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Rattail Fescue (*Vulpia myuros*) Control in Chemical-Fallow Cropping Systems

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Rattail fescue infestations are increasing in dryland conservation-tillage winter wheat cropping systems in the inland Pacific Northwest (PNW) region of Idaho, Oregon, and Washington. Rattail fescue typically is controlled with cultivation in conventional tillage farming systems. However, reduced soil disturbance has allowed infestations to increase significantly. The objectives of this research were to determine the effectiveness of glyphosate rates and application timings on control of rattail fescue during a chemical-fallow period in winter wheat cropping systems. Chemical-fallow field studies were conducted during two growing seasons at nine sites throughout the PNW. Glyphosate was applied early POST, late POST, or sequentially in early plus late POST timings. Additionally, paraquat + diuron was applied early and late POST alone or sequentially with glyphosate. Sequential application treatments (glyphosate followed by [fb] glyphosate, paraquat + diuron fb glyphosate, and glyphosate fb paraquat + diuron) controlled rattail fescue (~ 94% in Idaho and Washington, ~ 74% in Oregon) and reduced panicle number (~ 85% in Idaho, ~ 30% in Oregon and Washington) equivalent to or greater than one-time treatments. Rattail fescue control and panicle reduction generally increased with increasing rates of glyphosate within application timings. Paraquat + diuron usually provided similar control and reduced rattail fescue panicle number compared to glyphosate treatments applied at the same application timing. Although not completely effective, sequential applications of either glyphosate or paraquat + diuron, fb glyphosate will provide effective control during chemical fallow.

Nomenclature: Diuron; glyphosate; paraquat; rattail fescue, *Vulpia myuros* L.; winter wheat, *Triticum aestivum* L.
Key words: Conservation tillage, direct seed, growth stage, fallow, herbicide, no-till.

Rattail fescue is a relatively new weed problem infesting conservation-tillage dryland winter wheat production systems in the inland PNW region of Idaho, Oregon, and Washington. Rattail fescue traditionally has been controlled in conventional tillage systems with intensive tillage practices during seedbed preparation. However, increased awareness of the financial and environmental impacts of intense tillage practices (i.e., soil erosion, inefficient water conservation, and consumption of fossil fuels) has resulted in increased adoption of no-till, reduced-tillage, or conservation-tillage practices (Unger et al. 1971; Veseth 1988). Although conservation-tillage practices can reduce soil erosion and improve soil moisture retention by maintaining crop residue cover on the soil surface (Durham 2003; Locke 2002), eliminating some or all tillage can impact weed management because weeds traditionally controlled with tillage, such as rattail fescue, must be controlled using other methods.

Rattail fescue is a winter annual grass believed to have been introduced from Europe; however, the specific location and time of introduction were not recorded (Hitchcock 1951; Whitson 2000). Rattail fescue was previously assigned to the genus *Festuca* before being changed to *Vulpia* and it has several different common names, which include rattail fescue, foxtail fescue, and silver grass (Dillon and Forcella 1984). Rattail fescue is considered an invasive species to the western flora of the United States because it establishes quickly in disturbed areas and has the ability to compete with native plants (USDA NRCS 2005b). Active rattail fescue germination and growth can occur in the fall, winter, and spring and the plant can quickly reach 0.5 m in height, form thick tufts, and flower from May to July (Hitchcock 1951; USDA NRCS 2005a). Rattail fescue plants have been observed growing in winter wheat stands closely mimicking the growth pattern of wheat from seedling emergence to seed maturity (Forcella 1984).

Rattail fescue plant residues break down slowly and accumulate as dense mats on the soil surface, which can restrict establishment of other plant species. Plant residue extracts from this weed can be allelopathic to wheat, adversely affecting wheat radicle elongation and coleoptile growth (An et al. 1997). Persistence of this weed in the field from year to year is dependent on weed seed production, the quantity of residue being carried over on the soil surface from one season to the next, seed dormancy, and the absence or presence of tillage or prepared seedbeds (An et al. 1997; Dowling 1996; Forcella 1984). It is a common weed problem in pastures and rangeland and is considered a low-value pasture and rangeland forage because it has low winter production and is unpalatable to livestock during spring and summer growth periods (An et al. 1997; Dowling 1996). Rattail fescue competes with natural or established forage plant populations, and its seed heads injure livestock and contaminate wool (Leys et al. 1991).

