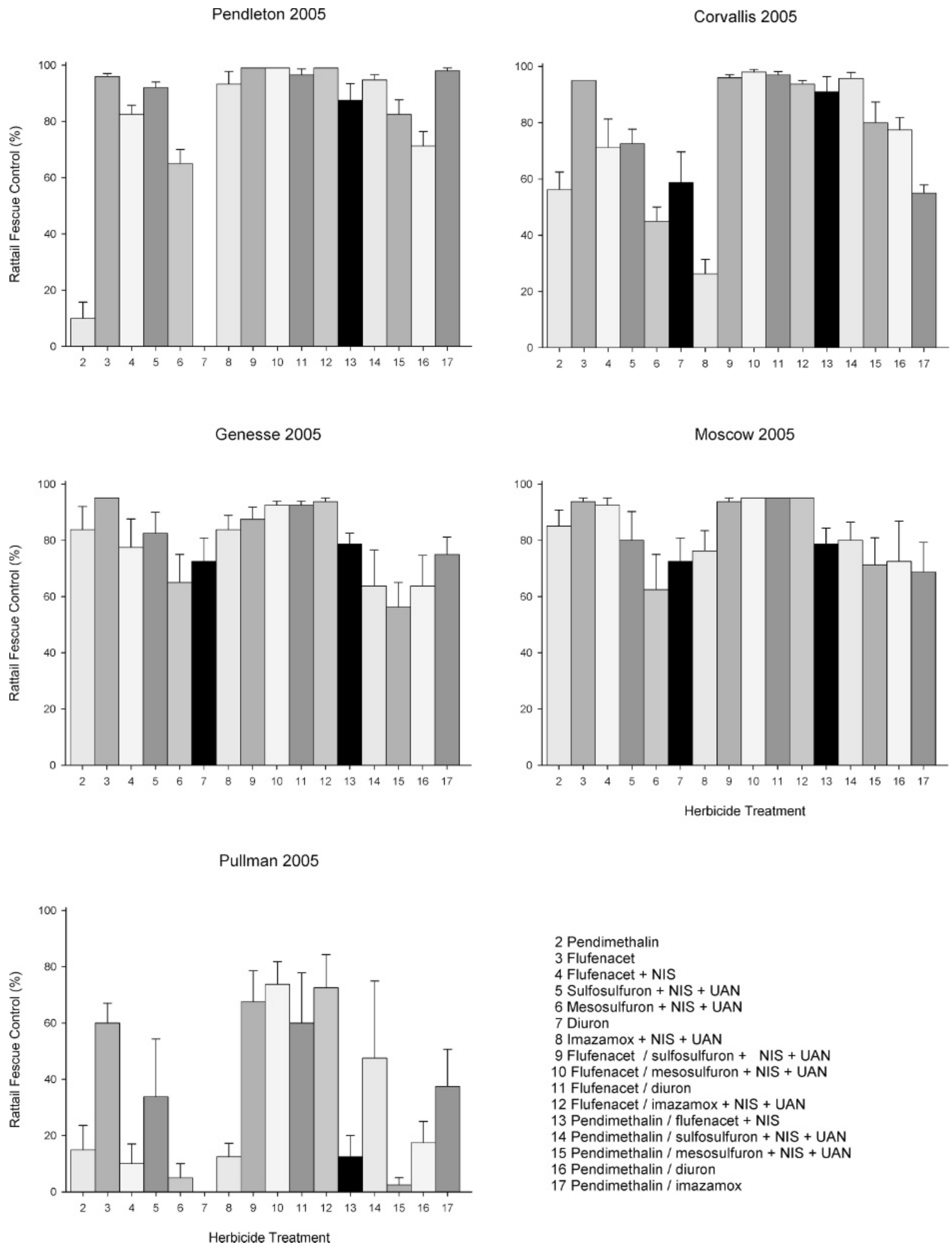

Figure 2. Late-season rattail fescue control (%) ratings with standard errors at five sites in 2005.

