Weed Science 2008 56:26–31

Biological Attributes of Rattail Fescue (*Vulpia myuros*)

Daniel A. Ball, Sandra M. Frost, Lynn Fandrich, Catherine Tarasoff, and Carol Mallory-Smith*

Control of rattail fescue, a winter annual grass, can be difficult in spring or winter wheat. Although rattail fescue is not a new weed species in the Pacific Northwest, occurrences have been increasing in circumstances where soil disturbances are minimized, such as in direct-seed cropping systems. To develop integrated management strategies for rattail fescue, information is needed on the longevity of seed viability in the soil, the presence of seed dormancy, vernalization requirements, and optimal environmental conditions for seed germination and establishment under field conditions. Controlled experiments on the biology of rattail fescue indicated that newly mature seed required an afterripening period of 1 to 12 mo to obtain high levels of seed germination, depending on germination temperature. Maximum seed germination was observed at constant day/night temperatures of approximately 20 C from thermogradient plate studies. Germination tests from seed burial studies indicated that a majority of buried seed was not viable after 2 to 3 yr. Field-grown rattail fescue plants required vernalization to produce panicles and germinable seed. A short afterripening period, cool germination temperature, and vernalization requirements support the classification of rattail fescue as a winter annual. This information will facilitate development of rattail fescue management systems, including crop rotations and various control tactics such as tillage or herbicide application timing during fallow periods.

Nomenclature: Rattail fescue, *Vulpia myuros* (L.) K.C. Gmel. VLPMY, wheat, *Triticum aestivum* L.

Key words: Afterripening, dormancy, germination, seed longevity, vernalization, thermogradient plate.

Concerns have been increasing among Pacific Northwest (PNW) dryland wheat producers about the incidence of rattail fescue in direct-seed cropping systems where soil disturbances are minimized. These systems, also referred to as no-till, are minimal soil-disturbance systems requiring no mechanical tillage other than that produced by the seed-drilling operation. Rattail fescue rapidly increased in Australia when producers adopted direct-seed planting of their cropping systems (Dillon and Forcella 1984; Dowling 1996; Forcella 1984). Rattail fescue reduced yields of dryland wheat (Dillon and Forcella 1984). Decomposed residues of rattail fescue adversely affected wheat growth because of allelopathic substances (An et al. 1997; Pratley 1989). Also, reliance on glyphosate for weed control during fallow favored expansion of this species. Control of rattail fescue with glyphosate has been marginal in chemical fallow (Jemmett 2006) or before establishment of direct-seeded spring or winter cereals (Ball et al. 2005), thereby allowing populations of rattail fescue to increase. In Australian studies, it was shown that twice the typical glyphosate application rate was required to obtain acceptable control of rattail fescue (Leys et al. 1991). In addition, no selective herbicide treatments are currently registered for rattail fescue control in wheat in the PNW.

Rattail fescue has been characterized as a winter annual because of general observations of a vernalization requirement and cool temperatures that favor seed germination (Dowling 1996; Wallace 1997). Information exists on many aspects of the biology and ecology of rattail fescue, including evidence of a short photoperiod floral-induction requirement, high seed production potential (Dowling 1996), the presence of seed dormancy (Dillon and Forcella 1984; Wallace 1997), and the inability of seed to germinate in a highly disturbed seedbed or when the seed is buried deeply (Dillon and Forcella 1984). To develop management recommendations for rattail fescue in the PNW and because there are differences in reported seed longevity depending on environment (Dillon and Forcella 1984; Jones 1992), further experiments are needed on the longevity of seed viability in the soil under PNW environmental and production conditions. Studies are also needed that further characterize seed dormancy, vernalization requirements, and optimal environmental conditions for seed germination and establishment under field conditions. The objectives of these studies were to improve understanding of rattail fescue seed biology so that appropriate management decisions can be implemented to reduce rattail fescue populations in wheat cropping systems.