Selective and nonselective herbicides are used to control weeds in place of tillage during chemical-fallow periods (Ireland 2003). Glyphosate, paraquat, paraquat + diuron, 2,4-D, chlorsulfuron, and dicamba are commonly used herbicides for chemical fallow (Moyer et al. 1994). Herbicide selection depends, in part, on rotational crop planting restrictions and

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weed species. Glyphosate and paraquat + diuron are commonly used in winter wheat chemical-fallow cropping systems because they effectively control weeds and volunteer crops and are affordable.

The objective of this research was to determine optimum glyphosate rates and glyphosate and paraquat + diuron application timings for chemical-fallow control of rattail fescue in dryland conservation-tillage winter wheat cropping systems in the inland PNW region of Idaho, Oregon, and Washington.

Materials and Methods

Field experiments were established at five locations in dryland wheat growing regions of the inland PNW during fall 2003 and 2004. Idaho experiments were established both years near Moscow at the University of Idaho Parker Research Farm, and near Genesee at the University of Idaho Kambitsch Research Farm. These sites were approximately 16 km apart. To obtain a uniform weed population, rattail fescue was seeded at Genesee on October 17, 2003, and October 4, 2004, and at Moscow on October 20, 2003, and October 7, 2004, into winter wheat stubble, which had been chisel plowed and disked prior to seeding. In 2003, rattail fescue was seeded at 17.9 kg/ha with a 1.2-m double-disk cone seeder drill equipped with openers spaced 16.2 cm apart. Every other seed tube was pulled to broadcast approximately one-half of the seed on the soil surface. However, in 2004, another 17.9 kg/ha of seed was broadcast seeded onto the soil surface in the opposite direction as the drilled seed with a 1.2-m-wide rolling grass seed and fertilizer spreader to enhance the low rattail fescue population densities encountered in 2003. A rolling harrow was used to cover surface seeds and compact the soil after seeding.

Oregon experiments were established in standing winter wheat stubble near Pendleton at the Columbia Basin Agricultural Research Center and near Mission in a commercial field; the sites were approximately 9 km apart. At Pendleton, rattail fescue seed was surface broadcasted with a drop spreader on November 4, 2003, and September 27, 2004, at 24.7 kg/ha to augment a sparse natural population. A heavy natural infestation was present at the Mission site both years.

An experiment also was established during the fall of 2003 near Pullman, Washington, at the Palouse Conservation Field Station in standing winter wheat stubble with a natural rattail fescue infestation.

The experimental design was a randomized complete block with four replications at all locations each year. Plots were 2.4 by 9.1 m in the Idaho experiments, 2.7 by 9.1 m in Oregon, and 3.1 by 10.7 m in Washington. All herbicide treatments were applied in the spring of 2004 and 2005 using CO_2-pressurized backpack sprayers. See Tables 1 and 2 for applications dates and conditions and soil information at all locations. At all three locations sprayers were calibrated to deliver 94 L/ha; however, pressure was 235, 207, and 221 kPa at Idaho, Oregon, and Washington, respectively. Glyphosate treatments were applied with ammonium sulfate at 10 g/L and paraquat + diuron treatments were applied with a nonionic surfactant.[1]

Table 1. Application conditions and soil parameters for rattail fescue control in chemical-fallow experiments, 2003 to 2004.