Table 3. Influence of herbicide treatment on rattail fescue biomass in winter wheat in 2004 and 2005 at five sites in Oregon, Idaho, and Washington.[a]

Treatment[b]	Timing	Pendleton, OR		Corvallis, OR		Genesee, ID		Moscow, ID		Pullman, WA	
		June 24, 2004	June 15, 2005	June 10, 2004	June 3, 2005	June 24, 2004	June 20, 2005	June 28, 2004	June 21, 2005	July 24, 2004	July 5, 2005
		g/m^2									
Nontreated check	—	25	38	730	105	13	10	7	19	59	397
Pendimethalin	PRE	6	16	477	38	3	1	0	0	39	600
Flufenacet	PRE	1	0	0	0	0	0	0	0	6	276
Flufenacet + NIS	POST	17	8	0	0	0	1	0	0	53	390
Sulfosulfuron + NIS + UAN	POST	18	0	19	0	1	2	0	0	89	286
Mesosulfuron + NIS + UAN	POST	19	8	161	17	5	2	0	3	114	291
Diuron	POST	7	24	216	6	7	3	1	1	91	419
Imazamox + NIS + UAN	POST	15	0	192	21	0	1	0	0	56	167
Flufenacet/sulfosulfuron + NIS + UAN	PRE/POST	0	0	0	0	0	0	0	0	7	211
Flufenacet/mesosulfuron + NIS + UAN	PRE/POST	1	0	0	0	1	0	0	0	2	145
Flufenacet/diuron	PRE/POST	0	0	0	0	0	0	0	0	1	178
Flufenacet/imazamox + NIS + UAN	PRE/POST	0	0	0	0	0	0	0	0	0	85
Pendimethalin/flufenacet + NIS	PRE/POST	0	4	0	0	0	1	0	1	14	401
Pendimethalin/sulfosulfuron + NIS + UAN	PRE/POST	0	0	2	0	0	4	0	1	39	142
Pendimethalin/mesosulfuron + NIS + UAN	PRE/POST	2	5	19	3	0	3	0	3	28	298
Pendimethalin/diuron	PRE/POST	0	10	97	6	0	2	0	1	26	467
Pendimethalin/imazamox +NIS + UAN	PRE/POST	5	0	9	11	0	3	0	1	20	264
LSD (0.05)[c]		12	12	88	21	5	—	—	—	44	NS

[a] Abbreviations: NIS, nonionic surfactant; UAN, urea ammonium nitrate; PRE, preemergence; POST, postemergence.

[b] NIS applied at 0.5 % v/v and 32% nitrogen (UAN) applied at 2.5% v/v.

[c] ANOVA was done and means separated using Fischer's protected LSD at the 5% level where data lent itself to analysis.

100% rattail fescue control and reduced biomass compared with the nontreated control biomass. Yields from the other treatments tended to be impacted by the level of rattail fescue control since yields usually were not different than the nontreated control when a treatment provided less than 80% rattail fescue control.

The major exception at Pendleton in 2004 was imazamox alone POST which provided 58% control and still yielded more than the nontreated control even with 20% early-season crop injury. Crop injury also was not a factor influencing yields as evidenced by the yield of this treatment and others including imazamox which caused 19 to 24% injury and also yielded greater than the nontreated control. Sulfosulfuron or mesosulfuron alone POST only provided 44% and 35% late-season rattail fescue control, respectively, and did not reduce biomass compared with the control biomass. While the yields from these treatments were greater than the nontreated control yield, they were numerically quite low.

