1998

SEED PRODUCTION RESEARCH

AT OREGON STATE UNIVERSITY
USDA-ARS COOPERATING

Edited by William C. Young III

Central Oregon Agricultural Research Center
F.J. Crowe, Superintendent, Associate Professor of Botany and Plant Pathology
N.A. Farris, Faculty Research Assistant

Columbia Basin Agricultural and Research Center
D.A. Ball, Associate Professor of Weed Science
D. Singh, Faculty Research Assistant

Cooperative Extension Service - OSU
M.D. Butler, Extension Agent, Jefferson County
G.A. Gingrich, Extension Agent, Marion County
M.E. Mellbye, District Extension Agent, Linn, Benton and Lane Counties

Department of Crop and Soil Science - OSU
B.D. Brewster, Senior Instructor
T.G. Chastain, Associate Professor Seed Crop Physiology
R.L. Cook, Extension Seed Certification Specialist and Project Manager
D.T. Ehrensing, Senior Research Assistant
A.E. Garay, Manager, Seed Laboratory
C.J. Garbacik, Senior Faculty Research Assistant
J.M. Hart, Professor and Extension Soil Scientist
P.E. Hendrickson, Faculty Research Assistant
J.A. Kilgore, Faculty Research Assistant, Extension Seed Certification Service
C.A. Mallory-Smith, Assistant Professor of Weed Science
P.D. Meints, Former Graduate Research Assistant
T.B. Silberstein, Faculty Research Assistant
T.M. Velloza, Former Graduate Research Assistant
W.C. Young III, Associate Professor and Extension Agronomist

Department of Entomology - OSU
J.T. DeFrancesco, Senior Faculty Research Assistant
G.C. Fisher, Professor and Extension Entomology Specialist
R.N. Horton, Faculty Research Assistant
S. Panasahatham, Graduate Research Assistant

National Forage Seed Production Research Center - USDA-ARS
S.C. Alderman, Professor and Research Plant Pathologist
R.E. Barker, Research Geneticist
S.M. Griffith, Assistant Professor and Research Plant Physiologist
G.W. Mueller-Warrant, Assistant Professor and Research Agronomist
W.F. Pfender, Associate Professor and Research Plant Pathologist
S.E. Warnke, Post-Doctoral Research Assistant

Other
R.J. Burr, Contract Researcher, Ag Research, Inc., Sublimity, OR
A.S. Herbert, Senior, Elmira High School, Elmira, OR
G.M. Walker, Science Research Advisor, Elmira High School, Elmira, OR

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DEFINING OPTIMUM NITROGEN FERTILIZATION PRACTICES FOR PERENNIAL RYEGRASS AND TALL FESCUE SEED PRODUCTION SYSTEMS IN THE WILLAMETTE VALLEY

W.C. Young III, M.E. Mellbye, G.A. Gingrich, T.B. Silberstein, S.M. Griffith, T.G. Chastain and J.M. Hart

Introduction
Oregon grass seed growers typically do not monitor crop or soil nitrogen (N) levels during the growing season and often apply fertilizer N in excess of recommended rates. Excessive fertilizer N use may result in leaching losses. This study has three objectives: 1) Determine the level of spring applied nitrogen fertilizer needed for optimizing both crop and economic returns; 2) Update OSU Extension Service Fertilizer Guidelines; and 3) Develop educational programs to reduce excessive N fertilization.

Large scale on-farm plots were established in three perennial ryegrass and three tall fescue fields. The fields were selected to represent soil types typically used for seed production in the Willamette Valley. Spring fertilizer treatments of 0, 45, 90, 135, 180, 225, and 270 lb N/a were split-applied (50/50) using precision application equipment. Normal grower equipment was used to swath and combine plots. Yields were measured using a weigh-wagon. Crop and soil samples were obtained for N uptake, soil N levels, and yield components. Results from the first-year crop indicated N levels above 135-180 lb N/a for perennial ryegrass and 90-135 lb N/a for tall fescue did not statistically increase seed yield. Perennial ryegrass was able to take up more N in above-ground biomass than tall fescue. Levels of soil NO_3-N were increased by the highest N rate (270 lb N/a) but were below 10 ppm. Based on sampling in the fall, the potential for leaching losses of N from normal application rates of N fertilizer does not appear to be a problem. These results are from the first year of a multi-year study.

Procedure
Large scale on-farm plots averaging 4.2 acres per site were established at 6 locations (3 perennial ryegrass, 3 tall fescue) prior to fertilizer applications. One North Valley and two South Valley sites for each species were established, encompassing soils in poorly drained to moderately well drained conditions (e.g., Concord-Amity and Woodburn soil types). All sites were in their first crop year and specific information for each site is shown in Table 1.

Table 1.   Site information for the perennial ryegrass and tall fescue locations.

Location	County	Variety	Planted	Soil type
Perennial ryegrass				
J Bar V Farms	Marion	Cutter	Fall 97	Woodburn silt loam
L3 Farms	Linn	DLF-1	Fall 97	Concord and Amity silt loam
Venell Farms	Benton	SR 4200	Fall 97	Dayton silt loam
Tall fescue				
Malpass Farms	Linn	Kittyhawk SST	Fall 96	Bashaw silty clay
Nixon Farms	Lane	Duster	Spring 97	Malabon silty clay loam
Roselawn Farms	Marion	Tomahawk	Fall 98	Woodburn silt loam

Plots were approximately 22 ft wide by 300 ft long (depending on fit in the field and grower equipment size). Spring fertilizer treatment rates of 0, 45, 90, 135, 180, 225, and 270 lb N/a were used. The seven treatments were replicated three times in a randomized complete block. Experimental data was analyzed using appropriate statistical analyses (e.g., ANOVA, Regression).

All sites were fertilized between February 26 and April 13 at the pre-determined rates using a split application (50/50) about four weeks apart. Applications were done between approximately 400 and 800 growing degree days (GDD) as is generally recommended. The 400 GDD and 800 GDD points were March 1 and April 18, 1998, respectively. Accumulated GDD using the T_{sum} method was calculated by summing the daily degree day values obtained by adding the maximum and minimum temperatures for the day, dividing by two and subtracting the base temperature, which for temperate grass is 0°C. Accumulated GDD was calculated beginning January 1. Additional details regarding calendar dates of N application and harvest at each site are shown in Table 2. Fertilizer was applied using a Gandy Orbit-air spreader pulled by a four-wheeler or small Kubota tractor. In addition to fertilizer N treatments, each site also fertilized with 275 lb/a of 0-15-20-10 at the same time as the first N application to ensure there were no other nutrient limitations. The plots were managed the same as the rest of the field for all other cultural management practices (weed control, fall fertilizers, disease control, etc.) by the grower-cooperator.

Table 2. Dates of fertilization, windrowing, and combining for optimum N study, 1998.

Location	Variety	Fertilizer application 1st date	Fertilizer application 2nd date	Swathing date	Combining date
Perennial ryegrass					
J Bar V Farms	Cutter	3/6	4/9	7/15	8/4
L3 Farms	DLF-1	3/19	4/13	7/17	7/30
Venell Farms	SR 4200	3/11	4/13	7/21	8/5
Tall fescue					
Malpass Farms	Kittyhawk SST	3/5	4/8	7/7	7/17
Nixon Farms	Duster	2/26	4/8	7/8	7/18
Roselawn Farms	Tomahawk	2/27	4/9	7/11	7/18

Plant samples were taken approximately 2 weeks following the first N application, at heading (May 12-15), and at maturity (June 26-30). Yield components samples were obtained at or following pollination during June. Plots were swathed into windrows between July 7 and July 21 and combined between July 17 and August 5 using grower equipment (Table 2). Seed yield from each plot was measured using a Brent YieldCart and adjusted for clean seed yield following an assessment of percent cleanout from sub-samples taken at harvest. Sub-samples taken at harvest were also used to determine seed size and are currently at the OSU Seed Testing Laboratory for purity and germination analysis.

Results and Discussion

Crop yield and response

Perennial ryegrass: Seed yield in perennial ryegrass increased as fertilizer rates increased up to the 135 lb N/a rate. Yield at rates higher than 135 lb/a was not significantly different at L3 Farms and Venell Farms (Table 3). However, the highest seed yield at J Bar V Farms was obtained at 180 lb N/a. Regression analysis of these data (Table 4) resulted in the response curves (not shown) which will be used for economic analysis at the completion of this study. Higher spring N application rates resulted in more biomass and increased N uptake by the crop as shown at the Venell site (Table 6). With harvest index remaining constant (Table 7), increased biomass generally increased seed yield.

Table 3. Seed yield (lb/a) of perennial ryegrass following varied rates of spring applied N, 1998.

Spring N rate (lb/a)	L3 Farms	Venell Farms	J Bar V Farms	3-site average
0	1526 c*	1163 d	1542 e	1410
45	1803 b	1690 c	1796 d	1763
90	1969 ab	1860 bc	1835 cd	1888
135	1998 ab	2078 abc	1914 bcd	1996
180	2087 a	2080 ab	1986 ab	2051
225	2193 a	2265 a	2041 a	2166
270	2165 a	2238 ab	1947 abc	2117
LSD 0.05	275	388	121	--

*Means in columns followed by the same letter are not significantly different by Fisher's protected LSD values (p=0.05).

2

Table 4. Seed yield statistical summary for perennial ryegrass and tall fescue, 1998.

Location	ANOVA	Regression analysis Linear (r^2)	Quadratic (r^2)
Perennial ryegrass			
L3 Farms	**	**(0.66)	**(0.74)
Venell Farms	**	**(0.69)	**(0.80)
J Bar V Farms	**	**(0.54)	**(0.68)
Tall fescue			
Malpass Farms	*	NS	NS
Nixon Farms	NS	NS	*(0.29)
Roselawn Farms	**	**(0.68)	**(0.83)

NS = not significant P value
* = P value < 0.05
** = P value < 0.01

Tall fescue: Seed yield in tall fescue was not as responsive to increased N fertilization rates as was observed in perennial ryegrass. Seed yield at two of the tall fescue sites (Malpass and Nixon Farms) showed little or no response to increasing fertilizer rates (Table 5). Regression analysis of these data (Table 4) resulted in response curves (not shown) which will be used for economic analysis at the completion of this study. At the Malpass site, one of the plots harvested at the 180 lb N/a rate was much lower in seed yield than the other two plots, hence the decrease in yield at that rate and subsequent affect on these statistics. The Malpass site is located in the poorly drained soil site and some of the stand was thin or missing. At the Nixon site there was no statistical difference in seed yield due to fertilizer rates. In contrast to these two locations, seed yield at the Roselawn site responded to N applications up to 135 lb N/a. Rates above 135 lb N/a did not increase seed yield. Harvest biomass at the Roselawn site increased as the N rates increased (P-value < 0.10). The Roselawn site was the only tall fescue site responsive to higher N fertilization rates.

Table 5. Seed yield (lb/a) of tall fescue following varied rates of spring applied N, 1998.

Spring N rate (lb/a)	Malpass Farms	Nixon Farms	Roselawn Farms	3-site average
0	1648 bc	1536	1313 d	1499
45	1709 abc	1724	1657 c	1697
90	1886 a	1771	1886 bc	1847
135	1796 ab	1708	2164 ab	1890
180	1556 c	1818	2166 ab	1847
225	1678 bc	1775	2335 a	1929
270	1796 ab	1673	2177 ab	1882
LSD 0.05	184	NS	304	--

Crop nitrogen uptake

Tissue nitrogen levels and uptake in above-ground biomass at harvest were very different between perennial ryegrass and tall fescue. Perennial ryegrass tissue N increased as the level of applied N increased (Table 8) and leveled off at the higher rates. In contrast, the tall fescue tissue N levels were not affected by the rates of N applied. Perennial ryegrass had a wider range of tissue N values (0.7 to 2.3% N) than tall fescue (0.8 to 1.7% N) and took up more total nitrogen in above ground biomass (Table 9). In addition, perennial ryegrass at all three locations took up significantly more N than was applied up to the highest applied N rates (Figure 1), while tall fescue N uptake did not increase significantly with higher applied N rates. When all three sites for tall fescue are averaged, N uptake peaked at about 90 lb N/a (Figure 2) and took up less N in above ground biomass than was applied at treatments above 135 lb N/a. As can be seen in Table 9, the soil provided a large amount of mineralized N even at the 0 N rate. Uptake in the 0 N/a applied treatment averaged 78 lb N/a in the perennial ryegrass stands and 104 lb N/a in the tall fescue sites, indicating a considerable amount of soil N mineralization.
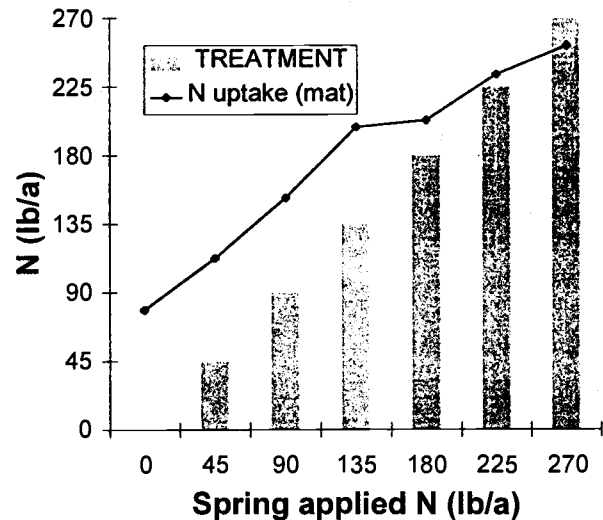

Figure 1. Perennial ryegrass crop nitrogen uptake across fertilizer nitrogen treatments, 1998
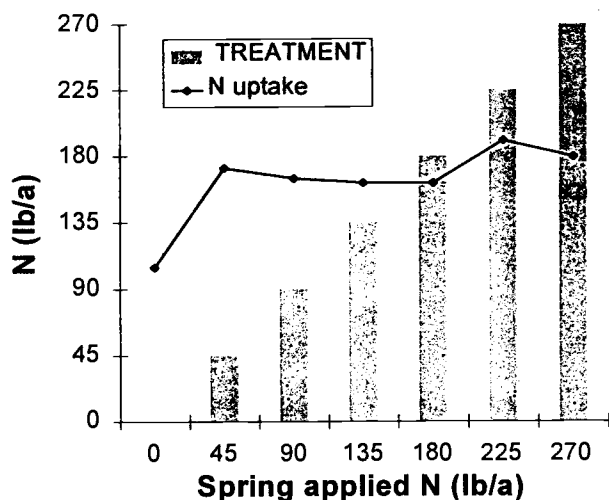
Figure 2. Tall Fescue crop nitrogen uptake across fertilizer nitrogen treatments, 1998

Chart: Y-axis N (lb/a) from 0 to 270; X-axis Spring applied N (lb/a) 0, 45, 90, 135, 180, 225, 270. Legend: TREATMENT, N uptake.

Table 10. Soil NO_3-N concentrations (ppm) at three soil depths of perennial ryegrass following varied rates of spring applied N, 1998.

Spring N rate (lb N/a)	pre-fert. 0-12 in.	Post harvest samples 0-12 in.	13-24 in.	25-36 in.	Soil NO_3-N changes (top 12 inches)
L3 Farms.					
0	1.3	1.9	1.0	1.1	0.6
135	--	3.7	1.6	1.2	2.4
270	--	7.7	4.4	3.5	6.4
LSD 0.05		NS	1.9	1.7	--
Venell Farms.					
0	1.1	1.5	1.2	1.2	0.5
135	--	2.6	1.3	1.3	1.5
270	--	4.7	1.7	2.5	3.6
LSD (0.10)	(2.0)	NS	NS		--
J Bar V Farms					
0	2.8	0.7	0.8	0.7	-2.1
135	--	2.4	1.1	0.9	-0.4
270	--	3.1	1.0	1.0	0.3
LSD 0.05		1.4	NS	NS	--
3 site average					
0	1.7	1.4	1.0	1.0	-0.4
135	--	2.9	1.3	1.1	1.2
270	--	5.2	2.4	2.3	3.4

Soil NO_3-N

Soil samples were taken prior to fertilizing in February (0-1ft depth only) and following crop harvest in late September. Samples taken post-harvest were obtained from three treatments: 0, 135, 270 lb N/a and at three depths: 0-1, 1-2, 2-3 ft. Results are detailed in Tables 10-13. At all perennial ryegrass and tall fescue sites, the highest fertilizer rate (270 lb N/a) generally increased the levels of NO_3-N in the top 12 inches of soil (see Tables 12 and 13). In the 1-2 ft and 2-3 ft profiles there were no differences in the levels of soil NO_3-N except at L3 Farms (Table 10). Soil NO_3-N concentrations taken after harvest, when compared with February samples, decreased slightly at the 0 N rate, were about the same at the 135 N rate, and increased slightly at the 270 N rate. Even though there were greater NO_3-N concentrations in the high applied N rate, concentrations were almost all below 10 PPM. Efficient soluble nitrogen removal by the fibrous root systems of these perennial grass seed crops during crop growth and development for seed production results in low NO_3-N concentrations in the soil following harvest. Use of recommended N rates will result in little potential for leachable N being available in the soil after harvest.