	Experiment sites									
	Moscow, ID		Genesee, ID		Pendleton, OR		Mission, OR		Pullman, WA	
Application dates	April 22, 2004	May 3, 2004	April 29, 2004	May 10, 2004	March 29, 2004	April 30, 2004	March 29, 2004	April 19, 2004	April 7, 2004	April 26, 2004
Application timing[a]	EPOST	LPOST	EPOST	LPOST	EPOST	LPOST	EPOST	LPOST	EPOST	LPOST
Rattail fescue growth stage	one- to three-tiller	three- to five-tiller	two- to five-tiller	seven- to ten-tiller	three- to five-leaf	two-to three-tiller	four- to seven-leaf	7-cm head	5 cm	7–10 cm
Panicle density/m[2]	735		1,704		2,731		4,279		247	
Air temperature (C)	16	18	12	9	22	22	16	17	11	26
Relative humidity (%)	50	46	48	64	28	36	28	52	58	25
Wind (km/h)	6	8	5	8	10	5	5	6	0	5
Cloud cover (%)	80	40	0	100	5	0	0	80	0	0
Soil temperature (C)	13	16	7	14	23	28	14	18	7	10
pH	5.6		5.2		5.7		6.5		5.0	
OM (%)	2.8		3.3		2.3		2.4		4.1	
CEC (meg/100 g)	16		19		16.7		18		20	
Soil classification	Palouse		Palouse		Walla Walla		Walla Walla		Naff	
Texture	silt loam		silt loam		silt loam		silt loam		silt loam	

[a] Abbreviations: EPOST, early POST; LPOST, late POST; OM, organic matter; CEC, cation exchange capacity.

Table 2. Application conditions and soil parameters for rattail fescue control in chemical-fallow experiments; 2004 to 2005.

	Experiment sites							
	Moscow, ID		Genesee, ID		Pendleton, OR		Mission, OR	
Application dates	March 3, 2005	April 15, 2005	March 3, 2005	April 18, 2005	March 21, 2005	April 20, 2005	March 21, 2005	April 20, 2005
Application timing[a]	EPOST	LPOST	EPOST	LPOST	EPOST	LPOST	EPOST	LPOST
Rattail fescue growth stage	one- to three-tiller	six- to eight-tiller	two- to five-tiller	seven- to ten-tiller	2.5–4 cm	5–10 cm	2.5–8 cm	5–12 cm
panicle density/m^2	5,036		4,938		1,331		3,027	
Air temperature (C)	14	16	12	7	12	18	13	14
Relative humidity (%)	55	52	52	70	64	38	60	52
Wind (km/h)	5	6	3	8	3	5	6	3
Cloud cover (%)	20	30	20	60	65	80	70	10
Soil temperature (C)	9	9	10	4	14	19	10	13
pH	5.6		5.4		5.9		6.3	
OM (%)[a]	2.8		3.6		1.6		2.2	
CEC (meq/100 g)[a]	16		25		14.9		21.4	
Soil classification	Palouse		Palouse		Walla Walla		Walla Walla	
Texture	silt loam		silt loam		silt loam		silt loam	

[a] Abbreviations: EPOST, early POST; LPOST, late POST; OM, organic matter; CEC, cation exchange capacity.

Glyphosate[2] treatments were applied early POST (EPOST), late POST (LPOST) (Tables 1 and 2), and as sequential EPOST and LPOST treatments at 0.42, 0.63, 0.84, and 1.05 kg ae/ha (Table 3). Paraquat + diuron[3] (0.56 kg ai/ha + 0.28 kg ai/ha) treatments were applied at 0.84 kg ai/ha EPOST, LPOST, and as sequential EPOST and LPOST treatments in combination with glyphosate.

Weed control was evaluated visually after the LPOST application timing using a scale from 0 (no control) to 100% (complete control) at 24 to 42 d after treatment (DAT) at the Idaho locations and 30 to 34 DAT at the Oregon locations both years, and 18 DAT at the Washington location in 2004. At maturity—in June (54 to 70 DAT) at the Oregon experiments, and in July at the Idaho (65 to 87 DAT) and Washington (73 DAT) experiments—rattail fescue plants were collected from three randomly placed 625-cm^2 quadrats in each plot and combined into a single sample, after which the total number of panicles was counted.