Table 4. Influence of herbicide treatment on 2004 visible wheat injury (0 to 100% scale) at early evaluation times for test sites having a significant crop response.[a]

Treatment[b]	Timing	Pendleton, OR April 20	Corvallis, OR February 9	Genesee, ID April 27	Moscow, ID April 27
		%			
Nontreated check	—	0	0	0	0
Pendimethalin	PRE	0	0	0	0
Flufenacet	PRE	0	11	3	0
Flufenacet + NIS	POST	0	4	1	1
Sulfosulfuron + NIS + UAN	POST	4	5	0	0
Mesosulfuron + NIS + UAN	POST	3	9	9	9
Diuron	POST	0	1	3	3
Imazamox + NIS + UAN	POST	20	11	10	4
Flufenacet/sulfosulfuron + NIS + UAN	PRE/POST	5	9	3	0
Flufenacet/mesosulfuron + NIS + UAN	PRE/POST	4	13	6	6
Flufenacet/diuron	PRE/POST	0	14	6	1
Flufenacet/imazamox + NIS + UAN	PRE/POST	19	17	15	12
Pendimethalin/flufenacet + NIS	PRE/POST	1	6	0	0
Pendimethalin/sulfosulfuron + NIS + UAN	PRE/POST	1	5	0	4
Pendimethalin/mesosulfuron + NIS + UAN	PRE/POST	6	5	8	3
Pendimethalin/diuron	PRE/POST	1	4	4	8
Pendimethalin/imazamox + NIS + UAN	PRE/POST	24	7	11	8
LSD (0.05)		8	4	8	5

[a] Abbreviations: NIS, nonionic surfactant; UAN, urea ammonium nitrate; PRE, preemergence; POST, postemergence.

[b] NIS applied at 0.5 % v/v and 32% nitrogen (UAN) applied at 2.5% v/v.

Table 5. Influence of herbicide treatment on grain yield of winter wheat at five sites in Oregon, Idaho, and Washington over 2 yr.[a]

		Pendleton, OR		Corvallis, OR	Genesee, ID		Moscow, ID		Pullman, WA	
Treatment[b]	Timing	July 27, 2004	July 18, 2005	July 22, 2004	August 10, 2004	August 5, 2005	August 13, 2004	August 8, 2005	August 16, 2004	August 4, 2005
		kg/ha								
Nontreated check	—	2,910	4,860	6,150	6,590	4,660	5,640	6,380	3,680	1,510
Pendimethalin	PRE	3,130	5,570	6,790	6,210	4,980	5,800	5,910	3,810	1,530
Flufenacet	PRE	3,590	5,490	8,210	6,030	4,970	5,850	7,260	3,550	2,290
Flufenacet + NIS	POST	2,860	5,480	8,000	7,280	4,830	5,530	6,730	3,690	1,570
Sulfosulfuron + NIS + UAN	POST	3,970	5,480	7,870	6,880	5,140	5,870	6,520	3,520	1,580
Mesosulfuron + NIS + UAN	POST	3,960	5,170	7,780	6,550	4,850	5,900	6,970	3,200	1,350
Diuron	POST	2,870	4,900	7,590	6,490	5,510	5,380	6,400	3,650	900
Imazamox + NIS + UAN	POST	4,610	5,290	7,110	6,370	4,900	5,510	7,210	3,710	1,790
Flufenacet/sulfosulfuron + NIS + UAN	PRE/POST	5,210	5,300	8,050	6,340	5,130	5,580	7,020	3,630	2,350
Flufenacet/mesosulfuron + NIS + UAN	PRE/POST	4,890	5,390	8,270	6,050	5,210	5,460	8,050	4,190	2,450
Flufenacet/diuron	PRE/POST	4,320	5,730	7,990	5,470	5,450	5,170	6,680	3,690	2,140
Flufenacet/imazamox + NIS + UAN	PRE/POST	5,050	5,510	7,470	5,530	5,120	4,960	6,960	3,500	2,790
Pendimethalin/flufenacet + NIS	PRE/POST	2,940	5,300	7,950	6,400	5,240	5,370	7,630	3,970	1,340
Pendimethalin/sulfosulfuron + NIS + UAN	PRE/POST	4,610	5,520	7,970	6,780	4,870	5,450	6,840	4,390	1,530
Pendimethalin/mesosulfuron + NIS + UAN	PRE/POST	3,860	5,500	7,860	6,400	4,740	5,660	6,250	3,520	1,610
Pendimethalin/diuron	PRE/POST	3,240	4,830	7,870	6,230	5,160	4,980	5,640	3,480	1,210
Pendimethalin/imazamox	PRE/POST	4,450	5,318	7,610	6,270	5,290	4,890	6,300	3,630	1,620
LSD (0.05)		650	ns	460	610	ns	550	ns	ns	550

[a] Abbreviations: NIS, nonionic surfactant; UAN, urea ammonium nitrate; PRE, preemergence; POST, postemergence; ns, nonsignificant.