Materials and Methods

Seed Dormancy. Afterripening requirements of rattail fescue seed were evaluated by germination of aged seed at two temperatures and with two prechilling treatments in 2002 and in 2003. Mature seed were hand-collected from plants in a fallow field near Mission, OR, in 2002. Seed were open-air dried for 5 d before initiating the experiment. Seed were surface-sterilized with a 5% bleach solution (0.25% sodium hypochlorite) for 5 to 10 s, then rinsed with deionized water three times to ensure removal of bleach from the seed coat. Germination experiments were established within 10 d after seed harvest (DAH) and subsequently at 30, 90, 180, and 365 DAH in 9-cm-diam petri dishes atop two pieces of moistened germination paper. A factorial treatment arrangement of seed dormancy breaking treatments included the five postharvest (DAH) intervals, two prechill treatments of 5 d at 5 C, no prechill treatment, and two constant germination temperatures of 20 or 30 C. Prechilling has been used to stimulate germination of other grass species (Association of Official Seed Analysts 2002). Treatments were evaluated for their effect on rattail fescue seed germination. Each experimental unit consisted of 50 seed replicated four times. Individual replicates were placed in sealed plastic bags to reduce evaporation and randomly arranged in a seed-incubation chamber. No photoperiod was used, but seed were exposed to ambient, florescent light during germination counts. Germination counts were made at 3, 7, 14, and 21 d after establishment of treatments. Seed were considered germinated when 2 mm of the coleoptile had emerged and the radicle was

---

DOI: 10.1614/WS-07-048.1

* First and second authors: Oregon State University, Columbia Basin Agricultural Research Center, Pendleton, OR; third, fourth, and fifth authors: Oregon State University, Department of Crop and Soil Science. Corresponding author's E-mail: daniel.ball@oregonstate.edu

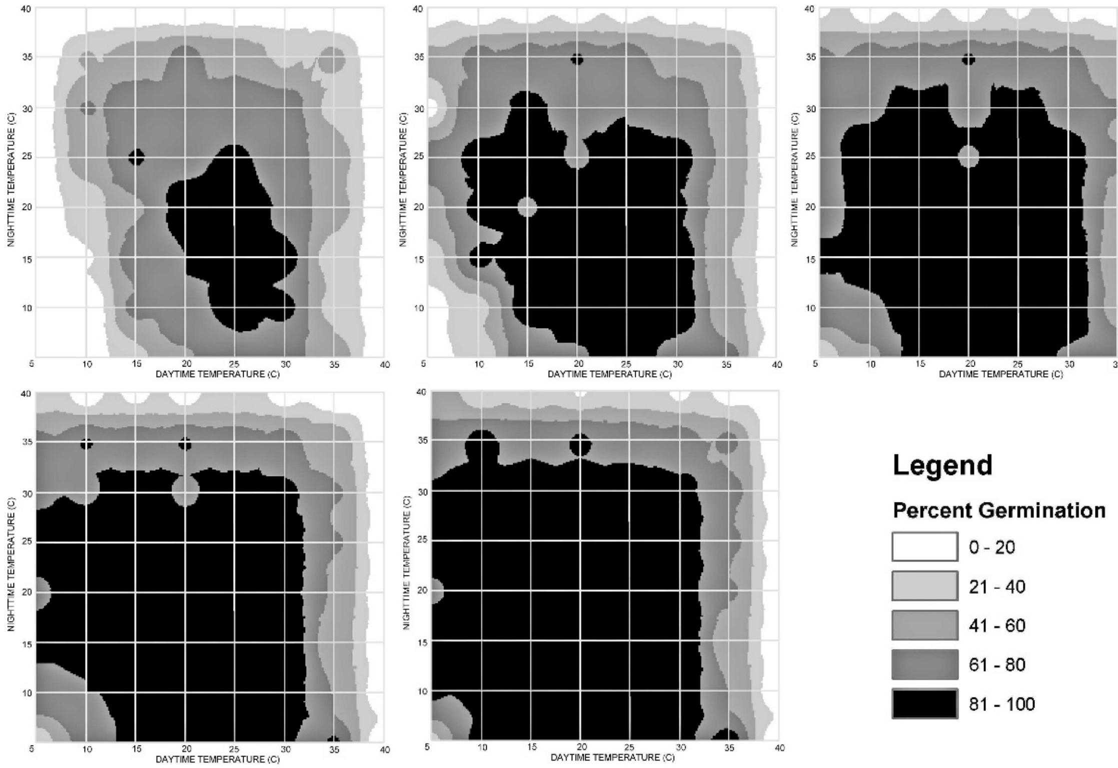

Figure 1. Germination of rattail fescue (from upper left to lower right) after 3, 6, 9, 12, and 15 d on a thermogradient plate.

visible. Germinated seed were counted and removed from the petri dish. Results for the 21 d counts were analyzed using PROC MIXED (Littell et al. 1996) and presented as an average percentage of germination value for each treatment. The study was repeated with seed collected from an irrigated grass seed production area at the Hermiston Agricultural Research and Extension Center near Hermiston, OR, in 2003.