Table 11. Soil NO₃-N concentrations (ppm) at three soil depths of tall fescue following varied rates of spring applied N, 1998.

Spring N rate (lb N/a)	pre-fert. 0-12 in.	Post harvest samples 0-12 in.	13-24 in.	25-36 in.	Soil NO₃-N changes (top 12 inches)
Malpass Farms					
0	3.3	5.4	2.3	2.1	2.2
135	--	7.8	4.0	3.3	4.6
270	--	12.6	3.8	2.9	9.3
LSD 0.05		NS	NS	NS	--
Nixon Farms					
0	2.1	1.4	1.4	1.3	-0.7
135	--	2.2	1.3	1.7	0.1
270	--	4.7	1.9	2.0	2.6
LSD (0.10)		(2.3)	NS	NS	--
Roselawn Farms					
0	3.5	1.9	1.3	1.1	-1.5
135	--	3.2	1.3	1.3	-0.3
270	--	9.0	2.8	5.3	5.5
LSD 0.05		NS	NS	NS	--
3 site average					
0	2.9	2.9	1.6	1.5	-0.0
135	--	4.4	2.2	2.1	1.5
270	--	8.7	2.9	3.4	5.8

Table 13. Soil NO₃-N concentrations (in ppm) from spring N fertilizer rate and depth of sampling of tall fescue, 1998.

Treatment	Malpass Farms	Nixon Farms	Roselawn Farms	3-site average
Spring N rate (lb N/a)				
0	3.3	1.4	1.4	2.0
135	5.1	1.7	1.9	2.9
270	6.4	2.8	5.7	5.0
LSD 0.05	*1	*1	2.5	--
Soil sample depth				
0-1 ft	8.6	2.7	4.7	5.4
1-2 ft	3.4	1.5	1.8	2.2
2-3 ft	2.8	1.6	2.6	2.3
LSD 0.05	*1	*1	NS	--

*1 Interaction of rate x depth significant at P≤0.05

Summary

Optimum levels of spring applied N for seed production were 135-180 lb N/a in the perennial ryegrass and 90-135 lb N/a in the tall fescue as shown by combining all three sites for each species. Applying more than the optimum rates did not ensure increased yield. It must be noted that these results are from first-year seed crops, and only by continuing these trials for 2-3 years will we be able to provide data over the life of these stands. Seed yields for all locations, as indicated in Tables 3 and 5, were well above Willamette Valley average yields of 1372 lb/a for perennial ryegrass and 1332 lb/a for tall fescue in the 1995-97 period. Soil test results show efficient use of applied N and potential for leaching losses reported appear low for recommended use rates. These sites are being continued for a second year (and possibly a third year) to determine the long-term economic and agronomic effects of these treatments.

Table 12. Soil NO₃-N concentrations (in ppm) from spring N fertilizer rate and depth of sampling of perennial ryegrass, 1998.

Treatment	L3 Farms	Venell Farms	J Bar V Farms	3-site average
Spring N rate (lb N/a)				
0	1.3	1.3	0.7	1.1
135	2.2	1.7	1.4	1.8
270	5.2	2.9	1.7	3.3
LSD 0.05	NS	*1	*1	--
Soil sample depth				
0-1 ft	4.4	2.9	2.0	3.1
1-2 ft	2.3	1.4	0.9	1.6
2-3 ft	1.9	1.7	0.9	1.5
LSD	(1.9)	*1	*1	--
P-value	0.080			

*1 Interaction of rate x depth significant at P≤0.05

Table 6. Total biomass (ton/a) at maturity of perennial ryegrass and tall fescue following varied rates of spring applied N, 1998.

Spring N rate (lb/a)	Perennial ryegrass				Tall fescue			
	L3 Farms	Vennel Farms	J Bar V Farms	3-site average	Malpass Farms	Nixon Farms	Roselawn Farms	3-site average
0	5.6	2.6	6.2	4.8	5.7	7.0	5.3	6.0
45	5.1	5.4	6.2	5.6	4.9	8.1	6.3	6.4
90	5.6	5.7	7.5	6.3	6.0	7.1	6.0	6.4
135	6.3	7.7	7.1	7.0	6.3	7.5	6.6	6.8
180	7.0	6.2	6.8	6.7	6.7	9.0	7.3	7.6
225	7.6	5.9	5.8	6.4	7.4	8.0	8.6	8.0
270	6.2	6.2	7.3	6.5	6.2	6.6	7.5	6.8
LSD 0.05(0.10)	NS	2.0	NS	--	NS	NS	(1.67)	--

Table 7. Harvest index (%) of perennial ryegrass and tall fescue following varied rates of spring applied N, 1998. (%=seed yield / total biomass * 100)

Spring N rate (lb/a)	Perennial ryegrass				Tall fescue			
	L3 Farms	Vennel Farms	J Bar V Farms	3-site average	Malpass Farms	Nixon Farms	Roselawn Farms	3-site average
0	12	19	13	15	13	10	11	12
45	15	14	13	14	15	10	12	12
90	15	14	11	13	14	11	14	13
135	14	12	12	13	13	11	14	12
180	13	15	13	14	10	10	13	11
225	13	16	15	15	10	10	12	11
270	15	16	12	14	13	12	13	12
LSD 0.05	NS	NS	NS	--	NS	NS	NS	--

Table 8. Tissue N concentration (%) in above ground biomass at maturity of perennial ryegrass and tall fescue following varied rates of spring applied N, 1998.

Spring N rate (lb/a)	Perennial ryegrass				Tall fescue			
	L3 Farms	Vennel Farms	J Bar V Farms	3-site average	Malpass Farms	Nixon Farms	Roselawn Farms	3-site average
0	0.7	0.8	0.9	0.8	1.0	0.9	0.8	0.9
45	0.9	1.0	1.1	1.0	1.6	1.2	1.3	1.4
90	1.2	1.1	1.3	1.2	1.3	1.3	1.4	1.3
135	1.5	1.1	1.6	1.4	1.3	1.3	1.2	1.2
180	1.2	1.7	1.9	1.6	1.4	0.8	1.0	1.1
225	1.6	1.5	2.4	1.8	1.2	1.1	1.3	1.2
270	1.6	2.0	2.2	1.9	1.6	1.0	1.3	1.3
LSD 0.05	0.4	0.6	0.8	--	NS	NS	NS	--

Table 9.

Table 9.   N uptake (lb/a) at maturity in above ground biomass of perennial ryegrass and tall fescue following varied rates of spring applied N, 1998.

Spring N rate (lb/a)	Perennial ryegrass				Tall fescue			
	L3 Farms	Vennel Farms	J Bar V Farms	3-site average	Malpass Farms	Nixon Farms	Roselawn Farms	3-site average
0	77	39	120	78	109	121	83	104
45	91	107	139	112	159	197	159	172
90	138	124	193	152	152	181	161	165
135	191	170	236	199	162	175	148	162
180	160	210	239	203	187	153	144	161
225	251	178	270	233	179	173	220	190
270	199	241	316	252	202	137	198	179
LSD 0.05	66	64	120	--	NS	NS	NS	--

RESIDUE MANAGEMENT AND STAND AGE DOES NOT AFFECT SEED QUALITY IN GRASS SEED CROPS

T.G. Chastain, W.C. Young III, C.J. Garbacik, P.D. Meints and T.B. Silberstein

Introduction. Field burning has been an important residue management practice in cool-season grass seed crops. Historically, residue burning has been justified on the basis of disease control, weed control, and stimulation of seed yield. Public concern over air quality has necessitated the identification of alternative residue management practices. Furthermore, recent research has established that agronomically feasible alternatives to field burning exist for all species grown in the region except for creeping red fescue. Seed growers have largely adopted field burning alternatives but many still believe that these practices may reduce seed quality. One concern has been that seed quality will progressively decline as crop stands age in the absence of field burning. The objective of our investigation was to determine how alternative post-harvest residue management techniques and stand age affect seed quality in cool-season perennial grasses.

Methods. On-farm residue management trials were conducted between 1992 and 1997 in 26 commercial seed production fields throughout Oregon. Species, cultivars, and duration of residue management trials are listed in Table 1. Residue management treatments included: (i) flail chopping with no straw removal (Straw), (ii) removal of straw by baling with or without further management of stubble (Bale), (iii) removal of straw by baling, followed by propane burning (Propane), and (iv) open-field burning (Burn). The treatments were evaluated in each of the following species included: perennial ryegrass (Straw, Bale, Propane); tall fescue (Straw, Bale); Chewings fescue (Straw, Bale, Propane, Burn); Kentucky bluegrass (Straw,

Bale, Burn); orchardgrass (Straw, Bale); creeping red fescue (Bale, Propane, Burn); and dryland bentgrass (Bale, Propane, Burn). Residue management treatments were conducted in each of the seed fields after the first seed harvest and ending when the field was removed from production. Fertilizer and herbicide applications were uniformly made across all residue treatment plots and at application timings and rates standard for each grass seed crop species.

Field plots were harvested with a farm-scale swather and windrows remained in the field until the seed dried. Dried windrows were combined with farm-scale combines equipped with pickup header attachments. Subsamples (1164) were taken by using a sampling tube from the harvested seed for seed quality analysis. Seed germination and purity tests were conducted according to rules of the Association of Official Seed Analysts. Seed samples were also examined for contamination by ergot sclerotia, and blind seed disease.

Results. There were no interactions between stand age and residue management technique evident for any of the species tested in our trials. This finding refutes one of the major concerns of seed producers that field burning alternatives would not only lower seed quality but that this problem would be exacerbated in aging stands. The incidence and severity of ergot and blind seed diseases in the 1164 harvested seed samples also were not related to residue management or stand age (data not shown). Control of ergot and blind seed has been attributed to field burning in grass seed crops, and has long been used as a justification for the use of field burning as a management practice in grass seed production.

Pure seed percentage in perennial ryegrass was reduced in 3rd- and 4th-year stands, and other crop percentage was higher in 4th-year stands (Table 2). Inert matter was increased in 3rd-year stands. Stand age had no effect on

weed seed contamination. Seed germination tended to be lower in 2nd-year stands and was reduced in 3rd-year stands. Residue management practices had no effect on seed purity and germination in perennial ryegrass (Table 2). No straw removal tended to increase the incidence of rough bluegrass (*Poa trivialis*) seed contamination in perennial ryegrass but these increases were not statistically significant. The straw mulch also suppressed weeds thereby reducing contamination by annual bluegrass (*P. annua*) and annual ryegrass seeds in perennial ryegrass seed.

Fourth-year stands of tall fescue had significantly greater levels of pure seed and pure seed levels were somewhat greater in 5th-year stands than in other stand ages (Table 3). Other crop seed contamination was greatest in 5th-year stands. Inert matter levels were high in 2nd- and 3rd - year stands, low in 4th -year stands, and intermediate levels were recorded in 5th-year stands. Weed seed levels were unaffected by age of stand. Seed germination tended to be higher in 4th- and 5th-year stands. No effect of residue management technique was evident in seed purity and seed germination results (Table 3).

Pure seed percentage levels were reduced and inert matter levels increased in 3rd-year stands of Chewings fescue (Table 4). Increased inert matter was responsible for the loss in seed purity. The reduction in seed purity in 3rd-year stands of Chewings fescue was accompanied by a reduction in seed germination. The cause of reduced seed germination was unknown as seed weight was not affected by management without straw removal (data not shown).

Management of straw without removal reduced percentage of pure seed in Chewings fescue (Table 4). This reduction in seed purity resulted from increased inert matter when straw was managed without removal. However, field burning did not improve seed purity levels in Chewings fescue. Germination percentage of seed produced without straw removal was lower than other management practices, including field burning.

Seed purity and seed germination were not influenced by age of stand nor by residue management practices in Kentucky bluegrass (Table 5), orchardgrass (Table 6), creeping red fescue (Table 7), and dryland bentgrass (Table 8).

Our results demonstrate that cool-season perennial grass seed crops can be produced using field burning alternatives without loss in seed purity or in seed germination. Straw management without removal (Straw) in Chewings fescue increased purity problems and caused reduced seed germination. Bale and propane based management approaches always produced seed purity and seed germination levels equivalent to burning.

Our trials did not reveal a consistent trend in seed germination level as the crop stands aged for any of the species tested. Seed purity was lower in older stands of perennial ryegrass but tended to be higher in older stands of tall fescue. Seed purity was not consistently related to age of crop stand in the other species evaluated in our trials. Reduced seed purity was often accompanied by increased inert matter and sometimes by lower seed germination.

Table 1.   Species, cultivar, and duration of on-farm residue management trials in cool-season grass seed crops. All trials
were initiated after the first seed harvest in each field. The number of seed quality tests represent the number of
samples submitted for individual seed germination and purity tests (total = 1164 germination and purity tests).

Species	Cultivar	Duration (harvest years)	Number of seed germination, seed purity tests performed
Kentucky bluegrass	Abbey	3	45
	Bristol	3	45
	Baron	3	54
Chewings fescue	Banner	4	45
	Barnica	3	45
	Jamestown II	3	36
Tall fescue	Rebel Jr. (Glaser site)	4	60
	Rebel Jr. (Wilfong site)	3	45
	Rebel II	3	45
	Anthem	3	45
	Crewcut	3	45
	Barlexas	2	30
	Titan II	2	30
Creeping red fescue	Pennlawn	3	45
	Shademaster	1	18
	Hector	2	36
Perennial ryegrass	Pennfine	3	54
	Pennant	3	54
	Yorktown III	2	36
	Linn	2	36
	Manhattan IIE	3	63
	Oasis	3	54
	Affinity	2	42
	Cutter	2	36
Orchardgrass	Elsie	3	45
Dryland bentgrass	Highland	5	75

Table 2. Influence of stand age and residue management on seed quality in perennial ryegrass.

| Stand age | Purity | | | | Germination |
	Pure seed	Other crop	Inert matter	Weed seed	
(Year)	--(%)--				
2nd	95.6 b†	1.3 a	3.0 a	0.1 a	92.1 ab
3rd	92.7 a	1.6 a	5.4 b	0.2 a	90.6 a
4th	93.5 a	3.7 b	2.7 a	0.1 a	93.9 b
Residue management					
Straw	93.8 a	2.0 a	3.9 a	0.1 a	91.6 a
Bale	94.2 a	1.9 a	3.8 a	0.1 a	92.4 a
Propane	94.1 a	1.6 a	4.1 a	0.1 a	91.3 a

†Means in columns within stand age and residue management followed by the same letter are not different by Fisher's protected LSD values ($P = 0.05$).

Table 3. Effect of stand age and residue management technique on seed quality in tall fescue..

| Stand age | Purity | | | | Germination |
	Pure seed	Other crop	Inert matter	Weed seed	
(Year)	--(%)--				
2nd	95.4 a†	0.2 a	4.3 b	0.0 a	89.9 a
3rd	94.9 a	0.3 a	4.8 b	0.1 a	90.6 a
4th	98.4 b	0.2 a	1.2 a	0.2 a	94.5 b
5th	95.9 ab	2.2 b	1.9 ab	0.0 a	91.5 ab
Residue management					
Straw	95.9 a	0.4 a	3.7 a	0.1 a	91.4 a
Bale	96.1 a	0.3 a	3.5 a	0.1 a	91.4 a

†Means in columns within stand age and residue management followed by the same letter are not different by Fisher's protected LSD values ($P = 0.05$).