All data were analyzed using PROC GLM and ANOVA. Prior to analyses, herbicide-treated rattail fescue panicle number/m^2 were converted to a percentage of untreated control panicle number/m^2 representing panicle number reduction. PROC UNIVARIATE was used to determine whether or not a data transformation was needed. Percentage of control as visually evaluated and panicle reduction means were separated using Fisher's Protected LSD test. Treatment means and LSMEANS were used to test for significant interactions and error significance when data were combined over locations and years, and significant interactions were plotted and evaluated to determine the cause and magnitude of interactions (Jemmett 2006). Preplanned single degree of freedom contrasts were used to compare rattail fescue control and panicle reduction by EPOST, LPOST, and sequential applications of glyphosate averaged over all rates within each application timing and to compare EPOST and LPOST glyphosate and paraquat + diuron applications as well as sequential glyphosate fb glyphosate and paraquat + diuron fb glyphosate treatments (Table 4). All computations were carried out using SAS version 9.1.

Results and Discussion

Initial analyses of the data indicated that there was a significant treatment by location and year interaction for all experiment locations within a state ($P < 0.0001$) and also when combined over all states (data not shown). Treatment means were plotted to show where the interactions occurred and if they would affect treatment rankings (data not shown). Plots of the interaction means indicated that treatment interactions were minimal and trends were not affected if treatments were pooled by states over locations and years. Interactions significant over all experiment sites were attributed to the timing transition from EPOST to LPOST to sequential application treatments. Interactions occurring when data were combined over years were attributed to the order of magnitude changes caused by climatic variations between the two growing seasons (Jemmett 2006).

Idaho Experiments. Herbicide treatment by application timings was significant for all parameters measured (data

Table 3. Rattail fescue control in chemical-fallow experiments at four study sites in Idaho, four study sites in Oregon, and one study site in Washington during 2003 to 2004 and 2004 to 2005 growing seasons.

Treatment[a]	Rate[b]	Application Timing[c]	ID 2004–2005[d]	OR 2004–2005[d]	WA 2004
	kg ae/ha		%		
Gly[e]	0.42	EPOST	75	37	84
Gly	0.63	EPOST	89	41	89
Gly	0.84	EPOST	92	44	87
Gly	1.05	EPOST	92	51	93
Paraquat + diuron	0.84	EPOST	83	35	75
Gly	0.42	LPOST	45	58	59
Gly	0.63	LPOST	54	66	71
Gly	0.84	LPOST	56	72	70
Gly	1.05	LPOST	64	76	66
Paraquat + diuron	0.84	LPOST	72	63	64
Gly fb gly	0.42 fb 0.42	EPOST fb LPOST	92	68	87
Gly fb gly	0.63 fb 0.42	EPOST fb LPOST	96	73	94
Gly fb gly	0.42 fb 0.63	EPOST fb LPOST	96	74	93
Gly fb gly	0.63 fb 0.63	EPOST fb LPOST	97	78	97
Gly fb gly	0.63 fb 0.84	EPOST fb LPOST	97	76	94
Gly fb paraquat + diuron	0.42 fb 0.84	EPOST fb LPOST	96	74	93
Paraquat + diuron fb gly	0.84 fb 0.42	EPOST fb LPOST	92	71	89
LSD $_{(0.05)}$			7	5	17

[a] Glyphosate applied with ammonium sulfate at 10 g/L. Paraquat + diuron was applied with a nonionic surfactant at 0.25% v/v. Product formulations: glyphosate = Roundup UltraMax® and paraquat + diuron = Surefire®, 2:1 ratio respectively, thus 0.84 kg/ha = 0.56 and 0.28 kg/ha, respectively.

[b] Glyphosate in kg ae/ha, paraquat + diuron in kg ai/ha. Spray volume = 94 L/ha.

[c] For early POST (EPOST) and late POST (LPOST) stage of growth see Tables 1 and 2.

[d] Data are combined over 2 yr.