Optimum Germination Temperature. Rattail fescue seed were collected in 1999 from Hermiston, and dry-stored at 21 C before, and for the duration of, an experiment conducted in 2002 and repeated in 2003. An experimental unit consisted of 50 seed placed on two pieces of germination paper moistened with 10 ml of deionized water in a covered, 9-cm-diam petri dish. Petri dishes were placed on a two-way thermogradient plate similar to one described by Larsen (1971). Alternating 16/8 h day/night temperatures were established. Temperature conditions ranged from 40/40 C to 5/5 C for a total of 64 temperature regimes, where the incremental temperature change was 5 C in any direction ± 1 C. No photoperiod was used, but seed were exposed to ambient, florescent light during germination counts.

Seed were considered germinated as described above. Germinated seed were counted every 3 d and removed from the petri dish for a total of 18 d. There were no differences between the repeated experiments, so data were combined, and average germination over time is presented using ArcMap v8.2[1] (ArcMap v8.2, 2002; Tarasoff et al. 2005) (Figure 1). Mean germination values at 18 d for each temperature regime were separated using Tukey's honestly significant difference and presented separately (Figure 2).

Longevity of Rattail Fescue Seed in Soil. A study was initiated to evaluate the influence of burial duration and depth on decomposition of rattail fescue seed. Burial sites were located on nonirrigated agricultural fields near Summerville, OR, and near Imbler, OR, and at the Columbia Basin Agricultural Research Center (CBARC) at Pendleton, OR. Average precipitation and soil properties for each site are reported in Table 1. The study was a randomized complete-block with 4 replications at each site. Factors studied were

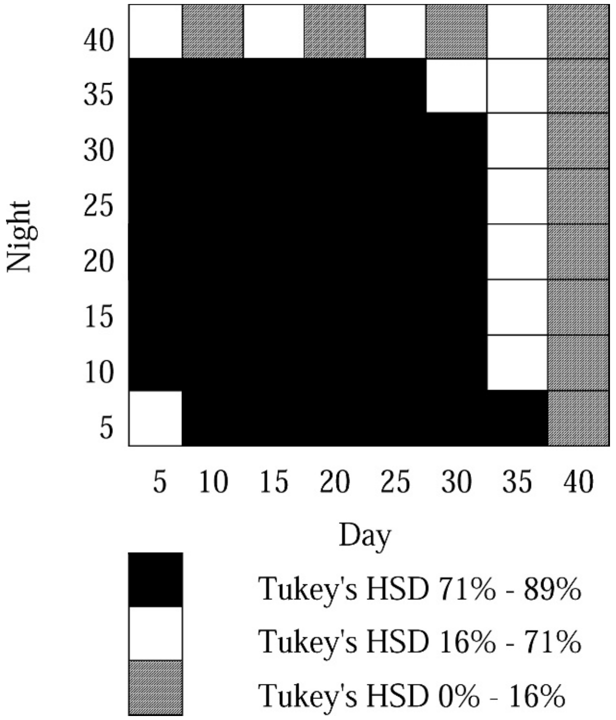

Figure 2. Statistically similar germination temperatures (C) for rattail fescue at 18 d (Tukey's honestly significant difference).

Table 1. Average annual precipitation, seed burial date, and soil conditions at three seed-burial locations in Oregon.

	Summerville	Imbler	Pendleton
Average precipitation (mm)	425	425	429
Burial date (2002)	September 11	September 10	September 16
Soil texture	Silt loam	Silt loam	Silt loam
Organic matter (%)	3.5	2.7	1.8
Soil pH	6.4	8.6	6.9

burial duration (6, 12, 24, or 36 mo) and burial depth (2.5, 5, 10, 15, or 20 cm). Rattail fescue seed, initially collected in June 2002 from a dryland wheat field near Mission, were placed in burial packets, or dry stored in the laboratory as a control. The experimental unit was 100 rattail fescue seed enclosed in a square packet, approximately 5 cm on a side, made of 0.2 mm nylon mesh screen[2] sewn with nylon thread. Packets were tied to a wire and buried at the appropriate depths. Each wire held a separate replication and was buried in a separate hole. The soil surface at the site was maintained free of vegetation using periodic glyphosate applications and hand-weeding. Packets were buried September 10, 11, and 16, 2002, at Imbler, Summerville, and Pendleton, respectively.

For each treatment, seed were exhumed at the appropriate burial interval, removed from the nylon packets, air-dried, and counted. A germination test was conducted to compare the remaining exhumed seed to dry-stored seed (control). Exhumed seed were surface-sterilized as previously described, and placed into 9-cm-diam petri dishes lined with moistened germination paper. Both buried and control seed were wetted and prechilled for 5 d at 5 C in the dark to promote seed germination. After the prechill, petri dishes were placed in a germinator set at 20 C. Percent germination was recorded at 21 d.