Table 4. Effect of stand age and residue management practices on seed quality in Chewings fescue.

| Stand age | Purity | | | | Germination |
	Pure seed	Other crop	Inert matter	Weed seed	
(Year)	-- (%)--				
2nd	91.7 b†	0.0 a	8.4 a	0.0 a	88.8 b
3rd	83.9 a	0.0 a	15.9 b	0.1 a	79.3 a
4th	93.5 b	0.0 a	· 6.5 a	0.0 a	89.2 b
Residue management					
Straw	83.9 a	0.0 a	17.1 b	0.0 a	76.0 a
Bale	90.4 b	0.0 a	9.4 a	0.1 a	86.4 b
Propane	91.4 b	0.0 a	8.5 a	0.1 a	88.5 b
Burn	89.9 b	0.0 a	10.0 a	0.0 a	86.6 b

†Means in columns within stand age and residue management followed by the same letter are not different by Fisher's protected LSD values (*P* = 0.05).

Table 5. Effect of stand age and residue management technique on seed quality in Kentucky bluegrass.

| Stand age | Purity | | | | Germination |
	Pure seed	Other crop	Inert matter	Weed seed	
(Year)	-- (%)--				
2nd	90.9 a†	0.0 a	9.3 a	0.0 a	88.0 a
3rd	91.6 a	0.0 a	8.4 a	0.0 a	82.4 a
4th	88.1 a	0.0 a	11.9 a	0.0 a	85.8 a
Residue management					
Straw	87.3 a	0.0 a	12.7 a	0.0 a	83.7 a
Bale	90.6 a	0.0 a	9.4 a	0.0 a	85.7 a
Burn	91.3 a	0.0 a	8.8 a	0.0 a	86.0 a

†Means in columns within stand age and residue management followed by the same letter are not different by Fisher's protected LSD values (*P* = 0.05).

Table 6.   Effect of stand age and residue management technique on seed quality in orchardgrass.

| Stand age | Purity | | | | Germination |
	Pure seed	Other crop	Inert matter	Weed seed	
(Year)			(%)		
2nd	92.5 a†	1.0 a	6.6 a	0.0 a	95.0 a
3rd	94.0 a	0.1 a	6.1 a	0.0 a	94.5 a
4th	96.2 a	0.5 a	3.5 a	0.0 a	96.0 a
Residue management					
Straw	94.2 a	0.4 a	5.4 a	0.0 a	95.3 a
Bale	94.2 a	0.5 a	5.3 a	0.0 a	95.0 a

†Means in columns within stand age and residue management followed by the same letter are not different by Fisher's protected LSD values ($P = 0.05$).

Table 7.   Effect of stand age and residue management practices on seed quality in creeping red fescue.

| Stand age | Purity | | | | Germination |
	Pure seed	Other crop	Inert matter	Weed seed	
(Year)			(%)		
2nd	93.1 a †	0.0 a	6.9 a	0.0 a	85.8 a
3rd	91.2 a	0.0 a	8.9 a	0.1 a	87.4 a
4th	95.3 a	0.0 a	4.7 a	0.0 a	89.0 a
Residue management					
Bale	93.5 a	0.0 a	6.4 a	0.1 a	88.0 a
Propane	91.6 a	0.0 a	8.5 a	0.0 a	87.7 a
Burn	93.0 a	0.0 a	7.1 a	0.0 a	86.0 a

†Means in columns within stand age and residue management followed by the same letter are not different by Fisher's protected LSD values ($P = 0.05$).

Table 8. Effect of stand age and residue management practices on seed quality in dryland bentgrass.

| Stand age | Purity | | | | Germination |
	Pure seed	Other crop	Inert matter	Weed seed	
(Year)	--(%)---				
2nd	95.2 a†	0.0 a	5.0 a	0.0 a	94.7 a
3rd	97.6 a	0.0 a	2.4 a	0.0 a	91.7 a
4th	96.0 a	0.0 a	4.1 a	0.0 a	93.7 a
5th	98.2 a	0.0 a	1.8 a	0.0 a	95.0 a
6th	93.9 a	0.0 a	5.9 a	0.1 a	93.0 a
Residue management					
Bale	96.2 a	0.0 a	3.7 a	0.0 a	94.0 a
Propane	95.9 a	0.0 a	4.1 a	0.0 a	93.8 a
Burn	96.4 a	0.0 a	3.7 a	0.1 a	93.0 a

†Means in columns within stand age and residue management followed by the same letter are not different by Fisher's protected LSD values ($P = 0.05$).

DIEBACK OF PERENNIAL RYEGRASS DOES NOT REDUCE SEED YIELD

*T.G. Chastain, T.M. Velloza, W.C. Young III,
M.E. Mellbye, C.J. Garbacik and T. B. Silberstein*

The cause of dieback, a form of premature stand loss in perennial ryegrass seed fields, has eluded researchers for nearly a decade. Seed growers have characterized this disorder as a failure of portions of the stand to regrow in autumn after harvest. Plants affected by this disorder cease to be perennial and act like an annual. Several potential causes of dieback have been investigated including plant diseases, pests, soil fertility, herbicide damage, and others. None have been successfully linked to dieback. An important clue to the appearance of the disorder is that it might be more prevalent in years with dry conditions in late summer extending well into autumn.

We used a rainfall simulator and rain-out shelters to control August and September rainfall in field trials with two cultivars of perennial ryegrass, Affinity and Buccaneer. The rainfall simulator was used to simulate a one-inch rainfall during the following times: mid-August, mid-September, and rainfall during both mid-August and mid-September. Rain-out shelters were used to exclude natural rainfall in August and September. Natural rainfall during these periods was compared to the artificial rainfall treatments.

Tiller production decreased as the stand aged, with the greatest decrease observed with low rainfall in August and September. Losses in tiller production were proportional to the amount of rainfall received in August and September. Tiller production at the same rainfall level in first-year stands was greater than in second- or third-year stands. In other words, crops were less responsive to rainfall in older stands than in young stands. This supports the contention that as plants become older they are increasingly more susceptible to stress conditions. Therefore, the ability to replace the older tillers as they die is markedly reduced. Continual summer and early-fall water stress may be a major contributing factor to the onset of dieback.

Stand cover was affected by the water stress in August and September and in some cases losses exceeded 50% of the original stand. No rain in August and September produced the lowest amounts of plant cover in each year, and contributed most to the decline of the stand. Higher rainfall treatments produced more stand cover, but stand loss was evident with increasing age across all rainfall treatments. Even in the low water stress environment created by the natural rainfall treatment, which averaged 3.65 inches (154% of average), stand loss was not prevented.

Climatological data for Corvallis indicate that the average rainfall for August and September is 2.38 inches. However, our research indicates that about 4 inches of rainfall during August and September may be necessary for optimum tiller production. Rainfall amounts that reach or exceed 4 inches are relatively rare in August and September. Our combined August and September treatment delivered a total of 2 inches whereas August and September treatments received 1 inch each. Rainfall during this period is 2 inches or less in nearly half of the years. Moreover, the extremely dry conditions simulated by the no rainfall or 1 inch in August or September treatments are more common than one might think. Less than 1 inch of rainfall can be expected during August and September in nearly one-third of the years. Therefore, perennial ryegrass seed crops may be under moderate to severe moisture stress during the

early regrowth period in most years. This stress may have had detrimental effects on the ability of plants to recover and produce the tillers necessary for stand persistence.

Flowering and seed yield were not reduced in drought-affected stands in any of the three-harvest years (1996, 1997, and 1998) in our study (Table 1). Although stand loss and reduction in crop regrowth were substantial under conditions of post-harvest summer drought stress, fertile tiller production in the following spring was unaffected. Plants growing in the drought-thinned stands produced more fertile tillers per plant than those receiving adequate rainfall after harvest, accounting for the lack of differences in fertile tiller production at the various rainfall levels. The innate ability of perennial ryegrass to compensate for great losses in stand is evident. Seed growers do not need to be concerned about these stand losses as seed yield is not impacted by dieback.

Table 1. Rainfall treatment effects on seed yield of Affinity and Buccaneer perennial ryegrass.

| Rainfall treatment | 3-year average seed yields | |
	Affinity	Buccaneer
	---------- (lb/a) ------------	
Natural	1104 a†	1067 a
No Rain	1052 a	1004 a
August	1026 a	1005 a
September	1058 a	1048 a
August + September	1057 a	1029 a

† Means within columns are not significantly different when followed by the same letter by Fisher's Protected LSD values ($P = 0.05$).

ROLE OF ROOT SYSTEMS IN THE PRODUCTIVITY OF GRASS SEED CROPS

*T.G. Chastain, W.C. Young III, C.J. Garbacik,
T.B. Silberstein and C.A. Mallory-Smith*

Introduction. Little is known about the role of root and rhizome systems in the persistence and long-term productivity of grass seed production fields. The influence of management practices, environment, and plant stand density on these vital plant organs remains to be discovered. The objectives of our study were to: (i) determine how burning promotes seed yields in creeping red fescue by comparative analysis of the root and rhizome systems of burned and non-burned plants and to (ii) determine how stand density and stand age impact root system development of bunch-type (perennial ryegrass, Chewings fescue, and tall fescue) and creeping-type (creeping red fescue) grass seed crops. The following article reports results from the first year of a three-year research project.

Progress. Crop residue management affected late fall root production in a 3-year old commercial field of Hector creeping red fescue (Figure 1). Root biomass density near the soil surface was significantly greater when the crop was burned than when stubble and straw were mechanically removed. This may help explain why seed yields are generally higher with burning than with nonthermal methods in creeping red fescue. Low stubble height and high stubble height reduced seed yield by 4% and 12%, respectively, compared with burning. Increased stubble removal (low stubble) improved both shallow root production and seed yield. No differences in root biomass density were observed among residue management methods in deeper portions of the soil profile. High stubble caused the greatest rhizome production in late fall (158 g/m³), followed by field burning (129 g/m³) and low stubble resulted in the fewest rhizomes (70 g/m³). Low stubble height likely depleted carbohydrate storage in the stubble resulting in lower rhizome production.

Experimental trials at the Hyslop Oregon State University Research Farm involve a rhizome-forming red fescue cultivar (Shademaster) and is contrasted against a cultivar that produces few rhizomes (Seabreeze) and Chewings fescue (SR5100), which produce no rhizomes. The trials were sown in May 1997 and residue management operations were conducted in July 1998. Three stubble treatments were used to differentiate root, rhizome, shoot, and seed yield responses: (i) no stubble removal, (ii) complete mechanical removal of stubble, and (iii) removal of stubble by burning. Results will be reported in future articles.

Additional trials were sown in 1997 at Hyslop Farm to learn how stand density and stand age impacts root system development of bunch-type and creeping type grass seed crops. Four different stand densities were evaluated: 15-, 30-, 45-, and 60-cm (6-, 12-, 18-, and 24-inch) row spacings.

Late fall root biomass density in first-year stands was affected by row spacing in Cutter perennial ryegrass and LRF 983 tall fescue, but not in SR5100 Chewings fescue, and Shademaster and Seabreeze creeping red fescue (Table 1). Root biomass density was generally greater when crops were sown in narrow row spacings than in wider row spacings. Differences in root biomass density attributable to row spacing were greatest for the shallow portions of the soil profile, whereas differences were least in the deepest portion of the profile sampled (Figure 2). Root biomass density declined rapidly with increasing distance from the crop row (Figure 3).

Shoot biomass production was affected by row spacing in Cutter perennial ryegrass, SR5100 Chewings fescue and in Seabreeze creeping red fescue, but not in Shademaster creeping red fescue and in LRF 983 tall fescue (Table 2). Shoot production was greatest in 15-cm rows.

Fertile tiller production was greater in narrow rows than wide rows in Shademaster creeping red fescue and in Cutter perennial ryegrass (Table 3). Row spacing had no effect on fertile tiller production in Seabreeze slender red fescue, SR 5100 Chewings fescue, and LRF 983 tall fescue.

Row spacing had no effect on seed yield in tall fescue (Table 4). Seed yield tended to be higher in 30-cm rows in creeping red fescue and Chewings fescue. Slender red fescue and perennial ryegrass sown in 15- and 30-cm rows produced greater seed yields than when sown in 45- and 60-cm rows.

These trials will continue for two additional seasons to determine whether roots play a role in stand persistence and in the stand-age related decline in seed yield.
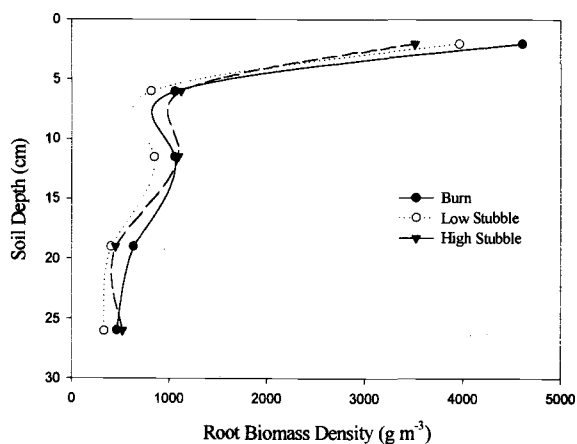

Figure 1. Effect of residue management on root biomass density and distribution in Hector creeping red fescue.
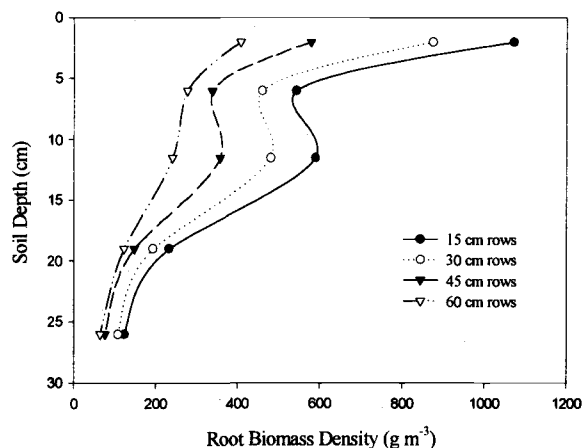

Figure 2. Root biomass density and distribution responses to crop row spacing in LRF 983 tall fescue.
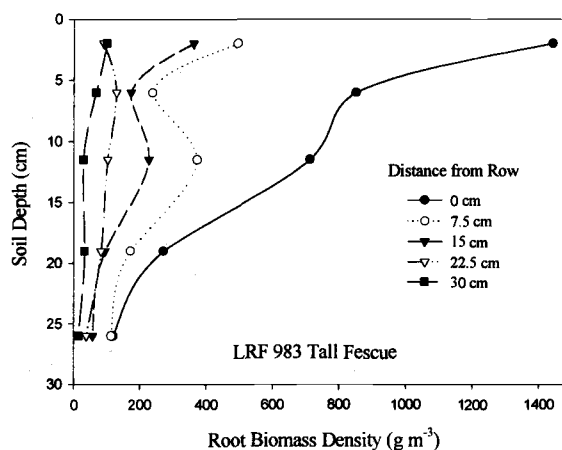

Figure 3. Effect of distance from crop row on root biomass density and distribution on LRF 983 tall fescue.

15

Table 1. Effect of row spacing on autumn root biomass density in grass seed crops. Root biomass densities are averaged over soil depths and sampling distance from crop row.

Grass seed crop	Row spacing (cm)			
	15	30	45	60
	------------------------------(g/m³)------------------------------			
Shademaster creeping red fescue	702 a†	1005 a	532 a	491 a
Seabreeze slender red fescue	630 a	598 a	523 a	489 a
SR5100 Chewings fescue	837 a	837 a	497 a	246 a
LRF 983 tall fescue	359 c	296 bc	210 ab	156 a
Cutter perennial ryegrass	1166 b	1090 b	636 a	452 a

†Means in rows followed by the same letter are not different.

Table 2. Effect of row spacing on autumn shoot biomass in grass seed crops.