[e] Abbreviations: gly, glyphosate; EPOST, early POST; LPOST, late POST; fb, followed by.

not shown). Interaction plots of the Idaho data showed that LPOST treatments at Moscow in 2004 visibly controlled rattail fescue better than LPOST treatments at Moscow in 2005 and Genesee in 2004 and 2005 (Jemmett 2006), and combined over sites within years, 2004 LPOST treatments controlled rattail fescue more than the same treatments applied in 2005.

All sequentially applied glyphosate treatments visibly controlled rattail fescue 92 to 97%, whereas EPOST glyphosate treatments provided 75 to 92% control and LPOST treatments controlled rattail fescue 45 to 64% (Table 3). Weed control with glyphosate applied EPOST or LPOST generally increased with increasing rates of glyphosate within each application timing. Paraquat + diuron applied EPOST controlled rattail fescue 83%, whereas control with the LPOST application was less, at 72%. The two highest glyphosate rates applied EPOST controlled rattail fescue better than paraquat + diuron applied at the same time. In contrast, control with paraquat + diuron applied LPOST was greater than control with all LPOST glyphosate treatments but significantly less than the EPOST paraquat + diuron treatment. Application timing contrasts averaged over glyphosate rates showed that EPOST treatments controlled rattail fescue 87% and this control was better than the 55% control by LPOST treatments, whereas control by sequential applications of glyphosate averaged over all rates was

Table 4. Single degree of freedom contrasts comparing visually evaluated percentage of rattail fescue control and panicle number reduction application timing means in chemical-fallow experiments in four experiments in Idaho, four experiments in Oregon, and one experiment in Washington, combined over the 2003 to 2004 and 2004 to 2005 growing seasons.

Contrasts[a,b]	Visually evaluated % control: ID	OR	WA	% Panicle reduction: ID	OR	WA
	P value					
Gly EPOST vs. Paraquat + diuron EPOST	0.2073	0.0002	0.0608	0.0877	0.0869	0.0292
Gly LPOST vs. Paraquat + diuron LPOST	< .0001	0.0184	0.6812	0.2316	0.3319	0.9513
Gly fb gly vs. Paraquat+diuron fb gly	0.3723	0.5339	0.6712	0.0109	0.3262	0.3318
Gly EPOST vs. Gly LPOST	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001
Gly EPOST vs. Gly fb gly	< .0001	< .0001	0.2516	< .0001	< .0001	0.1379
Gly LPOST vs. Gly fb gly	< .0001	< .0001	< .0001	< .0001	< .0001	0.0035

[a] Abbreviations: gly, glyphosate; EPOST, early POST; LPOST, late POST; fb, followed by.

[b] Glyphosate EPOST or LPOST represents an average of all rates applied EPOST or LPOST; glyphosate fb glyphosate represents an average of all rates applied EPOST followed by all rates applied LPOST; paraquat + diuron fb glyphosate represents an average of the EPOST paraquat+diuron fb LPOST glyphosate and EPOST glyphosate fb LPOST glyphosate treatments. DF = 1.

Table 5. Timing means for visually evaluated percentage of control and panicle reduction for rattail fescue control in chemical-fallow experiments at four study sites in Idaho, four study sites in Oregon, and one study site in Washington during 2003 to 2004 and 2004 to 2005 growing seasons.

Timing[a,b]	Visually evaluated control			Panicle reduction		
	ID	OR	WA	ID	OR	WA
	%					
Glyphosate (gly) EPOST	87	43	88	69	15	33
Gly LPOST	55	68	67	51	30	1
Gly EPOST fb LPOST	96	74	93	90	43	22
Paraquat + diuron EPOST	83	35	75	60	23	7
Paraquat + diuron LPOST	72	63	64	57	35	0
Paraquat + diuron fb gly	94	73	91	80	39	14

[a] Abbreviations: gly, glyphosate; EPOST, early POST; LPOST, late POST; fb, followed by.

[b] Paraquat + diuron fb glyphosate were applied EPOST fb LPOST and LPOST fb EPOST.

significantly greater, at 96%, than control by either EPOST or LPOST applications (Tables 4 and 5).