[b] NIS applied at 0.5 % v/v and 32% nitrogen (UAN) applied at 2.5% v/v.

Rattail fescue control levels also seemed to have an effect on yields at Corvallis in 2004 most likely because the fescue density there was quite high, therefore, all herbicide treatments, including the ones providing less than acceptable control, resulted in reduced rattail fescue biomass and greater yields than the nontreated control biomass and yield. Rattail fescue control ranged from 69 to 100%, and with one exception, treatments providing greater than 90% control resulted in yields similar to the highest yield from flufenacet alone PRE or the sequential application of flufenacet PRE followed by mesosulfuron POST, while less than 90% control translated to yields lower than the highest yield. The exception was flufenacet PRE followed by imazamox POST, which controlled rattail fescue 100% and totally eliminated biomass, yet yielded less than the treatment with the highest yield. In this case, crop injury seemed to be the major factor influencing yield reduction rather than control since the 17% early-season injury caused by this treatment was greater than early-season injury from all other treatments except one, and late-season injury was still relatively high at 18% (data not shown).

Only one treatment provided less than 90% rattail fescue control at Moscow in 2004 and all treatments reduced biomass compared with the nontreated control biomass. Even so, unlike results at the aforementioned sites when treatment yields were mostly affected by rattail fescue control levels and were the same as or greater than the nontreated control yield, treatment yields actually were less than the nontreated control yield three out of four times when 8% or greater early-season injury was visible. The treatments causing this level of injury resulted in reduced yields were imazamox POST following either pendimethalin or flufenacet PRE, and pendimethalin PRE followed by diuron POST. Unexpectedly, mesosulfuron POST alone, the only treatment providing less than 90% rattail fescue control, also caused 9% crop injury but did not yield less than the nontreated control. All other treatments caused only 0 to 6% early-season injury and did not have reduced yields compared with the control yield.

While either poor rattail fescue control or crop injury seemingly affected yields at the other sites, the three treatments at Genesee in 2004 providing the lowest control at 64 to 69% did not yield less than the nontreated control or 12 out of 14 of the other herbicide treatments which provided 83 to 99% control. Instead, inclusion of flufenacet PRE in a treatment seemed to impact yields negatively since flufenacet PRE followed by diuron or imazamox were the only treatments resulting in yields less than the nontreated control and two out of the other three treatments including flufenacet PRE alone or followed by mesosulfuron, resulted in yields which were numerically much less than the nontreated control yield.

All herbicide treatments at Genesee in 2004 reduced biomass compared with the nontreated control biomass. Treatments including flufenacet PRE provided greater than 93% rattail fescue control. Overall crop injury ranged from 0 to 15%. The two treatments with yields less than the nontreated control yield—flufenacet PRE followed by imazamox or diuron POST—caused 6 and 15% early-season injury, respectively. This injury, however, was not different than the 3 or 10% injury caused by imazamox or diuron applied alone POST, yet those herbicides applied alone POST yielded greater than treatments of either one of those herbicides following flufenacet PRE. In addition, both combination treatments controlled rattail fescue 99% while the POST alone treatments with greater yields provided less control at 65 and 84%, respectively. In contrast, flufenacet POST alone with 92% control and 1% crop injury yielded greater than any other treatment except sulfosulfuron POST alone or following pendimethalin PRE. The latter two treatments provided 84 and 97% control, respectively, and did not cause any crop injury.