Grass seed crop	Row spacing (cm)			
	15	30	45	60
	------------------------------(g/m³)------------------------------			
Shademaster creeping red fescue	397 a†	339 a	293 a	279 a
Seabreeze slender red fescue	372 b	213 a	287 ab	244 a
SR5100 Chewings fescue	485 b	263 a	179 a	145 a
LRF 983 tall fescue	588 a	482 a	497 a	330 a
Cutter perennial ryegrass	354 b	325 b	125 a	147 a

†Means in rows followed by the same letter are not different.

Table 3. Effect of row spacing on fertile tiller production in grass seed crops.

Grass seed crop	Row spacing (cm)			
	15	30	45	60
	------------------------------(no./sq. ft.)------------------------------			
Shademaster creeping red fescue	284 b†	249 ab	178 a	201 a
Seabreeze slender red fescue	457 a	372 a	273 a	274 a
SR5100 Chewings fescue	347 a	291 a	242 a	213 a
LRF 983 tall fescue	85 a	95 a	82 a	76 a
Cutter perennial ryegrass	284 bc	323 c	208 a	223 ab

†Means in rows followed by the same letter are not different.

Table 4. Effect of row spacing on seed yield in grass seed crops.

Grass seed crop	Row spacing (cm)			
	15	30	45	60
	------------------------------- (lb/a)-------------------------------			
Shademaster creeping red fescue	712 ab†	823 c	755 b	693 a
Seabreeze slender red fescue	637 b	664 b	546 a	570 a
SR5100 Chewings fescue	1074 ab	1205 b	996 a	1007 a
LRF 983 tall fescue	1212 a	1461 a	1176 a	1504 a
Cutter perennial ryegrass	1434 b	1523 b	1143 a	1037 a

†Means in rows followed by the same letter are not different.

COMPARING INVASIVE AND OPPORTUNISTIC WEEDS IN GRASS SEED CROPS

G. W. Mueller-Warrant

Abstract

Annual bluegrass (*Poa annua*, POAAN) is an opportunistic weed in perennial ryegrass (*Lolium perenne*, LOLPE) grown for seed, relying on thin crop stands to proliferate. Poor post-harvest regrowth and damage from weed control treatments are primary factors thinning perennial ryegrass stands. Maximum perennial ryegrass yield loss in dense stands of annual bluegrass averaged 44%. Downy brome (*Bromus tectorum*, BROTE), an invasive weed in Kentucky bluegrass (*Poa pratensis*, POAPR) grown for seed, weakens and destroys stands through intense competition. Complete Kentucky bluegrass yield loss occurred at 15 to 20 downy brome per ft^2. In perennial ryegrass, crop safety must be emphasized when selecting treatments to control or suppress annual bluegrass. In Kentucky bluegrass, control of downy brome must be maximized, and crop safety is a secondary concern.

Introduction

Stand loss and weed encroachment in perennial grasses grown for seed are interrelated, and causality is often unclear. Separating these phenomena could provide insights into past management failures and suggest improvements for the future. The question is a classic case of "which came first, the chicken or the egg?" Do stands thin because they are invaded by weeds, or do weeds proliferate because stands have thinned? Answers are important because they can tell us whether we need to try harder to control weeds or try harder to keep our stands healthy, objectives frequently at odds with each other using current technology.

Contamination by annual bluegrass is a serious concern in turfgrass seed production, and growers lose large quantities of crop seed while removing the weed to meet market demands for "*Poa*-free" seed. Because of the high costs associated with removing annual bluegrass seed during seed cleaning, growers try to control annual bluegrass in their fields with herbicides. Spectacular success was achieved in the 1970s in crops such as perennial ryegrass with the development of the carbon-plant, broadcast-diuron method for establishing new stands, along with the introduction of the selective herbicide ethofumesate (Nortron) (Lee, 1973 and 1981). During the recent phasedown in field burning in western Oregon, many perennial ryegrass seed growers experienced explosive increases in annual bluegrass populations. Various reasons for this have been proposed, and growers are modifying their management practices based on research results, personal experience, and guesswork. Decreased use of field burning and the development of resistance to diuron, ethofumesate, and other herbicides are major causes of the annual bluegrass outbreak. The severity of the problem, however, varies greatly with herbicide treatment and post-harvest residue management. Results from field trials over several years were used to test the hypothesis that thin stands of perennial ryegrass were the primary culprit in severe infestations of annual bluegrass, rather than the invasiveness of this weed.

Growers of Kentucky bluegrass seed in the intermountain regions of the Pacific Northwest have been plagued by downy brome for decades. Although downy brome impedes the seed cleaning process, it is not listed as noxious, and the presence of a few downy brome seeds in an official seed sample has lesser impact on profits than occurs with annual bluegrass. Growers often cite too much "cheatgrass" (downy brome) as their main reason for taking Kentucky bluegrass fields out of production. Results from field trials over several years were used to test the hypothesis that the invasiveness of downy brome was the primary reason for problems with this weed.

17

Materials and Methods

Tests were conducted over multiple years in established stands of perennial ryegrass near Tangent, Oregon, and Kentucky bluegrass near Madras, Oregon. Post-harvest residue was removed each year by open field burning, by baling followed by vacuum sweeping (VS), or by baling, flailing, and raking, or full straw load chop (FSLC) was used to reduce the residue to a fine mulch. Herbicides were applied between late-summer and early-winter at 26 gal/a to plots 9 by 60 ft in size. Plots were swathed at maturity, and 275 ft^2 was harvested by combine when windrows were dry. Seed was cleaned to 98% purity for annual bluegrass, perennial ryegrass, downy brome, and Kentucky bluegrass. Treatment means were separated at the $P \leq 0.05$ level of significance, and ground cover values were log transformed to correct for non-homogeneous variances. Ground cover was measured in mid to late March in all years, and, in 1998, it was measured again in mid-April to evaluate the effect of glufosinate (Rely) applied in late March. Regressions were conducted on treatment averages of 4 replications in all cases except the 1998 perennial ryegrass test. To reduce table size, only selected treatments are shown. Graphs include all treatments, but some were excluded from regressions based on excessive crop damage or variation in herbicide resistance.

Results and Discussion

A key question when classifying weeds as opportunistic or invasive is whether the loss of crop stand occurs before or after prolonged competition? Stands of perennial ryegrass thin as plants die due to a variety of stresses, especially moisture, during the post-harvest regrowth period of late-summer and early-fall, and also when treated in fall and early-winter with marginally selective herbicides such as diuron (Karmex), oxyfluorfen (Goal), and metolachlor (Dual) (Chastain et al., 1998). Surviving perennial ryegrass grows well in late-winter and spring, and competes with the annual bluegrass. The major problem is that too many gaps exist during fall and winter, and these niches are filled by annual bluegrass. For downy brome in Kentucky bluegrass, a different pattern is seen. In the absence of downy brome, stands damaged by fire, drought, or herbicides will fill back in because of the spreading growth habit of this crop, often yielding nearly as well as undamaged stands. If downy brome is present, yields will be reduced, even if crop stands were initially full. Even more telling is the fact that crop stands will thin and downy brome populations will increase in each successive year of competition.

Graphs of crop seed yield versus weed density can characterize weed species as opportunistic or invasive. Several features of the relationship between perennial ryegrass seed yield and annual bluegrass ground cover reveal the opportunistic nature of this weed (Fig. 1). First, the maximum observed annual bluegrass ground cover between crop rows in early spring was only 49, 65, and 50% in 1996, 1997, and 1998, respectively (Tables 1, 2, and 3). Second, although perennial ryegrass seed yield decreased with increasing annual bluegrass ground cover, the theoretical maximum yield loss at 100% annual bluegrass ground cover was only 46% in 1996, 44% in 1997, and 43% in 1998. In contrast, the theoretical maximum yield loss in Kentucky bluegrass approached 100% as downy brome density increased (Fig. 2 and 3). Complete yield loss at downy brome densities of 16, 17, and between 10 and 34 plants/ft^2 was predicted in 1995, 1996, and 1997, respectively. The maximum observed downy brome density was 29% of that required for complete crop failure in 1995, rising to 67% in 1996, and exceeding 100% in 1997. Another indication of the invasiveness of downy brome was the increase in population density from year to year, which ranged from 5 to 20-fold in untreated checks, with similar increases occurring in many herbicide treatments. Individual downy brome plants in the untreated checks were less competitive in 1997 than in previous years because their population density was so high they strongly competed with each other, resulting in a smaller average size than in previous years. Within three years of use at Madras, downy brome with increased resistance to primisulfuron (Beacon) had appeared. Resistant plants were injured by tank-mixes of primisulfuron + terbacil (Sinbar), but survived and produced seed. Resistant plants competed less vigorously with the crop, perhaps due to lingering stunting from the herbicides, and crop yield with 15 to 25 resistant downy brome per ft^2 was similar to that with 0 to 5 nonresistant downy brome per ft^2 (Fig. 3a). When competition was expressed as crop seed yield versus downy brome seed yield, results from resistant plots and untreated checks fell near the regression line for normal primisulfuron-susceptible downy brome (Fig. 3b).

Another indication of the opportunistic nature of annual bluegrass is the interaction between it and volunteer perennial ryegrass seedlings. A large fraction of the volunteer perennial ryegrass was controlled simply by vacuum sweeping without any herbicide (Tables 1, 2, and 3). However, annual bluegrass density in the untreated checks was always higher in vacuum sweep than full straw load chop conditions, indicating that annual bluegrass was filling in space vacated by seedling perennial ryegrass. Treatments seriously damaging the established crop often increased annual bluegrass ground cover or seed yield. Examples include full straw 0.25 lb/a oxyfluorfen + 1.6 lb/a diuron in 1996 and 1997, full straw 0.25 lb/a azafenidin (Milestone) in 1997, and vacuum sweep azafenidin + metolachlor followed by azafenidin + diuron in 1998. High rates of pendimethalin (Prowl) or moderate rates of it followed by 0.125 lb/a oxyfluorfen + 1.2 lb/a diuron maximized perennial ryegrass and minimized annual bluegrass seed yield. Pendimethalin was finally registered for this use in October 1998. Safety must be paramount when selecting treatments to control annual bluegrass in perennial ryegrass.

18

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Table 1.   Herbicide treatments on annual bluegrass and perennial ryegrass seedling density and yield, 1996.

Herbicide treatment and residue management	Seedling density		Seed yield	
	POAAN	LOLPE	POAAN	LOLPE
----(lb a.i./a and date applied, fall 1995)--	--- (% ground cover)---		---- (lb/a pure seed)----	
Untreated check VS	18 b-e	4 b	46 ab	734 b
Untreated check FSLC	16 cde	26 a	49 ab	879 ab
Pendimethalin 2 (Sept. 26) / oxyfluorfen 0.125 + diuron 1.2 (Nov. 16)				
VS	6 f	0 e	36 b	888 ab
FSLC	14 de	4 b	46 ab	1004 a
Pendimethalin 2 (flail inc. Oct. 2) / Oxyfluorfen 0.125 + diuron 1.2 (Nov. 16) FSLC	10 ef	2 bcd	50 ab	1055 a
No herbicide (flail Oct. 2) / Oxyfluorfen 0.25 + diuron 1.6 (Nov. 16) FSLC	31 a-d	2 bc	69 a	741 b
Metolachlor 1.5 + oxyfluorfen 0.28 (Oct. 2) / Oxyfluorfen 0.125 + diuron 1.2 (Nov. 16) FSLC	10 ef	0 de	71 a	607 b
Oxyfluorfen 0.25 + diuron 1.6 (flail inc. Oct. 2) FSLC	49 a	1 cde	65 a	876 ab
Rotary hoe (Nov. 16) - no herbicide FSLC	33 abc	1 cde	71 a	746 ab

Annual bluegrass and volunteer perennial ryegrass seedling density was measured in mid to late March.

Table 2.   Herbicide treatments on annual bluegrass and perennial ryegrass seedling density and yield, 1997.

Herbicide treatment and residue management	Seedling density		Seed yield	
	POAAN	LOLPE	POAAN	LOLPE
----(lb a.i./a and date applied, fall 1996)--	--- (% ground cover)---		----(lb/a clean seed)----	
Untreated check VS	45 ab	16 ef	356 bcd	928 a-e
Untreated check FSLC	13 d	61 a	277 cd	974 abc
Pendimethalin 3 (Sept. 19) VS	50 ab	6 h	341 bcd	926 a-e
Pendimethalin 3 (Sept. 19) FSLC	25 c	44 ab	267 d	1038 a
Pendimethalin 2 + oxyfluorfen 0.25 (Sept. 26) / oxyfluorfen 0.125 + diuron 1.2 (Oct. 24)				
VS	33 bc	1 j	394 bc	852 b-f
FSLC	48 ab	21 de	404 ab	1026 ab
Azafenidin 0.125 (Sept. 23) VS	36 bc	3 i	376 bcd	943 a-d
Azafenidin 0.125 (Sept. 23) FSLC	52 ab	28 bcd	382 bcd	751 ef
Azafenidin 0.25 (Sept. 23) FSLC	65 a	7 gh	422 ab	712 f
Rotary hoe (Oct. 1) - no herbicide FSLC	34 bc	38 abc	396 abc	814 c-f
Oxyfluorfen 0.25 + diuron 1.6 (Oct. 24) FSLC	63 a	11 fg	520 a	767 def
Oxyfluorfen 0.25 + metolachlor 1.5 (Sept. 26) / Oxyfluorfen 0.125 + diuron 1.2 (Oct. 24) FSLC	43 ab	11 fg	383 bcd	860 a-f

Annual bluegrass and volunteer perennial ryegrass seedling density was measured in mid to late March.

Table 3.   Herbicide treatments on annual bluegrass and perennial ryegrass seedling density and yield, 1998.

Herbicide treatment and residue management	Seedling density		Seed yield	
	POAAN	LOLPE	POAAN	LOLPE
----(lb a.i./a and date applied, fall 1997)--	--- (% ground cover)---		---- (lb/a clean seed)----	
Untreated check VS	50 a	9 c	314 a	1001 c
Untreated check FSLC	18 c	67 a	211 bcd	1035 c
Pendimethalin 3 + oxyfluorfen 0.125 (Sept. 15) VS	30 abc	1 d	216 bc	1333 ab
Pendimethalin 3 + oxyfluorfen 0.125 (Sept. 15) FSLC	29 abc	25 b	222 bc	1218 abc
Pendimethalin 6 + oxyfluorfen 0.125 (Sept. 15) VS	17 c	1 d	135 e	1380 a
Pendimethalin 6 + oxyfluorfen 0.125 (Sept. 15) FSLC	18 c	6 ghi	138 e	1321 ab
s-Metolachlor 0.94 + oxyfluorfen 0.25 (Sept. 15) / diuron 1.6 (Oct. 23)				
VS	32 ab	1 d	254 b	1205 abc
FSLC	22 bc	10 bc	185 cde	1210 abc
Azafenidin 0.075 + s-metolachlor 0.94 (Sept. 15) / azafenidin 0.075 + diuron 1.2 (Oct. 23)				
VS	25 bc	0 d	252 b	1129 bc
FSLC	28 bc	13 bc	157 de	1302 ab

Ground cover measured in late March, prior to application of Rely.