Percentage of panicle reduction of rattail fescue showed little difference over sites within years for EPOST and sequential application treatments, whereas LPOST treatments showed greater variation in percentage of panicle reduction (Jemmett 2006). Percentage of panicle reduction of rattail fescue was greatest with LPOST treatments at the Moscow site in 2004 and at the Genesee site in 2005. When data were pooled over locations within Idaho, percentage of panicle reduction of rattail fescue was always greater in 2004, at 62 to 100%, than in 2005, at 19 to 93%, and these differences were attributed to precipitation and temperature variations between the two growing seasons (data not shown). November 2004 through February 2005 was drier and warmer than the previous growing season and the 30-yr average. This resulted in rattail fescue plants reaching the appropriate stage for herbicide application, one to three tillers, 3 to 4 wk earlier in 2005 compared to 2004. However, precipitation was greater and mean, maximum, and minimum temperatures tended to be lower in March and April of 2005 compared to 2004. These environmental conditions may have reduced the effectiveness of the herbicide treatments and allowed greater plant recovery following herbicide treatment in 2005 than in 2004.

Sequential glyphosate treatments reduced rattail fescue panicle number 85 to 96%, whereas EPOST and LPOST glyphosate applications only reduced panicle number 47 to 84% and 42 to 64%, respectively (Table 6). As with visually evaluated percentage of control, panicle reduction with EPOST and LPOST treatments generally increased with increasing rates of glyphosate. Paraquat + diuron reduced rattail fescue panicle number similarly when applied EPOST (60%) and LPOST (57%). Similar to visually evaluated control, panicle reduction with the EPOST paraquat + diuron treatment was less than with the two highest glyphosate rates applied EPOST, whereas the LPOST paraquat + diuron application reduced panicle number as much or more than the LPOST glyphosate treatments. Panicle number reduction was the greatest with sequential glyphosate treatments, the highest rate of glyphosate applied EPOST, and glyphosate fb paraquat + diuron applied sequentially. Application timing contrasts averaged over glyphosate rates showed that panicle reduction with the EPOST treatments was greater, at 69%, compared to LPOST treatments, at 51% (Tables 4 and 5). Percentage of panicle reduction with the sequential glyphosate application timings was greater, at 90%, than by both LPOST and EPOST glyphosate treatments.

Oregon Experiments. Interactions plots of the Oregon data showed order of magnitude differences in percentage of rattail fescue control for the EPOST and sequential treatments across all four experiments (data not shown). LPOST treatments at Pendleton in 2004 controlled rattail fescue better than those at Pendleton in 2005 and Mission in 2004 and 2005, whereas control with EPOST treatments was less than at Pendleton in 2005 and Mission in 2004. When data were combined across locations within years, control was 5 to 25% greater for all treatments in 2005 compared to 2004. Differences in control between years were likely caused by climatic differences (data not shown) as previously explained for the Idaho sites.

All sequentially applied glyphosate treatments visibly controlled rattail fescue 68 to 78%, whereas EPOST glyphosate provided 37 to 51% control and LPOST, 58 to 76% control (Table 3). Similar to the Idaho locations, control by both EPOST and LPOST treatments generally increased with increasing glyphosate rates. The 35% control by EPOST paraquat + diuron was less than the 63% control by the LPOST application. Rattail fescue control by paraquat + diuron applied EPOST was less than control by all glyphosate rates except the lowest rate applied EPOST, whereas control with paraquat + diuron applied LPOST was not different than control by the two lowest glyphosate rates applied LPOST. Application timing contrasts averaged over glyphosate rates showed that LPOST treatments controlled rattail fescue greater, at 68%, than EPOST treatments, at 43%, and control with sequential applications was greater, at 74%, than both LPOST and EPOST treatments (Tables 4 and 5).

Location within year interaction plots indicated that percentage of panicle reduction of rattail fescue was greater by LPOST and sequential application of glyphosate than by EPOST applications at Pendleton in 2004 whereas the opposite was true at Mission that year (data not shown). When combined over locations within years, percentage of panicle reduction was greater in 2005 than in 2004.