Rattail Fescue Vernalization Requirements. Two field studies investigated the vernalization requirements of 'eastern' and 'western' biotype rattail fescue plants. The two biotypes were included in the study because winters in western Oregon are milder than winters in eastern Oregon. Therefore, it is possible that plants from seed collected in western Oregon would have been selected to have a decreased vernalization requirement for flowering. Seed from the eastern biotype were collected near Hermiston, and seed from the western biotype were collected from a crop seed-cleaning facility in the Willamette Valley of western Oregon. Field studies were conducted at the CBARC station near Pendleton, at the Oregon State University Lewis Brown research farm near Corvallis, OR; and at the CBARC station near Moro, OR. Rattail fescue seed from each biotype were sown over 6 mo intervals from October through March into 2-m rows spaced 40 cm apart at an approximate seeding rate of 11 kg ha^{-1}. The study was arranged as a randomized complete-block with three replications. Sites were hand-weeded as necessary.

Studies were terminated near the time of winter wheat harvest appropriate for each location, approximately early to mid July in both years. Plants within each treatment were assessed for the presence or absence of panicles. At time of harvest, a 50-cm length of row was sampled in an area representative of each treatment. The number of plants and reproductive tillers within the 50-cm length of row were counted, and all panicles were harvested. Seed yield for each treatment was determined by hand-cleaning and weighing seed. Seed were collected randomly from panicles outside the sampled row, dry-stored for a minimum of 3 mo, and tested for germination using the temperature criteria described in the thermogradient study. Four replicates of 50 seed were tested for each field treatment and replicate. Germinated seed were counted 14 d after incubation and averaged over each treatment. The average number of reproductive tillers and seed weight per plant were calculated.

Daily weather data for the three locations for both years were obtained from nearby weather stations. Growing-degree days (GDD) were calculated based on a base temperature of 0 C subtracted from the daily average air temperature (C). Daily mean temperatures less than 0 C were assigned a zero heat-unit value. Accumulated GDD were calculated as the sum of daily heat values from planting until harvest. Vernalization days were calculated by multiplying daily GDD values from planting until May 31 by a series of effectiveness factors described in the CERES wheat-development model (Baloch et al. 2003; Fandrich and Mallory-Smith 2006; Ritchie et al. 1998). In the CERES model, vernalization temperatures in the 3 to 6 C range are assigned a greater vernalization effectiveness factor, and vernalization days are only calculated on GDD values between 0 and 15, as previously described for the CERES wheat model. Weather records for the 30-yr average suggested that very little vernalization was expected to occur at Corvallis after May 31 (Baloch et al. 2003). Corvallis weather data for 2003 to 2004 and 2004 to 2005 confirmed that temperatures did not drop consistently below 15 C after this date. Weather data during the study were similar to the 30-yr averages at Moro and Pendleton.

Data were analyzed using PROC GLM (SAS 1989) to test the main effects of year, location, planting date, and biotype on the number of reproductive tillers per plant, seed yield per plant, and seed germination.

Results and Discussion

Seed Dormancy. Analysis of data indicated temperature by chilling by afterripening interactions in both years. In 2002, the only freshly harvested seed to germinate were those exposed to both a prechill and 20 C incubation, and the total germination was only 9% (Figure 3A). The prechilling and 20 C germination temperature promoted the greatest percentage of germination through a 3-mo seed afterripening period. Seed incubated at 20 C without prechilling resulted in somewhat reduced germination through the 3-mo treatment until the 6-mo seed afterripening. Seed incubated at 30 C exhibited reduced germination compared with the 20 C incubation temperature regardless of prechill treatment until 12 mo of afterripening (Figure 3A).