Tangent 1996: Yield vs. POAAN

Yield = 1045 - 4.842 X % POAAN

Tangent 1997: Yield vs. POAAN

Yield = 1105 - 4.885 X % POAAN

Tangent 1998: Yield vs. POAAN
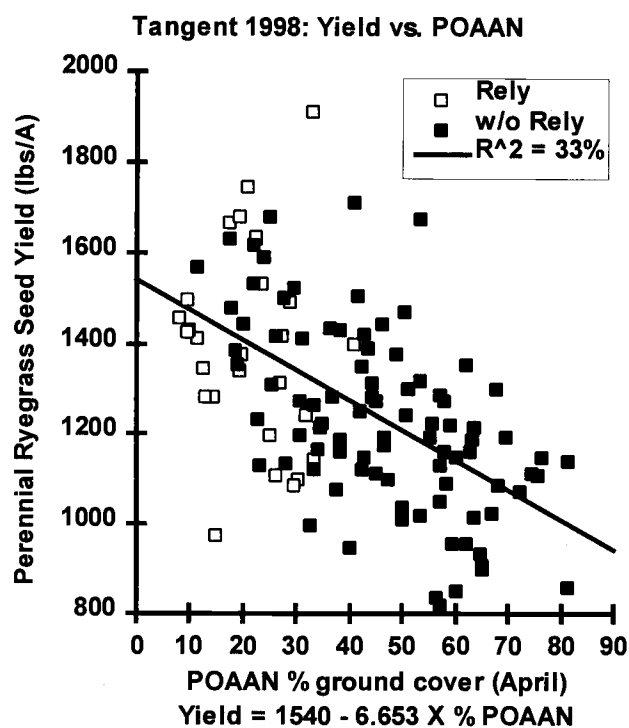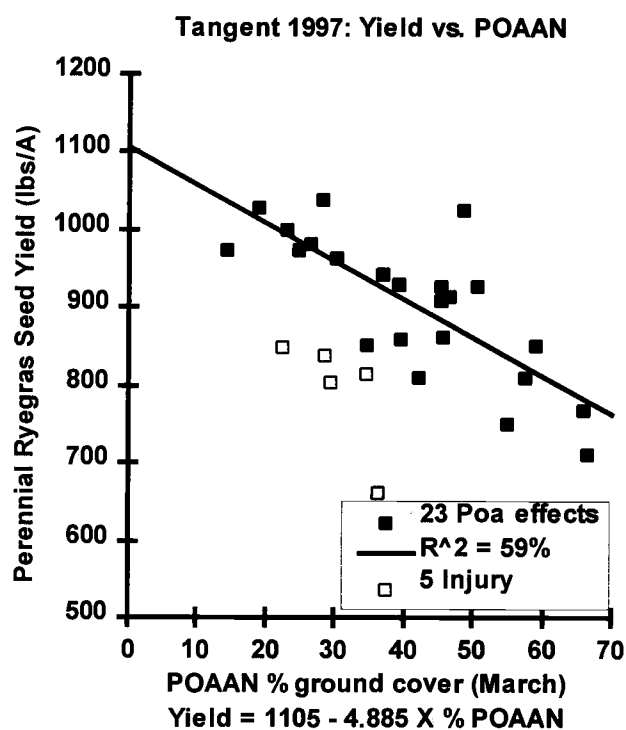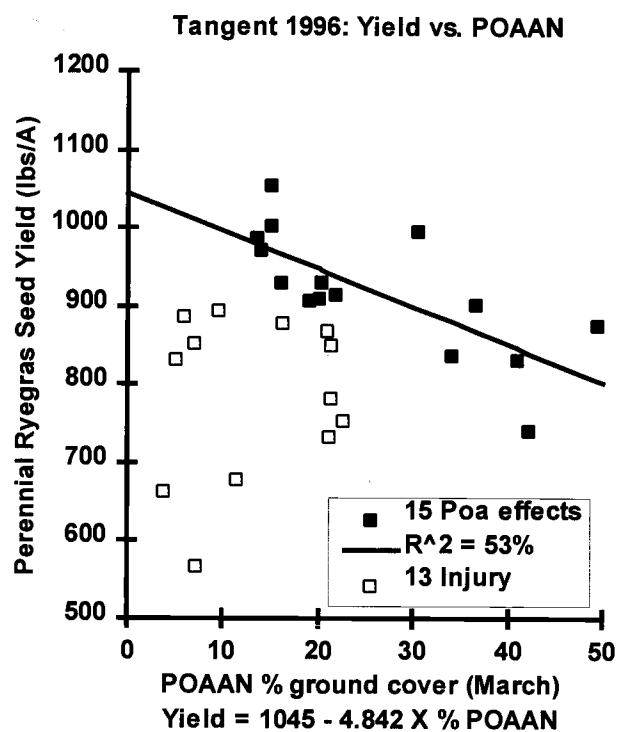
Yield = 1540 - 6.653 X % POAAN

Figure 1.   Relationship between perennial ryegrass seed yield and annual bluegrass ground cover in 1996, 1997, and 1998 at Tangent, Oregon. Annual bluegrass biotypes were resistant to diuron. Ground cover in 1998 was measured April 16, approximately 3 weeks after Rely treatment.

Madras 1995: Yield vs. BROTE

Madras 1996: Yield vs. BROTE

BROTE population (#/ft^2)
Yield = 910 - 56.59 X BROTE #

BROTE population (#/ft^2)
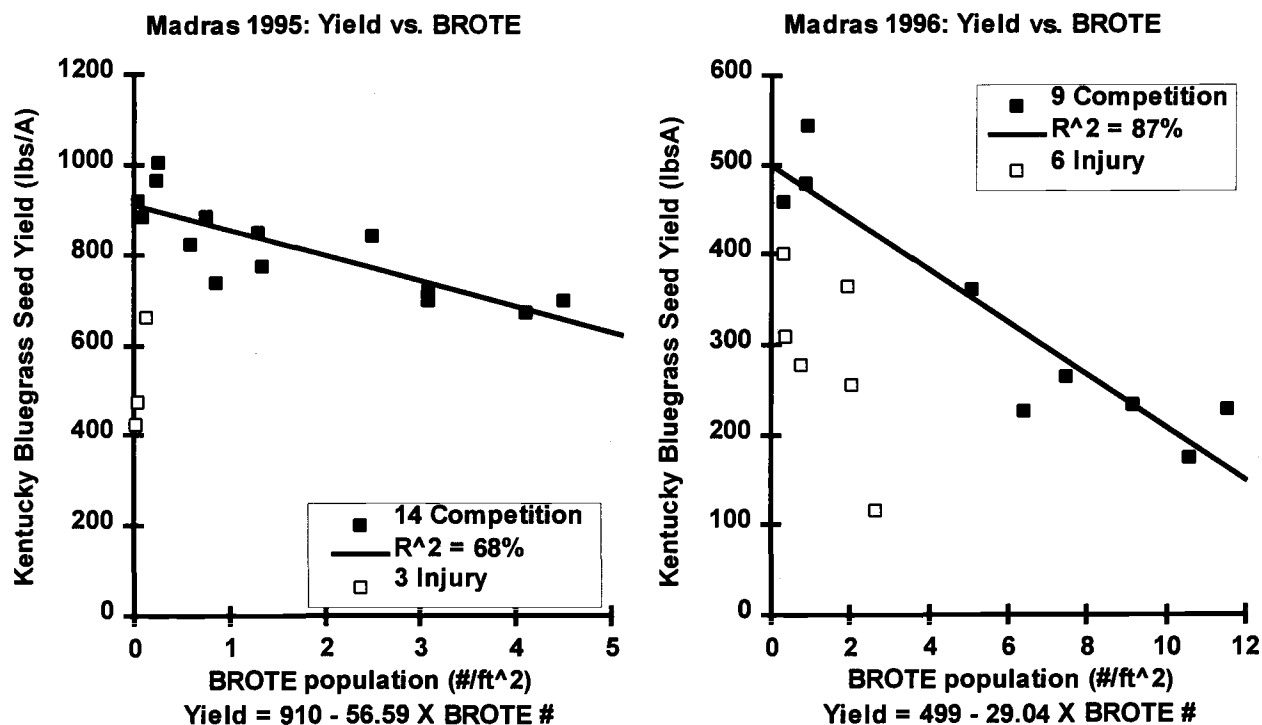Yield = 499 - 29.04 X BROTE #

Figure 2.   Relationship between Kentucky bluegrass seed yield and downy brome population density, Madras, Oregon, 1995 and 1996 harvests. Stand was sown in August 1992, with first harvest in July 1993.

Madras 1997: Yield vs. BROTE density

Madras 1997 Yields: KBG vs. BROTE

BROTE population (#/ft^2)
Yield = 340 - 37.36 X BROTE #

BROTE Seed Yield (lbs/A)
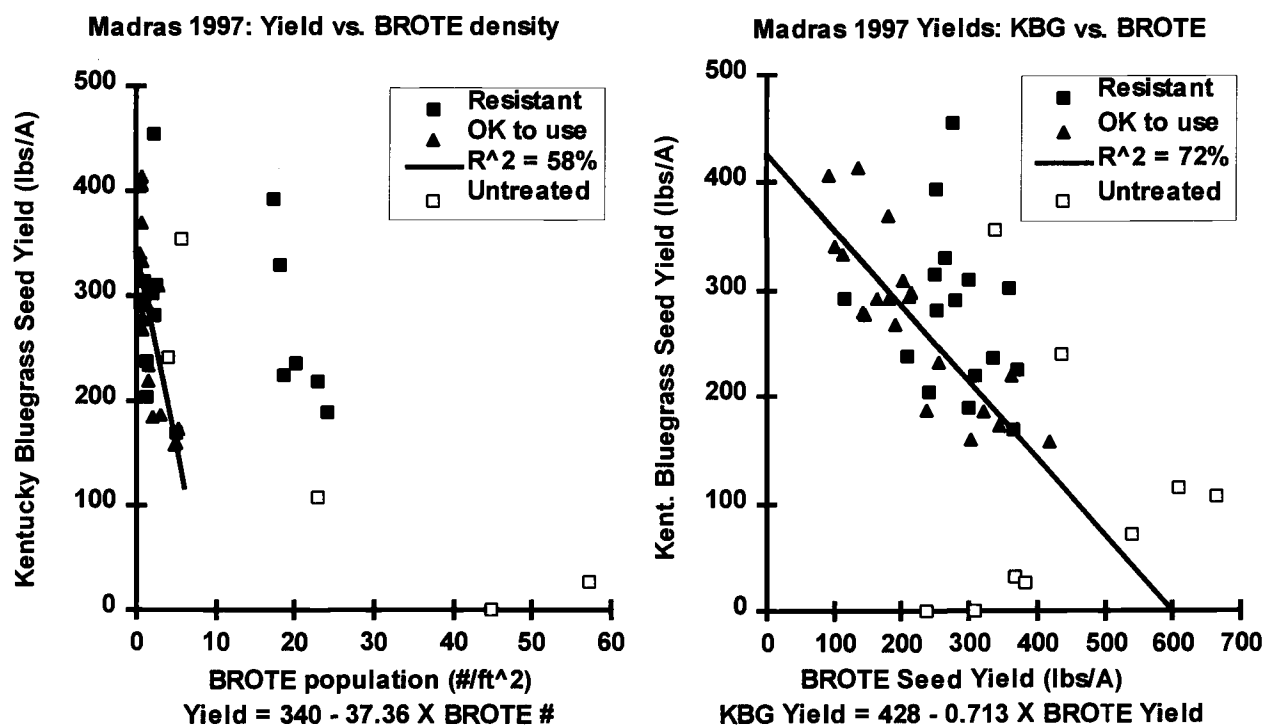KBG Yield = 428 - 0.713 X BROTE Yield

Figure 3.   Relationship between Kentucky bluegrass seed yield and downy brome population density or seed yield, Madras, Oregon, 1997 harvest. Regressions exclude plots with resistant brome and untreated checks.

ANNUAL BLUEGRASS SUPPRESSION WITH HERBICIDES

G. W. Mueller-Warrant

Attempts to control annual bluegrass with herbicides are hindered by limited crop tolerance to available herbicides and increasing resistance in this weed species. Low rates of Rely (glufosinate) have the potential to suppress annual bluegrass in crops such as perennial ryegrass and tall fescue. However, because Rely is a relatively non-selective herbicide, similar to Roundup (glyphosate) and Gramoxone (paraquat), crop tolerance is a major concern. Research in the 1996-97 growing season showed that perennial ryegrass seed yield was reduced by mid-May applications of Rely at all rates beyond 0.175 lb/a, while annual bluegrass control improved with Rely rate up to 0.3 lb/a. Tall fescue seed yield in 1997 was reduced by some, but not all, treatments in which Rely was applied in early March. Two approaches were adopted in the 1997-98 growing season to further evaluate the effects of Rely on crop yield and annual bluegrass suppression.

In the first approach, Rely was applied in mid-March to plots that had received a variety of herbicide treatments during the previous fall, creating a series of paired treatments between which the major difference was whether or not Rely was applied in mid-March. The treatments with and without Rely could then be averaged, providing the equivalent of 22 replications at each site to test the effects of Rely (Table 1). At the Tangent perennial ryegrass site, where there was a high population of diuron-resistant annual bluegrass, the average effect of mid-March Rely was to increase crop yield by 175 lb/a, or 14%. There was no significant effect on perennial ryegrass yield at the other two sites. Since there was virtually no annual bluegrass needing to be controlled at these other two sites, the absence of any effects on yield suggests that mid-March application of 0.3 lb/a Rely is safe on perennial ryegrass. Results in tall fescue are less clear cut. Because there was also a high population of annual bluegrass at the tall fescue site, crop yield should have increased as annual bluegrass was controlled with Rely. Since Rely treatment didn't increase yield despite reducing annual bluegrass growth, there must have been enough crop injury to counteract any weed control benefit. Tall fescue took far longer to recover from damage by Rely than did perennial ryegrass. Indeed, some stunting was present through harvest, and it would be much harder to justify the use of Rely on tall fescue than on perennial ryegrass. Application of Rely in mid-March reduced annual bluegrass seed yield an average of 47% (Table 2). Rely treatment in mid-March "burned back" the annual bluegrass, but failed to kill most of the plants. Annual bluegrass ground cover in mid-April in Rely-treated plots was nearly the same as it had been three weeks earlier, whereas annual bluegrass ground cover had more than doubled in plots not treated with Rely. Rely treatment also greatly reduced the proportion of annual bluegrass plants that were flowering in mid-April. A tank-mix of 1 lb/a Avenge plus 0.25 lb/a Rely was about as effective as 0.3 lb/a Rely.

In the second approach to evaluate this herbicide, Rely was applied in mid-April at a range of rates to a perennial ryegrass stand that was nearly free of annual bluegrass (Table 3). Nine replications were used to improve the ability to detect any perennial ryegrass yield losses caused by Rely. The ability of an additional 60 lb/a of spring-applied nitrogen to overcome the damage by Rely was also tested. This additional nitrogen had no significant effect on perennial ryegrass seed yield. The most damaging treatment was 0.5 lb/a Rely, reducing yield an average of 52%. However, damage from 0.375 lb/a Rely (44% yield loss) was statistically similar to that from 0.5 lb/a. Ryegrass yield for the two lower rates of Rely (0.25 and 0.3 lb/a) was significantly better than for 0.375 lb/a. However, even the 0.25 lb/a rate caused a 16% yield loss, while the 0.3 lb/a rate reduced yield by 22%. Mid-April timing of Rely in 1998 caused less damage than mid-May timing had in 1997. However, since yield losses from mid-April Rely in the absence of annual bluegrass were larger than the benefits from mid-March Rely in the presence of annual bluegrass, there is a clear need for further research into the optimum timing and rate of spring-applied Rely. Studies underway in 1999 are focusing on the mid-March to mid-April time period. This is the same period that was found to be critical as a cut-off date for application of Horizon (fenoxaprop), and corresponds to the beginning of rapid tiller elongation and elevation of the growing point.

Fall-applied herbicide treatments can have great impact on crop yield, volunteer seedlings, and annual bluegrass. Much effort has been expended over the past decade trying to find the "best" treatments for use in the fall. As indicated in an accompanying article, the problem is that the opportunistic nature of annual bluegrass allows it to fill in any space vacated by volunteer seedlings controlled by herbicides or vacated by crop itself when damaged by herbicides or other causes. Several fall-applied herbicides used in the current studies provided partial control of annual bluegrass, although none were perfect (Table 4). Prowl (pendimethalin) at 6 lb/a reduced annual bluegrass seed yield compared to that of the untreated checks or the lower rate (3 lb/a) of Prowl in both vacuum sweep and full straw load chop conditions. At 3 lb/a, Prowl reduced annual bluegrass seed yield compared to the vacuum sweep check but not the full straw load check. Sequential application of Prowl at 3 lb/a plus Goal (oxyfluorfen) followed by Diuron plus Goal reduced annual bluegrass seed yield compared to untreated checks in both residue management systems. Sequential application of Dual Magnum (s-metolachlor) at 0.94 lb/a plus Goal followed by Diuron reduced annual bluegrass seed yield compared to the untreated check only in vacuum sweep. Axiom was the most effective fall-applied herbicide in these tests, reducing

annual bluegrass seed yield by 64% in vacuum sweep. Although Axiom treatments caused serious injury to perennial ryegrass during late fall and early winter, even thinning the stands, yields were not reduced at any site. Indeed, the highest yielding treatment at Tangent was Axiom followed by Goal plus Diuron. Factors influencing the safety of Axiom will be a major focus of research efforts over the next few years. Fall and winter weather patterns, herbicide rate, application date, other herbicide treatments, and stand vigor will all interact in determining the extent of injury from Axiom. Combinations of Prowl plus Axiom may come close to providing adequate weed control without the need for any postemergence treatment.