Overall, flufenacet PRE alone or followed by sulfosulfuron, mesosulfuron, diuron, or imazamox POST consistently controlled rattail fescue at an effective level over a wide range of PNW dryland conditions. Even when control did not exceed 75% at a site where the rattail fescue population was dense and naturally occurring, winter wheat yields were improved by flufenacet treatments compared with less effective treatments providing less than 50% control. A program including flufenacet applied PRE appears to have good potential as a rattail fescue management tool in winter wheat under PNW dryland conditions. Sequential treatments of pendimethalin PRE followed by one of the aforementioned POST herbicides provided effective control at some locations in our study and further investigation of these combinations is warranted. However, the increased cost of multiple herbicide applications may outweigh the weed control benefits and needs to be considered. Imazamox and mesosulfuron applied POST caused early-season winter wheat injury in our study and even though late-season injury was not evident, except at Corvallis (data not shown), the imazamox injury negatively affected grain yields at a few locations. Treatments including flufenacet PRE also caused crop injury at a site with high annual precipitation and shallow winter wheat seed placement may also be a factor in these conditions, so recommendations should be developed accordingly.

Flufenacet is primarily active on annual grass weeds such as rattail fescue and may not provide acceptable control of broadleaf weeds if applied alone. Additionally, herbicidal control of rattail fescue was generally less effective under high infestation levels of rattail fescue, as evidenced by the weed population pressure at the Pullman sites. For this reason, practices such as crop rotation away from winter wheat and effective rattail fescue control during fallow periods are needed as part of an integrated management program, in addition to possible herbicide treatment in winter wheat.

Sources of Materials

[1] Nonionic surfactant, R-11, Wilbur Ellis Co., 345 California Street, 27th Floor, San Francisco, CA 94104.

[2] Rhino (bromoxynil + MCPA), McGregor Company, P.O. Box 740, Colfax, WA 99111.

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Literature Cited

Affeldt, R. P., J. B. Colquhoun, C. M. Cole, and C. A. Mallory-Smith. 2005. Influence of seeding depth and flufenacet timing in winter wheat. Proc. West. Soc. Weed Sci. 58:22.

Ball, D. A., S. M. Frost, C. Tarasoff, and C. Mallory-Smith. 2005. Biology of rattail fescue and its management in direct-seeded winter wheat and chemical fallow. Pages 92–103 *in* 2005 Dryland Agricultural Research Annual Report. Corvallis, OR: Oregon State Univ. Spec. Rep. 1061. 109 p.

Dillon, S. P. and F. Forcella. 1984. Germination, emergence, vegetative growth and flowering of two silvergrasses, *Vulpia bromoides* (L.) S.F. Gray and *V. myuros* (L.) C.C. Gmel. Aust. J. Bot. 32:165–175.

Douglas, C. L., D. J. Wysocki, J. F. Zuzel, R. W. Rickman, and B. L. Klepper. 1990. Agronomic zones for the dryland pacific northwest. PNW Extension Publication PNW 354. 8 p.

Dowling, P. M. 1996. The ecology of *Vulpia*. Plant Prot. Quart. 11(suppl. 1): 204–206.

Ismail, B. S. and K. Kalithasan. 1997. Effects of repeated application on persistence and downward movement of four herbicides in soil. Aust. J. Soil Res. 35:503–514.

Jemmett, E. D. 2006. The biology and management of rattail fescue in winter wheat cropping systems. M.S. thesis. Moscow, ID: University of Idaho. 64 p.

Rouchaud, O., K. Neus, and R. Bulcke. 1999. Flufenacet soil persistence and mobility in corn and wheat crops. Bull. Environ. Contam. Toxicol. 63:460–466.

Vasilakoglou, I. B., I. G. Eleftherohorinos, and K. B. Dhima. 2001. Activity, adsorption and mobility of three acetanilide and two new amide herbicides. Weed Res. 41:535–546.

Wallace, A. 1997. The biology of Australian weeds. 30. *Vulpia bromoides* ((L.) S.F. Gray) and *V. myuros* ((L.) C.C. Gmelin). Plant Prot. Quart. 12:18–28.

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