For 2003, the 20 C germination temperature improved germination of freshly harvested (10 DAH) rattail fescue seed compared with a 30 C incubation temperature until after 6 mo of afterripening (Figure 1B). The prechill treatment was not needed to improve germination at 20 C because germination percent at that temperature was high, but prechilling did increase germination at 30 C (Figure 1B). In general, the combination of 20 C incubation temperature and prechilling had the greatest effect on seed germination, especially for the 2002 seed collection. Prechilling became less necessary to enhance seed germination as seed aged, presumably because of an afterripening requirement being met. The improved germination at lower temperatures, with prechilling, would be similar to the environmental conditions experienced during

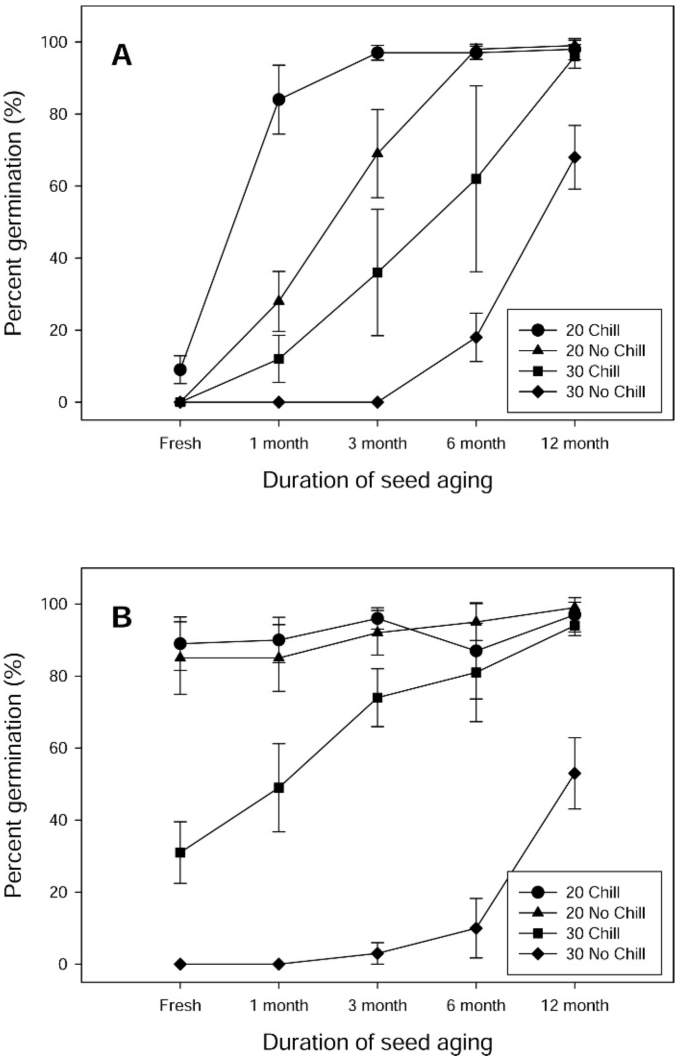

Figure 3. Effect of germination temperature, prechilling, and afterripening on rattail fescue seed germination after 21 d incubation. (A) 2002 seed collected from a dryland fallow field near Mission, OR. (B) 2003 seed collected from an irrigated field near Hermiston, OR. Values presented are the mean with standard error.

autumn or early spring field germination, given adequate soil moisture. This afterripening requirement would facilitate rattail fescue seed germination during more favorable environmental conditions in the PNW. Therefore, rattail fescue management operations would be best targeted to those times when favorable seed germination conditions would increase rattail fescue vulnerability to tillage or herbicide applications.

Seed Germination Temperature Optimum. Maximum germination occurred at a range of temperature combinations around 20/20 C in all three replications (Figure 1). Many temperature treatments resulted in similar rattail fescue germination at 18 d (mean germination values of 71 to 89%) (Figure 2). Temperature treatments exceeding 35 C resulted in low germination (mean values of 0 to 16%). Other temperature treatments resulted in intermediate (16 to 71%) germination percentages. The rate of germination differed between germination temperatures. At temperatures near the germination optimum of 20/20 C, germination between 81 and 100% occurred after 3 d of incubation (Figure 1). These observations are similar to those reported from an earlier study (Dillon and Forcella 1984) and are consistent with prevailing soil temperatures during typical autumn or spring times for rattail fescue germination under field conditions. There were no differences in germination percentage or rate between experiments conducted in 2002 and repeated in 2003, indicating that germination was not affected by the additional 1 yr of dry seed storage in the original seed collected in 1999.