Table 1.   Perennial ryegrass and tall fescue seed yield response to early spring treatment with Rely.

| Treatment comparison | Perennial ryegrass | | | Tall fescue Shedd |
	Tangent	Amity	Hyslop	
	----------------------------(lb/a clean seed)----------------------------			
Six treatments with LPOST Rely	1399 a	850 a	579 a	1138 a
Comparable treatments without Rely	1224 b	846 a	541 a	1185 a

High populations of diuron-resistant annual bluegrass were present at Tangent perennial ryegrass and Shedd tall fescue. Moderate populations of diuron-resistant Italian ryegrass were present at Amity perennial ryegrass. Hyslop perennial ryegrass was virtually weed-free except for volunteer crop seedlings. LPOST Rely was applied March 13 at Hyslop and March 17 at the other sites.

Table 2.   Annual bluegrass response to selected treatments at the Tangent perennial ryegrass site.

| Herbicide Treatment (lb a.i./a) | Annual bluegrass | | |
	Seed yield July 7	Ground cover April 16	Proportion flowering April 16
	(lb/a)	(%)	(%)
Vacuum sweep treatments			
1-leaf: Prowl 3 + Goal 0.125	216 b	54 b	59 a
1-leaf: Prowl 3 + Goal 0.125 / 4-leaf: Rely 0.3 / LPOST: Rely 0.3	79 e	18 cd	22 d
1-leaf: Prowl 3 + Goal 0.125 / 4-leaf: Rely 0.25 + Avenge 1 / LPOST: Rely 0.25 + Avenge 1	99 de	26 c	27 cd
1-leaf: Prowl 3 + Goal 0.125 / 4-leaf: Goal 0.25 + Diuron 1.2	173 bc	44 b	55 a
1-leaf: Prowl 3 + Goal 0.125 / 4-leaf: Goal 0.25 + Diuron 1.2 / LPOST: Rely 0.3	110 de	21 cd	19 de
Untreated check	314 a	70 a	58 a
Full straw load chop treatments			
1-leaf: Prowl 3 + Goal 0.125	222 b	51 b	41 b
1-leaf: Prowl 3 + Goal 0.125 / 4-leaf: Rely 0.3 / LPOST: Rely 0.3	93 de	20 cd	10 e
1-leaf: Prowl 3 + Goal 0.125 / 4-leaf: Goal 0.25 + Diuron 1.2	141 cd	28 c	36 bc
1-leaf: Prowl 3 + Goal 0.125 / 4-leaf: Goal 0.25 + Diuron 1.2 / LPOST: Rely 0.3	113 de	11 d	9 e
Untreated check	211 b	54 b	41 b
4-leaf: Rely 0.3 / LPOST: Rely 0.3	144 cd	24 c	17 de
1-leaf: Milestone 0.15 / LPOST: Rely 0.3	110 de	29 c	16 de
Treatment contrasts			
Six treatments with LPOST Rely	106 A	20 A	17 A
Comparable treatments without Rely	196 B	48 B	49 B

Means followed by the same letter do not differ at the P=0.05 level.

Table 3. Perennial ryegrass seed yield response to rates of nitrogen and Rely applied in mid-spring in the absence of annual bluegrass.

| Herbicide Treatment | Perennial ryegrass seed yield | | |
	120 lb/a nitrogen	180 lb/a nitrogen	Average
	-------------------------------(lb/a clean seed)----------------------------		
Untreated check	691 a	687 a	689 A
Rely 0.25 + Avenge 1 April 17	538 b	520 bc	528 B
Rely 0.25 April 17	537 b	616 ab	577 B
Rely 0.3 April 17	546 b	530 b	538 B
Rely 0.375 April 17	393 cd	376 d	385 C
Rely 0.5 April 17	323 d	340 d	331 C
Average	505 x	511 x	

Means followed by the same letter do not differ at the P=0.05 level. Nitrogen rate by herbicide treatment interaction was non-significant.

Table 4. Annual bluegrass and perennial ryegrass response to selected fall-applied treatments at the Tangent perennial ryegrass site.

| Herbicide Treatment (lb a.i./a) | Annual bluegrass ground cover March 25 | Seed yield July 7 | |
		Annual bluegrass	Perennial ryegrass
	(%)	---------(lb/a clean seed)-------	
Vacuum sweep treatments			
Untreated check	52 a	314 a	1001 d
1-leaf: Prowl 3 + Goal 0.125	31 b	216 bc	1333 abc
1-leaf: Prowl 6 + Goal 0.125	20 bcd	134 fg	1381 ab
1-leaf: Prowl 3 + Goal 0.125 / 4-leaf: Goal 0.25 + Diuron 1.2	28 bc	173 c-f	1266 abc
1-leaf: Dual Magnum 0.94 + Goal 0.25 / 4-leaf Diuron 1.6	33 b	254 b	1206 bcd
1-leaf: Axiom 0.51 / 4-leaf: Goal 0.25 + Diuron 1.2	5 d	112 g	1455 a
Full straw load chop treatments			
Untreated check	19 bcd	211 bcd	1035 d
1-leaf: Prowl 3 + Goal 0.125	30 b	222 bc	1218 bcd
1-leaf: Prowl 6 + Goal 0.125	20 bcd	138 fg	1321 abc
1-leaf: Prowl 3 + Goal 0.125 / 4-leaf: Goal 0.25 + Diuron 1.2	21 bcd	141 fg	1161 cd
1-leaf: Dual Magnum 0.94 + Goal 0.25 / 4-leaf Diuron 1.6	24 bc	185 c-f	1209 bcd
1-leaf: Axiom 0.51 / 4-leaf: Goal 0.25 + Diuron 1.2	12 cd	157 d-g	1257 bc
1-leaf: Axiom 0.64 / 4-leaf: Goal 0.25 + Diuron 1.2	16 bcd	147 efg	1302 abc

Means followed by the same letter do not differ at the P=0.05 level.

SUPPRESSING THE GROWTH OF ANNUAL BLUEGRASS

A.S. Herbert, G.M. Walker and M.E. Mellbye

Annual bluegrass (*Poa annua L.*) is a serious weed problem facing grass seed growers in the Willamette Valley. This weed has developed resistance to two widely used herbicides, diuron and ethofumesate. Due to the ineffectiveness of herbicides and reductions in field burning, other methods to control annual bluegrass need to be investigated. The purpose of this research was to investigate the ability of straw mulches to prevent the germination of this important weed.

Methods

A greenhouse study was conducted to determine the effect of straw length and application rate on the germination and growth of annual bluegrass. Twenty-eight trays were packed with a mixture of river loam and transplanting soil. Annual bluegrass seed, provided by Steve Glaser Farm, was applied to each tray at a rate of 200 pounds per acre. This rate was representative of a grass seed field with a high infestation. The seeds were evenly dispersed onto the trays filled with the soil mixture, and kept moist near 50 degree F.

Tall fescue grass straw was cut into two lengths: short length pieces ranging from 1-3 inches, and long length pieces ranging from 5-7 inches. Straw was then applied at a rate of two tons per acre to eight trays. Four of these trays were treated with short length straw, the other four with long length straw. This procedure was repeated for straw application rates of four and eight tons per acre. A group of four control trays that were not treated with straw were also included.

Two different methods were used to measure the effects of the straw mulch on the growth of annual bluegrass. The first method was to count the germinated seeds in each tray seven days after planting, to determine the initial effect on germination. The second method was to measure percent groundcover of annual bluegrass after germination and growth was underway. To do this, a clear grid was held over each tray and the areas of grass growth were outlined with an erasable pen. Measurements of groundcover were made every five days following the initial germination count. Final data was collected on the twenty-seventh day after planting. By that time the growth and germination of grass seed had tapered off and the control trays had reached nearly one hundred percent coverage.

Results

Both the rate of straw used and its length had a significant effect on the germination of annual bluegrass (table 1). The first seeds to germinate appeared five days after planting. Straw applied at all rates, except for short straw at 2 tons/acre, reduced germination. Long straw was more effective in suppressing initial germination than short straw.

Table 1. The effect of straw length and rate of application on the germination and groundcover of annual bluegrass, 1998.

Straw mulch treatments		Initial germination day 7	Days from planting			
Rate	Length		12	17	22	27
(ton/a)		(no./ft²)	-------- (% groundcover)--------			
0	0	141 a[1]	56 a	90 a	96 a	98 a
2	short	155 a	42 b	86 a	91 b	93 b
2	long	46 b	36 b	75 b	90 b	92 b
4	short	29 bc	27 c	73 b	80 c	81 c
4	long	21 bcd	7 d	16 c	28 d	29 d
8	short	7 cd	5 d	15 c	20 e	20 e
8	long	0 d	0.5 d	3 d	6 f	6 f

[1]Means in columns followed by the same letter are not significantly different by Fisher's protected LSD values $P=0.05$.

The rate and length of straw application also affected annual bluegrass groundcover. Similar to the effect on initial germination counts, long length straw suppressed subsequent groundcover more than short straw. In contrast to the initial germination counts though, this difference was only significant at the higher rates of straw application (4-8 tons/acre). For example, straw applied at a rate of two tons per acre resulted in very little weed suppression, regardless of straw length. Both lengths provided some initial suppression, but by the end of the study, there was nearly as much growth at this lowest application rate as there was in the control trays.

Overall, rate of application had a greater effect on suppressing the growth of annual bluegrass than length of straw. Straw applied at a rate of eight tons per acre was the most effective treatment. It is important to note, however, that eight tons per acre is an extremely large application rate. Most fields do not have this much straw remaining after harvest. Rates of two and four tons per acre are more realistic in terms of actual straw production in Willamette Valley grass seed fields.

Currently, many grass seed farmers have the straw baled off their fields after grass seed harvest. The remaining stubble is then flail chopped and either left on the field or vacuumed off. This study indicates that the short length mulch left after flailing stubble is not an effective weed deterrent. If a farmer is experiencing a significant problem with annual bluegrass, it could be more effective to leave the straw on the field rather than having it baled and removed. Furthermore, long length straw could suppress annual bluegrass germination more effectively than finely chopped straw. This needs to be verified under field conditions, where the effect of crop competition and herbicide applications can be taken into account. Similarly, the suppression of annual bluegrass at lower straw rates (2

tons/acre) in a commercial grass seed field could be greater than observed in this study due to management practices that contribute to weed control.

THE INFLUENCE OF MEADOWFOAM SEEDING RATE, SEEDING METHOD, AND PRESENCE OF ANNUAL BLUEGRASS ON MEADOWFOAM SEED YIELD AND ANNUAL BLUEGRASS GROWTH

C.A. Mallory-Smith, B.D. Brewster and P.E. Hendrickson

Meadowfoam is one of the few crops that can be grown on the poorly drained soils of the mid and southern Willamette Valley. These soils have largely been in grass seed production for several decades. This continuous cropping system, with a reliance on a limited number of herbicides for weed control, has caused the development of herbicide resistant annual bluegrass (*Poa annua* L.) in many of these fields. In some cases the annual bluegrass populations have become very dense and a large number of bluegrass seeds are produced each year. As a rotation crop, meadowfoam may have to compete with this weed if control measures are not successful. Research was conducted for four years (1994-95 through 1997-98) at the Oregon State University Hyslop Research Farm near Corvallis to investigate the interaction of meadowfoam and annual bluegrass. In the first two years of these studies, hand-weeding and applications of Stinger herbicide were used to control broadleaf weeds, and Prism was used to control grasses in the bluegrass-free plots. During the final two years of these studies, the soil was fumigated with methyl bromide prior to seeding to reduce weed interference from non-subject weeds. Infestations of *Scaptomyza* sp. fly larvae during the first 2 years of the studies greatly reduced meadowfoam growth despite an application of Metasystox-R in the 1995-96 trial. Sequential applications of Dimethoate and Metasystox R greatly reduced the fly problem in the third year, and an even more aggressive insecticide application schedule implemented in the fourth year eliminated the problem.

The experimental design was a randomized complete block with four replications and 8 ft by 30 ft plots. Annual bluegrass seed was broadcast over half of the plots prior to seeding the meadowfoam. 'Floral' meadowfoam was drilled in 6-inch rows in half of the plots and was broadcast in the other half; the application of both seeding methods was accomplished with a Nordsten drill. A harrow was pulled behind the drill in both seeding methods. Four meadowfoam seeding rates (15, 30, 45, and 60 lb/a) were used in each of the four studies. The seeding dates were as follows: October 6, 1994; October 5, 1995; October 10, 1996; and September 29, 1997. The fertilizer program consisted of 40 to 50 lb/a of nitrogen applied as urea in February each year. Annual bluegrass stand counts in November for the bluegrass-infested plots were as follows: 1994, 15 per sq ft; 1995, 74 per sq ft; 1996, 32 per sq ft; and 1997, 40 per sq ft.

Meadowfoam seed yields were significantly greater in broadcast-seeded plots than in drill-seeded plots in 1995 and 1997 (Table 1). The reason for this greater seed yield is not clear since there were more meadowfoam plants established in the drill seeding in 1995, while there were more in the broadcast seeding in 1997 (data not shown). In both years the seed weight was greater in the broadcast seeding. Annual bluegrass had no negative effect on meadowfoam seed yield, and in 1996 and 1997, annual bluegrass infested meadowfoam significantly out-yielded annual bluegrass free meadowfoam (Table 2).

Table 1. Meadowfoam seed yield as influenced by seeding method in four consecutive years.

Seeding method	Seed yield[1]			
	1995	1996	1997	1998
	----------------(lb/a)----------------			
Drill	324	188	711	754
Broadcast	400	201	902	791
LSD 0.05	38	NS	53	NS

[1]Values are means of 16 annual bluegrass infested plus 16 weed-free plots.

Table 2. Meadowfoam seed yield as influenced by the presence of annual bluegrass in four consecutive years.

Annual bluegrass	Seed yield[1]			
	1995	1996	1997	1998
	----------------(lb/a)----------------			
Present	363	265	958	780
Absent	361	125	655	765
LSD 0.05	NS	62	53	NS

[1]Values are means of 16 drill-seeded plus 16 broadcast-seeded plots.

Other research that we have recently completed shows that populations of annual bluegrass as dense as 800 plants per square foot have little effect on meadowfoam seed yield. This may be partially due to the low nitrogen requirement

of meadowfoam, which may make it fairly tolerant of competition for nitrogen from the bluegrass. Higher meadowfoam seeding rates resulted in higher seed yields in 1995 and 1997 (Table 3). The cost of the seed seems to be the only negative factor in considering higher seeding rates. When looking within the four seeding rates in each year (Table 4), the broadcast seeding with annual bluegrass present had the highest average seed yield in 12 of the 16 observations, although most of these yields were not statistically greater than the three other yields in each observation.

Table 3. Effect of seeding rate on meadowfoam seed yield in four consecutive years.

Seeding rate	Seed yield[1]			
	1995	1996	1997	1998
	(lb/a)			
15	286	183	580	796
30	367	201	787	755
45	388	192	923	776
60	408	203	936	761
LSD 0.05	54	NS	76	NS

[1]Values are means of 8 drill-seeded plus 8 broadcast-seeded plots.

There was no clear advantage of one seeding method over the other in suppressing annual bluegrass dry weight (Table 5). In only one year (1997) was there a statistically significant difference, with broadcast seeding suppressing the bluegrass to the greater degree.

Table 5. Annual bluegrass dry weight in drill-seeded and broadcast-seeded meadowfoam in 4 consecutive years.

Seeding method	Dry weight[1]			
	1995	1996	1997	1998
	(g/sq ft)			
Drill	2.9	3.6	3.5	4.8
Broadcast	4.0	3.2	2.6	5.9
LSD 0.05	NS	NS	0.9	NS

[1]Values are means of 16 annual bluegrass-infested and 16 bluegrass-free plots.