Sequential glyphosate treatments reduced rattail fescue panicle number 34 to 52%, whereas EPOST and LPOST applications reduced panicle number 9 to 23% and 18 to 40%, respectively (Table 6). Panicle reduction with LPOST

Table 6. Rattail fescue panicle reduction in chemical-fallow experiments at 4, 4, and 1 study sites in Idaho, Oregon, and Washington, respectively, during 2003 to 2004 and 2004 to 2005 growing seasons.

		Application	ID	OR	WA
Treatment[a]	Rate[b]	Timing[c]	2004–2005[d]	2004–2005[d]	2004
	kg ae/ha		%		
Gly[e]	0.42	EPOST	47	16	45
Gly	0.63	EPOST	66	11	21
Gly	0.84	EPOST	78	9	38
Gly	1.05	EPOST	84	23	28
Paraquat + diuron	0.84	EPOST	60	23	7
Gly	0.42	LPOST	48	18	0
Gly	0.63	LPOST	42	32	0
Gly	0.84	LPOST	51	40	0
Gly	1.05	LPOST	64	31	3
Paraquat + diuron	0.84	LPOST	57	35	0
Gly fb gly	0.42 fb 0.42	EPOST fb LPOST	85	34	0
Gly fb gly	0.63 fb 0.42	EPOST fb LPOST	91	34	19
Gly fb gly	0.42 fb 0.63	EPOST fb LPOST	91	45	21
Gly fb gly	0.63 fb 0.63	EPOST fb LPOST	89	49	43
Gly fb gly	0.63 fb 0.84	EPOST fb LPOST	96	52	29
Gly fb paraquat + diuron	0.42 fb 0.84	EPOST fb LPOST	90	44	13
Paraquat + diuron fb gly	0.84 fb 0.42	EPOST fb LPOST	70	34	15
LSD (0.05)			13	12	30

[a] Glyphosate applied with ammonium sulfate at 10 g/L. Paraquat + diuron was applied with a nonionic surfactant at 0.25% v/v. Product formulations: glyphosate = Roundup UltraMax® and paraquat + diuron = Surefire®, 2:1 ratio respectively, thus 0.84 kg/ha = 0.56 and 0.28 kg/ha, respectively.

[b] Glyphosate in kg ae/ha, paraquat + diuron in kg ai/ha. Spray volume = 94 L/ha.

[c] For early POST and late POST stage of growth see Tables 1 and 2.

[d] Data are combined over 2 yr.

[e] Abbreviations: gly, glyphosate; EPOST, early POST; LPOST, late POST; fb, followed by.

treatments generally increased with increasing rates of glyphosate. Paraquat + diuron applied EPOST (23%) and LPOST (35%) reduced panicle number equally. Percentage of panicle reduction with the EPOST application of the paraquat + diuron treatment usually was not different from EPOST glyphosate treatments, whereas paraquat + diuron applied LPOST was not different from glyphosate treatments applied LPOST, except the lowest rate of glyphosate. Application timing contrasts averaged over glyphosate rates showed that percentage of panicle reduction of rattail fescue with LPOST treatments, at 30%, was greater than EPOST treatments, at 15% (Tables 4 and 5). Percent panicle reduction with the sequential glyphosate application timings at 43% was greater than both LPOST and EPOST glyphosate treatments.

Washington Experiments. Only one Washington experiment year and location was included in the study because acceptable populations of rattail fescue failed to establish at this location in 2004 to 2005 growing season, and during either growing season at the second location. All sequentially applied glyphosate treatments controlled rattail fescue 87 to 97%, which was similar to the 84 to 93% control by EPOST glyphosate treatments but greater than the 59 to 71% control by LPOST treatments (Table 3). Weed control with EPOST treatments generally increased percentage of control with increasing rates of glyphosate. Similar control of rattail fescue occurred with EPOST (75%) and LPOST (64%) applications of paraquat + diuron. Rattail fescue control with paraquat + diuron applied EPOST only was less than control with the highest glyphosate rate applied at the same timing, whereas paraquat + diuron and all glyphosate rates applied LPOST controlled rattail fescue similarly. In contrast to control in Oregon but somewhat similar to control in Idaho, rattail fescue control by EPOST applications of glyphosate in Washington averaged over glyphosate rates (88%) was better than the 67% control by the LPOST glyphosate applications. Also, the 94% control by sequential glyphosate applications was greater than control by LPOST but not different than control by EPOST glyphosate applications (Table 4 and 5).