Longevity of Rattail Fescue Seed in Soil. Analysis of the 3-yr seed-burial studies indicated a location by burial time by depth interaction. After 6 mo of burial, rattail fescue seed exhumed at each of the three sites failed to germinate, presumably because of a dormancy mechanism (Table 2), because seed exhumed after 1 yr of burial exhibited a higher percentage of germination than seed buried 6 mo. At the Pendleton burial site, seed buried more deeply germinated to a greater degree than seed shallowly buried after 1 and 2 yr of burial but not after 3 yr of burial. However, burial depth did not greatly affect germination at the Summerville site. Seed buried at the Imbler site had a very low percentage of germination at all exhumation times, which could possibly be related to the high soil pH at that site (Table 1), although that was not substantiated, experimentally. In general, percentage of germination declined at all sites as time of burial increased. Seed longevity was not influenced by burial depth at any location after 3 yr of burial. After 2 yr, germination was less than 11%, and after 3 yr, less than 3%. This observed seed-bank persistence is somewhat shorter than the observed 3-yr seed longevity study under northern Australian conditions (Jones 1992). However, the methodology of burying seed in packets used in this experiment could possibly overestimate the longevity of buried seed in natural situations (Van Mourik et al. 2005).

Table 2. Rattail fescue germination response to burial at five depths over 3 yr at Pendleton, Summerville, and Imbler, OR.

	Exhumed											
	6 mo March 10, 2003			1 yr September 10, 2003			2 yr September 10, 2004			3 yr September 8, 2005		
Depth	Pend[a]	Sum	Imb	Pend	Sum	Imb	Pend	Sum	Imb	Pend	Sum	Imb
cm	%											
2.5	0	0	0	3	25	2	0	5	0	1	3	0
5.0	0	1	0	5	25	1	1	2	0	0	3	0
10.0	0	1	0	7	22	3	1	7	1	1	1	0
15.0	0	3	0	12	31	3	5	11	0	1	0	0
20.0	1	1	0	24	17	1	2	9	0	1	3	0
LSD (0.05)	ns	2	ns	8	ns	ns	2	ns	ns	ns	ns	ns

[a] Abbreviations: Pend, Pendleton, OR, burial site; Sum, Summerville, OR, burial site; Imb, Imbler, OR, burial site; ns, not significant.

Table 3. Summary of heading and seed germination for two biotypes of rattail fescue grown at Pendleton and Corvallis, OR, in 2003 to 2004.

				Eastern biotype				Western biotype			
Location	Planting date	GDD	Vernalization days	Panicles present	Tillers per plant[a]	Seed per plant[a,b]	Germination[a]	Panicles present	Tillers per plant[a]	Seed per plant[a,b]	Germination[a]
						g	%			g	%
Pendleton	Oct. 20	2,663	116	yes	22 ± 6.1	2.7 ± 1.7	98 ± 0.9	yes	46 ± 7.3	2.7 ± 0.6	96 ± 0.9
	Nov. 17	2,476	102	yes	96 ± 45.1	6.2 ± 6.0	96 ± 0.8	yes	129 ± 28.1	5.0 ± 1.7	84 ± 7.0
	Dec. 16	2,351	81	yes	75 ± 6.9	6.1 ± 0.6	98 ± 0.2	yes	129 ± 44.7	6.9 ± 3.4	94 ± 0.8
	Jan. 28	2,298	66	yes	99 ± 36.4	7.9 ± 2.1	92 ± 0.7	yes	101 ± 32.7	1.9 ± 0.5	85 ± 3.8
	Feb. 24	2,188	44	no	—	—	—	no	—	—	—
	Mar. 18	1,997	27	no	—	—	—	no	—	—	—
Corvallis	Oct. 15	2,731	149	yes	22 ± 9.8	1.6 ± 0.6	96 ± 0.6	yes	8 ± 1.4	0.8 ± 0.2	95 ± 1.2
	Nov. 11	2,436	125	yes	15 ± 5.5	0.7 ± 0.4	92 ± 1.0	yes	11 ± 0.0	0.1 ± 0.0	71 ± 0.0
	Dec. 13	2,200	107	yes	7 ± 0.0	0.1 ± 0.0	93 ± 0.0	yes	6 ± 0.0	0.1 ± 0.0	missing data
	Jan. 20	2,087	78	no	—	—	—	no	—	—	—
	Feb. 18	1,851	44	no	—	—	—	no	—	—	—
	Mar. 15	1,569	23	no	—	—	—	no	—	—	—

[a] Values presented are the mean and standard error.
[b] Rounded to the nearest 0.1 g.

Rattail Fescue Vernalization Requirements. Results from both study years indicated that rattail fescue plants required vernalization to produce panicles and germinable seed (Tables 3 and 4). Plants from seed sown on the earliest planting dates were physiologically mature at harvest, whereas plants from seed sown later in the season remained vegetative. Analysis showed that the number of reproductive tillers per plant, seed yield per plant, and germination were significantly more affected by year than location, planting date, or biotype. Consequently, data were not combined over years in the final analysis. Rattail fescue plants did not establish at the Moro site in year 1, presumably because of poor seedbed conditions.