Meadowfoam seeding rate had a definite suppressing effect on annual bluegrass growth (Table 6). Growers concerned with preventing annual bluegrass seed production could consider higher seeding rates of meadowfoam as part of their control program, but annual bluegrass control seems unnecessary for meadowfoam seed production.

Table 6. Annual bluegrass dry weight as influenced by meadowfoam seeding rate in 4 consecutive years.

Seeding method	Dry weight[1]			
	1995	1996	1997	1998
	(g/sq ft)			
15	4.9	5.6	4.3	9.1
30	4.7	2.4	3.0	5.4
45	3.1	3.1	2.8	4.2
60	1.0	2.5	1.8	2.7
LSD 0.05	2.0	1.6	1.2	2.1

[1]Values are means of 8 bluegrass-infested and 8 bluegrass-free plots.

Table 4. Meadowfoam seed yield as influenced by seeding method, seeding rate, and presence of annual bluegrass in 4 consecutive years.

Seeding method	Seeding rate	Annual bluegrass	Meadowfoam seed yield			
			1995	1996	1997	1998
			----------------------------------- (lb/a) -----------------------------------			
Drilled	15	P[1]	242 a[2]	217 bcde	753 de	791
Drilled	15	A	278 ab	136 abc	251 a	711
Broadcast	15	P	322 abcd	302 e	882 ef	891
Broadcast	15	A	302 abc	78 a	433 b	794
Drilled	30	P	353 bcdef	299 e	866 ef	722
Drilled	30	A	290 abc	109 a	530 bc	763
Broadcast	30	P	415 defg	264 de	1001 fg	786
Broadcast	30	A	412 defg	132 ab	752 de	750
Drilled	45	P	344 abcde	262 de	967 f	722
Drilled	45	A	359 bcdefg	136 abc	657 cd	784
Broadcast	45	P	391 cdefg	239 cde	1132 g	803
Broadcast	45	A	458 fg	133 abc	936 f	797
Drilled	60	P	374 bcdefg	247 de	929 f	786
Drilled	60	A	354 bcdef	101 a	738 de	755
Broadcast	60	P	466 g	289 e	1138 g	741
Broadcast	60	A	436 efg	174 abcd	941 f	764

[1]P = present, A = absent
[2]Mean separation according to Duncan's Multiple Range Test, means within a column followed by the same letter or group of letters are not different at P = 0.05.

RUST CONTROL IN PERENNIAL RYEGRASS GROWN FOR SEED

G.A. Gingrich and M.E. Mellbye

Rust is the most serious fungal disease affecting perennial ryegrass seed fields in western Oregon. Left untreated, seed yield loses of over 60% have been reported. An estimated 95% of the acres get 1 to 4 fungicide applications each year to prevent or control stem rust. Perennial ryegrass seed growers have relied heavily on essentially one fungicide (Tilt) for controlling rust infestations for nearly 20 years.

During 1993, in response to concerns about potential development of rust resistance to a single type of fungicide, field trials to evaluate other products were established. These trials included various sulfur products and other additives applied alone and in tank mixes with Tilt to evaluate their effectiveness against rust. These materials were selected because it was believed they had some rust suppression activity and could be readily labeled for use on grass seed crops. After two years research Sulforix and Thiolux were registered for use in combination with Tilt for rust control.

By 1996 work with these products was discontinued and other, new fungicides were being tested in several on-farm rust control trials. This report covers the results of field trials conducted in 1997 and 1998. The three fungicides evaluated in 1997 were Tilt, Folicur and Quadris. Tilt, the standard fungicide in most rust control programs and Folicur are sterol inhibitor fungicides. Quadris, a strobilurin fungicide, has a completely different chemistry and mode of action.

At each trial, plots were replicated three times. Initial applications were made just prior to or at the very first visible appearance of any rust development in the field. The first fungicide applications were made about May 20 with succeeding treatments being applied at approximately 21-day intervals. A non-ionic surfactant was added to all fungicide treatments at a rate of 0.25% by spray volume. Fungicides were applied in twenty gallons of water per acre.

Replicated, small plots were established in 1997 on three production fields of perennial ryegrass to evaluate the effectiveness of the three fungicides for rust control. Two trials were located east of Salem and one southwest of Albany. Rust severity often varies widely from one year to the next and from one field to another in any particular year. In fields where trials were located in 1997 rust severity in untreated checks were rated from light to

moderate at the time of the final fungicide application. Treatments included multiple, single and sequential applications. Under moderate rust pressure conditions all three fungicides (Tilt, Folicur and Quadris) provided adequate stem rust control through the end of the season (Fig. 1).
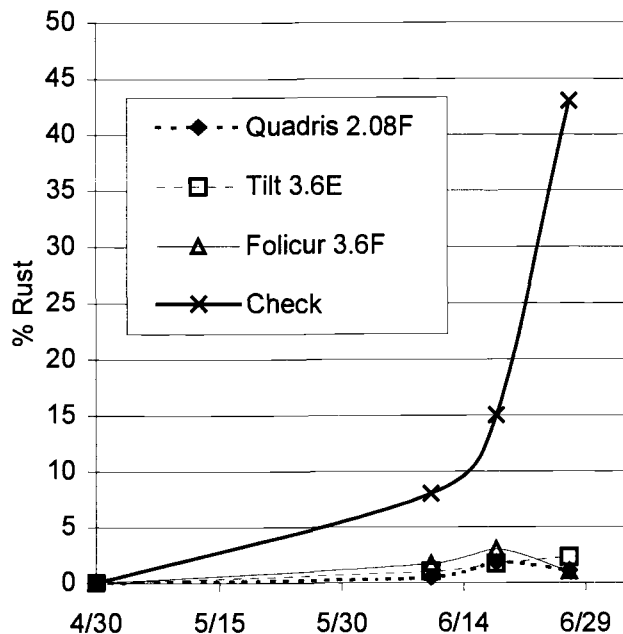

Figure 1. Stem rust development on Affinity perennial ryegrass during a year of moderate disease pressure, 1997.

Visual evaluations of each treatment were made 2 to 3 times between the initial fungicide treatment and just prior to swathing. Control ratings are listed as a percentage of rust infection for each treatment (Table 1). Tilt and Folicur consistently provided adequate and similar control of rust. Quadris provided equal or slightly superior control at each location. The treatments using the fungicide rotation sequences provided equal control to the treatments using a single fungicide under moderate rust pressure in 1997.

On-farm trials using Tilt, Folicur and Quadris were again conducted at three locations in 1998. In addition, several fungicides not previously tested in our trials were included. The fungicides added included Systhane, Dithane and a numbered, experimental fungicide manufactured by Novartis, CGA6425 + CGA279202. Both Folicur and Quadris received Oregon Sec. 24c registrations for rust control in grass grown for seed and were used commercially in rust control programs during the spring rust season.

Of the on-farm sites used in 1998, one was located east of Salem and two in the south valley, one at Junction City and the other near Harrisburg. In general, rust infection levels in most fields were significantly higher than was observed in 1997. At two of the sites rust levels were rated as severe but only moderate at the Harrisburg location. As in the

previous year Quadris, Tilt and Folicur provided acceptable control in most treatments. These and other fungicide trials have shown that Quadris has consistently provided slightly superior rust control late in the season and in situations where rust pressure is very high (Fig. 2).
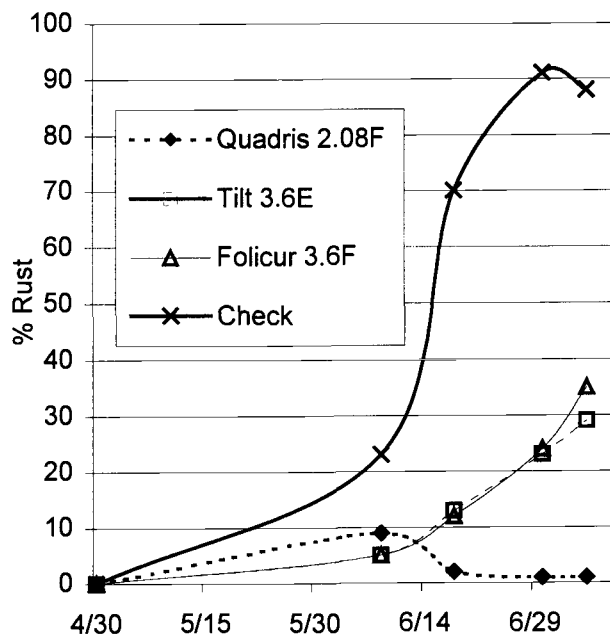

Figure 2. Stem rust development on Affinity perennial ryegrass during a year of severe stem rust pressure, 1998.

The spray program used at all sites in 1998 used three fungicide applications to provide adequate rust control. Where rust pressure was severe, treatments that included a Quadris application again provided equal or superior rust control to any other fungicide application.

The level of control from the different treatments varied between sites depending on the level of rust infection (Table 2). In general the new fungicide products added in 1998, provided equal control to Tilt and Folicur but were not as good as the best Quadris treatments under heavy rust conditions. The first early treatment using Tilt plus Bravo followed with three applications of Tilt was not any more effective than the best three application treatments with Quadris.

Based on the results of these trials and the apparent interest of major chemical manufacturers the Oregon grass seed industry should have additional, effective fungicides available for disease control for the foreseeable future.

30

Table 1. Visual ratings of rust infection levels in three perennial ryegrass varieties at end of season, July, 1997.

| Treatment | Rate | Variety | | |
		Dasher 2 July 2	JB3 July 9	Affinity July 3
	(product/a)	------------------- (% rust infection) -------------------		
Quadris(3x)	9 oz.	1	1	0
Tilt(3x)	6 oz.	12	1	2
Folicur(3x)	6 oz.	2	1	1
Tilt/Quadris/Tilt	6/9/6 oz.	1	1	1
Folicur/Quadris/Folicur	6/9/6 oz.	4	1	0
Check	0	67	27	41
LSD 0.05		20	4	31

Table 2. Visual ratings of rust infection levels in three perennial ryegrass varieties at end of season, July 6, 1998.

| Treatment | Rate | Variety | | |
		Top Hat June 29	Elf July 6	Affinity July 6
	(product/a)	-------------------(% rust infection) -------------------		
Tilt + Bravo(1x)/ Tilt(3x)	6 oz. + 1.5pt/6oz.	7	1	14
Quadris(3x)	6 oz.	3	2	4
Quadris(3x)	9 oz.	0	1	1
Tilt(3x)	6 oz.	14	3	29
Folicur(3x)	6 oz.	17	3	35
CGA6425 + CGA279202(3x)	10 oz	9	3	10
Systhane + Dithane(3x)	10 oz. + 32 oz.	11	3	28
Tilt/Quadris/Folicur	6/9/6 oz.	6	2	8
Quadris/Tilt/Quadris	9/6/9 oz.	2	0	4
Check	0	97	70	88
LSD 0.05		13	12	8

CORRELATION OF YIELD REDUCTION IN PERENNIAL RYEGRASS WITH MEASUREMENTS OF STEM RUST SEVERITY

W.F. Pfender

Introduction

To make good economic decisions about applying disease control measures, it is important to know how the level of disease will affect harvestable yield. If a small amount of disease causes little or no yield loss, then it would be uneconomical to pay for a fungicide application in lightly-infected fields; on the other hand, if a given amount of disease does cause significant yield loss, then it will pay to incur the cost of a fungicide application. One aspect of our current research on grass stem rust is to determine the measures of rust severity that correlate best with yield loss, and to estimate the quantitative relationship between such measures and yield.

The amount of rust in the crop at a single time during the season (for example at flowering, or at early seed fill) may correlate with the amount of yield lost in a given year. But since the amount of disease after that point may increase quickly or slowly, depending on subsequent conditions, this single-point correlation of disease with yield loss may not be generally applicable. The same could be said concerning the level of disease leading up to that single

point in time. Therefore a measurement of disease that includes the amount of damage occurring during a substantial part of the growing season may be more useful. We have begun to examine this possibility using data for disease severity and yield loss in two different seasons.

Methods

Data for the 1998 cropping season were obtained from experimental plots maintained at the Hyslop experiment farm. Perennial ryegrass (cv. Morningstar) was grown in replicate plots, each plot 25 x 15 ft. The crop was carbon-band seeded in September 1997, and grown using normal commercial practices except that disease was controlled at different levels by varying the number and timing of fungicide (propiconazole) applications. We also applied nitrogen fertilizer at two treatment rates. Stem rust severity was monitored weekly from March until harvest on July 7. Seed was harvested from a 20 x 6 ft strip from the center each plot, using a small plot harvester. Seed was threshed and cleaned to commercial standards. Average clean-seed yield from five replicate plots per treatment was compared with average measures of rust severity taken at weekly intervals from the same five plots per treatment.

Data for the 1997 cropping season were obtained from a first-year planting of perennial ryegrass (cv. Allaire). These plots, set up in a grower's field and maintained by Ron Burr of Ag Research, Inc., were 8 x 25 ft in size. There were four replicate plots per treatment, and treatments varied in timing and type of fungicide applied (see "Stem rust control in perennial ryegrass", by Pfender and Burr, in 1997 OSU Seed Production Research report). For the current analysis, data from 6 different fungicide treatments and two application timings were used. Four treatments were used to obtain average values for final clean-seed yield, and for amount of disease on 4 dates: May 29, June 15, June 26, and July 7. Plots were harvested on July 10, and seed was cleaned to commercial standards before taking weights.

Disease severity data for both years were originally quantified on the "Cobb scale." On this scale the maximum amount of disease possible, which is only about 37% of the actual leaf area covered with rust pustules, is called "100%." Thus a Cobb scale reading of 10% rust is equivalent to 3.7% of the actual leaf area occupied by pustules. In order to correlate yield loss with proportion of plant leaf area affected, we converted Cobb scale readings to actual percentage of leaf area affected. In 1998, the rust was severe enough to kill some plants in the nontreated plots; killed leaves were designated 100% actual area affected.

We graphed the proportion of leaf area affected over time, and compared that with the graph of total leaf area over time (see Figure 1). The complete area beneath each graphed line is the durationXarea, so that the area under the 'total leaf area' curve is the durationXarea of all leaves in the canopy, and the area under the 'diseased leaf area' curve is the durationXarea of nonproductive plant tissue.

By subtracting the area under the disease curve for a particular treatment from the area under the total leaf-area curve, we have a measure of the available photosynthetic area for that treatment multiplied by its duration, called the 'Healthy Area Duration' for that treatment (Figure 1). We compared healthy area duration with yield for all treatments in the 1998 data.
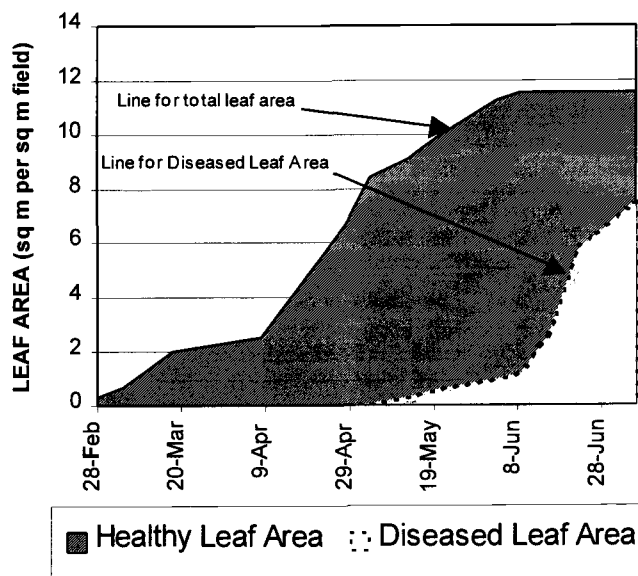

Figure 1.   Concept of Healthy Area Duration

In this comparison, we tried various parts of the growing season. When we compared yield to healthy area duration for the entire growing season, the correlation was not very good because a long period of healthy foliage at the beginning of the season did not prevent severe yield depression caused by severe disease later in the season. On the other hand, if we compared yield to the healthy area present during only the final two weeks of the season, plots which had remained healthy up until those final two weeks and then became disease would yield better than plots that were equally diseased during the final two weeks but also had been diseased for several previous weeks. After trying several comparisons, we found the best agreement between yield and the healthy area duration from flowering to harvest. To test this relationship for the 1997 and 1998 data together, we converted the yield data for each year to percent of the maximum yield observed that year. We also converted healthy area duration for each treatment to the percent of the maximum possible leaf area duration from flowering to harvest that year.