All EPOST and sequential treatments in Washington reduced rattail fescue panicle number 13 to 45%, whereas the LPOST treatments only reduced panicle number 0 to 7% (Table 6). As with visual estimates of control at this location, the 33% and 22% panicle reduction by EPOST applications of glyphosate as averaged over rate and the sequential glyphosate applications, respectively, was similar but greater than the 1% reduction by LPOST applications (Tables 4 and 5). In contrast to visual control and panicle number reduction at the other locations, control and reduction by the various glyphosate rates applied either EPOST or LPOST in Washington was similar. A rate effect was marginal (Tables 3 and 6).

In general, visually evaluated percentage of rattail fescue control and panicle number reduction by EPOST and LPOST treatments generally increased as glyphosate rates increased within each application timing at Idaho and Oregon, but panicle reduction was similar across rates within each timing at Washington (Tables 3 and 6). Visually evaluated percentage of control was comparable in all states for the LPOST treatments, ranging from 45 to 76%. However, control with EPOST treatment was less effective at Oregon, ranging from 35 to 51%, compared to 75 to 93% in Idaho and Washington. Less control with EPOST applications also reduced control with sequential treatments in Oregon (71 to 78%) compared to Idaho and Washington experiments (87 to 97%) (Table 3). Visible control of rattail fescue in Washington was similar to Idaho even though Washington had natural infestations.

Although rattail fescue is a winter annual grass, it has the ability to continue germination throughout the spring (Hitchcock 1951; USDA NRCS 2005a). Germination and seedling emergence may still have been occurring at the Oregon locations after the EPOST applications, especially because the rattail fescue stands there were mostly established, natural infestations. The dense mats of residue from previous stands of rattail fescue and winter wheat stubble also may have acted as a physical barrier preventing herbicide interception and absorption. Plant residue also may have slowed seedling emergence due to colder soil temperatures. Additional rattail fescue seed was added at Pendleton experiments. If rattail fescue seedling emergence continued after the EPOST applications, EPOST would be less effective than LPOST applications. In contrast, little or no emergence probably was occurring after the EPOST application timings in Idaho and Washington, thus providing better control than treatments applied LPOST when the plants were larger and more robust. In fact, the effectiveness of glyphosate and paraquat has been shown to be dependent on the growth stage of rattail fescue (Forcella 1984; Leys et al. 1991).

Percentage of rattail fescue panicle reduction within a state tended to follow the same general trend as visually evaluated control, but was always numerically less than or equal to visually evaluated control (Tables 3 and 6). Differences in panicle reduction compared with visually evaluated control may be partially related to differences in when control was evaluated and when panicles were collected. Visually evaluated control was assessed about 1 mo earlier than when panicle numbers were determined, which may have allowed rattail fescue to recover and produce panicles. Moreover, it was also observed that some plants emerged following late spring rains and prior to panicle counts. Additionally, treated rattail fescue panicles appeared chlorotic and this was included in percentage-of-control ratings. However, panicle numbers usually were not reduced even when the plants had these symptoms.

Although not completely effective, sequential applications of glyphosate, paraquat + diuron fb glyphosate, or glyphosate fb paraquat + diuron provided adequate rattail fescue control during the chemical-fallow period in conservation-tillage winter wheat cropping systems in the inland PNW.

Sources of Materials

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

[2] Roundup UltraMax®, Monsanto Agriculture Products Co., 800 North Lindbergh Boulevard, St. Louis, MO, 63167.

[3] Surefire®, 2:1 paraquat:diuron mixture from UAP Loveland Products, Inc., P.O. Box 1286 Greeley, CO 80632.

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