There were no differences in reproductive tiller number or seed yield among plants that were physiologically mature at harvest in the first study year. Reproductive panicles and seed were produced on plants exposed to as few as 66 d vernalization and 2,200 GDD. These values correspond to the late January planting at Pendleton and the mid-December planting at Corvallis. Reproductive tiller number per plant ranged from 6 to 129 with no consistent trend and large standard errors. Between 0.1 and 7.9 g of seed were produced per plant with no consistent trend and large standard errors. Neither the effect of biotype nor of site location affected the production of reproductive tillers or seed yield.

In the second study year, planting date and location affected the production of reproductive tillers and seed. Reproductive panicles and seed were produced on plants exposed to as few as 75 d vernalization and 1,653 GDD. These values correspond to the January 19 planting date at Pendleton. Plants from seed sown on January 20 at Corvallis also successfully completed their life cycle, whereas plants from seed sown January 18 at Moro did not. Reproductive tiller and seed production per plant decreased when plants were sown later in the season at Pendleton and Corvallis. Between 108 and 119 reproductive tillers and 11.2 and 9.3 g of seed were produced per plant at Pendleton on plant from

Table 4. Summary of heading and seed germination for two biotypes of rattail fescue grown at Pendleton, Corvallis, and Moro, OR, in 2004 to 2005.

				Eastern biotype				Western biotype			
Location	Planting date	GDD	Vernalization days	Panicles present	Tillers per plant[a]	Seed per plant[a,b]	Germination[a]	Panicles present	Tillers per plant[a]	Seed per plant[a,b]	Germination[a]
						g	%			g	%
Pendleton	Oct. 13	2,127	137	yes	108 ± 7.4	11.2 ± 1.1	95 ± 1.8	yes	119 ± 20.3	9.3 ± 1.1	96 ± 0.0
	Nov. 10	1,890	117	yes	85 ± 11.8	6.8 ± 1.7	95 ± 3.5	yes	68 ± 3.7	4.4 ± 0.5	91 ± 3.7
	Dec. 9	1,751	92	yes	93 ± 27.2	5.9 ± 2.0	97 ± 0.7	yes	64 ± 12.9	4.2 ± 1.9	89 ± 5.2
	Jan. 19	1,653	75	yes	23 ± 2.0	0.6 ± 0.3	41 ± 11.0	yes	30 ± 5.7	1.2 ± 0.3	61 ± 13.7
	Feb. 17	1,528	55	no	—	—	—	no	—	—	—
	Mar. 18	1,348	35	no	—	—	—	no	—	—	—
Corvallis	Oct. 15	2,418	162	yes	32 ± 0.5	2.0 ± 0.2	95 ± 2.4	yes	28 ± 5.7	2.6 ± 0.6	95 ± 0.7
	Nov. 11	2,183	142	yes	21 ± 0.8	1.3 ± 0.4	95 ± 1.3	yes	15 ± 3.6	1.5 ± 0.7	93 ± 2.4
	Dec. 13	1,976	115	yes	16 ± 3.3	0.6 ± 0.2	90 ± 4.2	yes	12 ± 3.5	0.5 ± 0.2	96 ± 2.0
	Jan. 20	1,806	84	yes	2 ± 0.3	0.0[c] ± 0.0	36 ± 20.1	yes	6 ± 1.1	0.1 ± 0.0	89 ± 3.5
	Feb. 18	1,649	57	no	—	—	—	no	—	—	—
	Mar. 15	1,418	39	no	—	—	—	no	—	—	—
Moro	Oct. 12	2,077	141	yes	50 ± 30.2	2.2 ± 1.2	98 ± 1.2	yes	42 ± 11.2	2.0 ± 0.8	97 ± 1.3
	Nov. 9	1,842	121	yes	38 ± 10.3	2.5 ± 1.0	99 ± 0.7	yes	60 ± 7.9	4.3 ± 0.6	99 ± 0.7
	Dec. 8	1,733	97	yes	38 ± 1.5	1.9 ± 0.1	99 ± 0.7	yes	50 ± 14.4	3.5 ± 0.8	84 ± 12.2
	Jan. 18	1,665	83	no	—	—	—	no	—	—	—
	Feb. 16	1,534	62	no	—	—	—	no	—	—	—
	Mar. 17	1,345	43	no	—	—	—	no	—	—	—

[a] Values presented are the mean and standard error.
[b] Rounded to the nearest 0.1 g.
[c] Actual value was 0.0258 g.

seed sown in October. These values decreased to 23 to 30 reproductive tillers per plant and from 0.6 to 1.2 g of seed per plant when seed were sown in January. A similar trend was observed at Corvallis. However, production of both factors was much less at Corvallis, and that may indicate better conditions for growth and reproductive development for both biotypes at Pendleton (an eastern site) compared with Corvallis (a western site).

At Moro, when panicles were produced on plants, reproductive tiller and seed production per plant were similar for all planting dates (Table 4). The consistency between reproductive tiller and seed production values at Moro may be explained by their timings to the three earliest planting dates. Plants from seed sown on planting date 4, remained vegetative at Moro (see above), whereas plants sown during this time window at Pendleton and Corvallis were reproductive, albeit with only a few reproductive tillers and seed. Plants from seed sown on the fourth planting at Moro were exposed to temperatures that were similar in vernalization effectiveness and GDD as plants at Pendleton and Corvallis. A factor other than temperature, such as limited soil moisture resulting in delayed germination, may explain why rattail fescue plants at Moro remained vegetative.

Germination of seed harvested from mature plants produced in the first study year was affected by location, planting date, and biotype (Table 3). Seed from the western biotype germinated less than seed from the eastern biotype. This trend was especially noticeable in plants from seed sown later in the growing season and at Pendleton more than at Corvallis. The western biotype did not establish well in the Corvallis plots, and that led to a limited data set. However, germination values were all greater than 70% and demonstrate that germinable seed can be produced from plants that emerge in December and January. Germination in the second study year was affected only by planting date. The average germination was 92% or greater for planting dates 1 through 3, but fell to a mean of 58 ± 8.9% for planting date 4. Because of limited data from 2003 to 2004 and the absence of a biotype effect in 2004 to 2005, we cannot infer from these data that there has been selection for an eastern and western biotype.

This information about rattail fescue seed biology can help facilitate the development of effective integrated-management strategies for PNW dryland wheat cropping systems. The presence of an afterripening requirement and germination temperature optimum helps to explain the occurrence of significant flushes of rattail fescue in the spring (D. Ball, personal observation). The presence of a vernalization response in these studies supports the classification of rattail fescue as a true winter annual.

Rotation to a spring cereal crop or a spring seeded-pulse or *Brassica* crop could disrupt the life cycle of rattail fescue and serve as an effective management strategy. Although rattail fescue sown in January successfully completed its life cycle by harvest, approximately 50% fewer seed were produced on these plants compared with October- and November-sown plants. A spring crop could be sown after the emergence and control of rattail fescue seedlings. Knowledge of seed longevity in the soil will facilitate the design of crop-rotation intervals as one rattail fescue management tool. Because of the relatively short seed longevity under PNW conditions, a 2-yr crop rotation without winter wheat could substantially reduce the rattail fescue seed bank. These cultural management tactics, along with more effective chemical control in wheat crops and during fallow periods, should facilitate successful management of rattail fescue in direct-seed wheat systems in the PNW.

Sources of Materials

[1] ArcMap v8.2, ESRI, 380 New York Street Redlands, CA 92373-8100.

[2] Sefar America, Inc. Ontario, CA 91761.

Acknowledgments

This research was partially funded with grants from the USDA–CSREES STEEP III program and from the Agricultural Research Foundation at Oregon State University.

Literature Cited

An, M., J. E. Pratley, and T. Haig. 1997. Phytotoxicity of *Vulpia* residues, I: investigation of aqueous extracts. J. Chem. Ecol. 23:1979–1995.

Association of Official Seed Analysts. 2002. Rules for Testing Seeds. Stillwater, OK: Association of Official Seed Analysts, p. 38.

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 University Press Special Report 1061.

Baloch, D. M., R. S. Karow, E. Marx, J. G. Kling, and M. D. Witt. 2003. Vernalization studies with Pacific Northwest wheat. Agron. J. 95:1201–1208.

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.

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

Fandrich, L. and C. A. Mallory-Smith. 2006. Vernalization responses of field grown jointed goatgrass (*Aegilops cylindrica*), winter wheat, and spring wheat. Weed Sci. 54:695–704.

Forcella, F. 1984. Size structure of silvergrass (*Vulpia spp.*) populations in direct drilled wheat. Aust. Weeds 3:3–5.

Jemmett, E. D. 2006. The biology and management of rattail fescue in winter wheat cropping systems. M.S. thesis. Moscow, ID: University of Idaho Press. 63 p.

Jones, C. E. 1992. Ecology and Management of *Vulpia* spp. in Pastures—Final