Results

As shown in Figure 2, the percent healthy (non-rusted) leaf area duration between flowering and harvest was related in a somewhat consistent way with yield. The greatest variation in yield with healthy leaf area duration is at high levels of both (upper right corner of Figure 2). The two 1998 values at 100 percent leaf area duration are from two nitrogen treatments, and fertilizer had a predictable effect on yields.

32

And whereas the data for 1998 are the result of various rust intensities managed through the use of the single fungicide, the data from 1997 are the result of treatments using a range of fungicides. The higher variability of yields among plots with very little disease in 1997 than in 1998 may be the result of non-target fungicide effects. Despite this variability however, we can see a general pattern: minimal yield reduction at healthy leaf area durations of 90% or better, then a steep decline in yield with decreasing healthy leaf area duration down to about 75%, then a reduced rate of yield decline with disease down to very little yield at very low levels of healthy area duration.

These data were collected from only two years, and analysis of additional data in years to come can be expected to give somewhat different specific results. However, the fact that there is reasonable general agreement between the two years' data, which came from different locations and cultivars as well as different years, indicates that the leaf area duration after flowering may be a good indicator for yield reduction. If this is correct, then the most meaningful measures of damage due to stem rust would be those taken at several intervals between flowering and harvest, so that an evaluation of percent reduction in healthy area duration can be made.
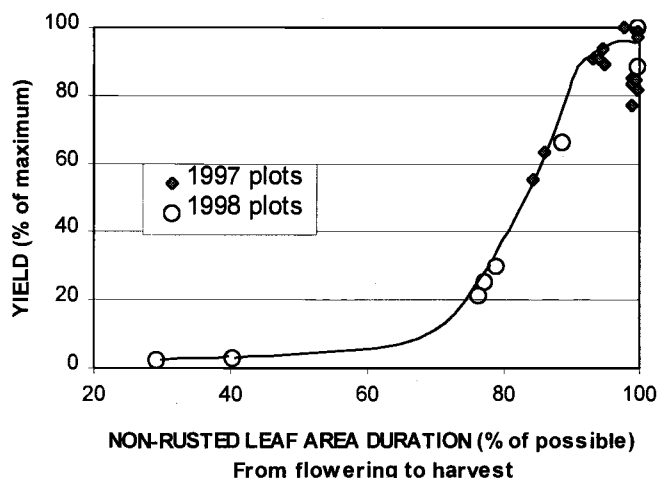

Figure 2. Relationship of seed yield to 'Healthy Area Duration' in perennial ryegrass, 1997 and 1998.

The fact that early-season disease levels may not correlate well with yield reduction does not mean that early-season disease is unimportant. The only way that stem rust levels at flowering can be severe enough to affect yields, is by being present in the stand earlier in the season. So it is important to manage for low rust levels well before flowering, in order to keep rust levels low enough during the flowering-to-harvest period to avoid yield losses. But in evaluating the effectiveness of any particular rust management program, the best measure of success appears to be severity of rust during the time from flowering to harvest.

1998 GEOGRAPHICAL DISTRIBUTION AND SEVERITY OF ORCHARDGRASS CHOKE IN THE WILLAMETTE VALLEY

W.F. Pfender and S.C. Alderman

Introduction

Epichloe typhina is a damaging endophytic fungus that can be found in several grass species, including orchardgrass. Symptoms are manifested near the time of flowering, when growth of the fungus physically prevents ("chokes") the emergence of the grass inflorescence by growing out through the enveloping leaf sheaths to form a yellowish-orange growth on the external plant surface. Ascospores produced from this fungus tissue can infect other plants by entering through the pith of cut stems soon after harvest. There is no evidence that this strain of *E. typhina* is seed-borne in orchardgrass.

Although the disease is not economically significant to the use of orchardgrass as forage, it has a severe effect on orchardgrass seed production. In France incidence of choke commonly reaches 30% in an orchardgrass field by the fourth year of seed production, making the stand unprofitable. In the Willamette Valley, where fields commonly remain productive for a decade or more, orchardgrass choke was until recently unknown. This situation has changed, however, with the recent appearance of the disease in the Willamette Valley. First noticed as a single, unconfirmed specimen from a post-harvest field in 1996, the presence of the disease was verified in several fields of one cultivar in 1997. The discovery was made shortly before harvest, however, and there was not time enough for a thorough survey of orchardgrass fields in 1997.

This survey was conducted to determine the geographical distribution and severity of choke among cultivars grown in the Willamette Valley. We also obtained data regarding the potential for this disease to increase under Oregon conditions.

Methods

Thirty-seven orchardgrass fields were arbitrarily selected from the 1998 certification program to include a range of

cultivars and the geographic extent of production in the Willamette Valley. An additional 9 fields were included in a second survey to determine distribution of choke in fields within a 2½ mile radius of the heavily-infested fields that had been observed in 1997. Seven of the fields for the Valley-wide survey were also in this area, so that we surveyed 16 fields in the vicinity of the observed 1997 infestation. The total of all fields surveyed (46) included 12% of the orchardgrass acreage, and 29 of the 53 cultivars grown under certification for 1998.

Fields were surveyed between June 12 and June 27, 1998, by examining 40 samples, each 2.75 square feet, along 4 diagonal transects in each field. All stems for which the choked portion was included inside the sampling frame were counted. The percentage choked tillers was calculated based on estimates of the number of total tillers per sampling area. If all 40 samples were negative for choke, but other choked stems were seen in the field, the field was assigned a percent choke of <0.05%. If no choke was observed, a value of 0% was recorded.

When the disease was first discovered here just prior to harvest in 1997, the three infested fields were immediately surveyed for incidence of choke. In the 1998 survey the same three fields were surveyed on transects taken in the same location as the 1997 transects, so that a comparison could be made between choke levels in 1997 and 1998.

Results
Choke was detected in 70% (26 of 37) of the arbitrarily selected orchardgrass fields in the Valley-wide survey (Fig. 1). About half of the fields had choke levels of 0.05 to 10%, and 4 of the 37 fields had more than 10% diseased tillers. The disease was detected all six counties surveyed (Benton, Lane, Linn, Marion, Polk and Yamhill).

In the area within a 2½ mile radius of the 1997 disease observation, 14 of the 16 orchardgrass fields surveyed were infested to some degree with choke disease. Five of these fields were infested at >10% diseased tillers. The most severely-affected fields (>20% diseased) were in very close proximity to each other and were all of the same cultivar, but had been planted in several different years between 1991 and 1995. Another cultivar in this area had disease incidences varying from 0 to 8% among the 8 fields planted to it.
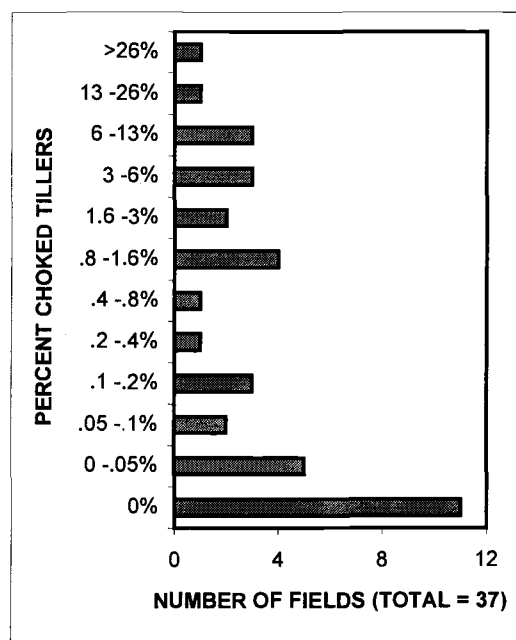

Figure 1. Distribution frequency of choke incidence (% tillers affected) in 37 arbitrarily-selected fields of Oregon's Willamette Valley in 1998.

When data from the three fields sampled in both years (1997 and 1998) were analyzed statistically, we found choke increased significantly during this 1-year period. The increases from 1997 to 1998 in these three fields were: from 13 to 35% (2.7-fold), from 9 to 19% (2.1-fold) and from 3 to 10% (3.3-fold).

This survey demonstrates that choke disease in orchardgrass, unknown in Oregon before 1997, is now established and widespread in the Willamette Valley. This disease has the potential to be a very serious problem for orchardgrass production in the US for two reasons: 1) disease level and yield loss are directly correlated; 2) the rapid year-to-year increase in incidence observed in Europe can occur in Oregon, at least under some conditions.

It should be noted that although orchardgrass choke reduces seed yield, it does not reduce the quality of forage seed produced. Previous research shows that the pathogen is not generally seedborne in orchardgrass, and even if it were, it does not affect vegetative growth of the orchardgrass plant. And whereas other closely related endophytic fungi are known to produce alkaloids toxic to grazing mammals, such does not appear to be the case for *E. typhina* in orchardgrass. We submitted two samples of tissue from heavily choked orchardgrass to A.M. Craig and J.T. Hovermale at the Oregon State University Veterinary Diagnostic Laboratory, where it was determined that the plant tissue contained no detectable ergovaline and <300 ppb lolitrem B (toxicosis is observed in animals feeding on material containing greater than 1800 ppb lolitrem B). These results are from a single cultivar and therefore may not be representative of all infected cultivars, but there is

currently no evidence that choked orchardgrass has significant toxin levels.

Factors controlling disease increase and spread in the area are not yet known. We noted examples of adjacent fields, both of the same cultivar, that differed markedly in choke incidence. The weather, particularly rainfall and humidity, at harvest is known to be important in infection, and these fields may have been harvested under different weather conditions the previous year.

It is clear that choke disease of orchardgrass is now well-established in this region, and its impact can only be minimized by developing and incorporating disease management procedures into cultural practices for this crop.

PERENNIAL RYEGRASS RESPONSE TO FOLIAR APPLICATION OF TRINEXAPAC-ETHYL PLANT GROWTH REGULATOR, 1998

T.B. Silberstein and W.C. Young III

Introduction

Perennial ryegrass grown for seed is prone to lodging at the high fertility rates used to maximize seed production. Lodging of the crop can result in increased problems from disease and can reduce the efficacy of pollination. Use of manufactured plant growth regulators (PGRs) to control stem elongation and optimize seed production in cool season grasses had some success in the mid 1980s. Research developed during this period was based on the use of a residual, soil applied PGR in the triazole family (paclobutrazol) that gave reliable control of lodging and was able to improve seed yields. However, due to the longevity of this chemical in the soil, and difficulties in funding registration of chemicals for use on minor crops, use of this family of chemicals is not allowed.

Recent development of new foliar applied PGR type chemicals that readily breakdown in the environment and are effective at controlling rapid stem elongation are being studied to assess their potential for use in grass seed production systems. These experiments were conducted to examine the effect of Trinexapac-ethyl, a foliar applied PGR manufactured by Novartis on perennial ryegrass grown for seed production.

Procedure

Established stands (planted fall 1994) of 'Affinity' and 'Buccaneer' perennial ryegrass at Hyslop Crop Science Research Farm were used for these trials. The experiment was treated with 1.6 lb a.i./a diuron in the fall as well as 250 lb/a 16-20-0 fertilizer. Spring N was applied March 9 at 120 lb N/a and April 17 at 30 lb N/a. The experimental designs were randomized complete blocks replicated four times. PGR treatments were applied at walking speed using a bicycle type 6-foot wide boom sprayer with nozzles at 18 inch spacing. The sprayer operated at 20 psi with XR TEEJET 8003VS nozzles (approx. 30 gal/a water). In the 'Affinity' perennial ryegrass stand, seven treatments were applied as follows: an untreated check and three rates of Trinexepac-ethyl (200, 400, and 600 g a.i./ha) applied at one of two dates (April 19 and May 2, 1998). In the 'Buccaneer' perennial ryegrass stand, four treatments were applied as follows: an untreated check, Trinexepac-ethyl applied @ 400 g a.i./ha on April 21, May 5, and split equally (200 + 200g a.i./ha) on both dates. Plot size was 6 ft x 25 ft. The first (early) application was made at the onset of active internode elongation and during rapid leaf development. The second (late) application was made at about two palpable nodes during rapid internode elongation. Elongation and nodal development was assessed using a weighted average of tiller size and internode expansion from plant samples taken the day of or day prior to treatments.

Plots were sampled (9-inch row samples) at early bloom for fertile tiller counts, length measurements, and above ground biomass weights. Ten inflorescences were also randomly sampled for yield component analysis and spike length measurements. Harvesting was done using a 5 ft wide swather for windrowing and a Hege 180 small plot combine for harvest. All plots were swathed July 15 and combined July 27. Combined seed samples were cleaned using an M2-B clipper cleaner for final cleanout; subsamples of clean seed were taken for 1000 seed weights.

Results

The highest seed yields in the Affinity stand resulted from the highest PGR rate at both early and late application dates. Seed yield from the 600 g a.i./ha rate was almost twice the untreated check (Table 1). In the Buccaneer stand all of the treated plots yielded about the same whether the treatment was done in a single application or split (Table 2). Yields from both varieties were similar at the 400 g a.i./ha rate application rate. No differences in maturity were observed due to PGR treatments. All treatments increased seed yield and no phytotoxic effects were observed from the foliar applications. Last year (1997 crop), treatments in the Affinity stand indicated higher rates (1000 - 1500 g a.i./ha) had some phytotoxicity and did not yield as much as the 500 g a.i./ha rate. It was suggested that the expected maximum rate should be around 500-600 g a.i./ha for highest yield. This year's data also indicates the same.

Fertile tiller number per unit area in the Affinity stand were increased by the treatment when using a contrast analysis comparing all the treated plots with the untreated check, yet a similar increase was not observed in the Buccaneer stand. Specifically what component(s) of harvest improved

seed yield was not apparent in either experiment. Floret numbers and spikelet numbers were affected (data not presented), but with mixed results. However, the effect on crop lodging was dramatic in relation to the check. The untreated stands were lodging by bloom and were level with the ground at harvest, in contrast, the stand in treated plots remained upright past bloom and were well into seed fill when the lower rates began leaning. At harvest the treated plots were still off the ground which allowed for easy windrowing. In the highest PGR treated plots, the windrows were much smaller and had less crop residue to combine.

Cleanout was significantly reduced in the treated plots. Improved cleanout may be attributed to less total dry matter running through the combine as well as the makeup of the windrow. In the untreated plots there was a lot of leaf and stem material, and in the treated plots the swaths were much smaller and had less plant material as previously mentioned.

In addition to improved cleanout, the increase in harvest index indicates better seed set in the crop. The overall tiller length and the spike length was reduced an average of 30% across all treatments (Table 1). This along with reductions in lodging may have improved conditions for seed set as well as seed recovery during harvest.

It should be noted that these trials were conducted on older stands (3-4 years old) and therefore results may be affected by the age of the stand as younger and first year fields often yield at the levels the treated plots did in this trial. But this study shows the significant impact this product has on seed yield in older stands. Experiments are being conducted during the 1999 crop year in young stands of perennial ryegrass, tall fescue and fine fescue to determine the impact this PGR has on seed production in these species.

Table 1. Effects of foliar applied Trinexepac-ethyl on seed yield, harvest components, and tiller length in Affinity perennial ryegrass, 1998.

Treatment	Seed Yield	Seed Yield	Aboveground biomass	Fertile tillers	Clean-out	Harvest index	Culm reduction	Lodging score
(g a.i./ha)	(lb/a)	(% of check)	(ton/a)	(no./sq. ft.)	--------(%)--------			$(1-5)^2$
Untreated check	952 e*	100	5.1	209[1]	20 a	8.5 d	0 c	5.0 a
Early (April 19)								
200	1441 cd	151	4.7	227	12 c	14.3 abc	15 b	4.5 b
400	1644 bc	173	4.9	268	14 bc	14.7 ab	27 a	3.8 c
600	1894 a	199	5.1	286	13 c	15.8 a	33 a	3.3 d
Late (May 2)								
200	1316 d	138	5.8	235	15 bc	10.8 cd	13 b	4.5 b
400	1555 c	163	5.9	256	14 bc	12.0 bcd	24 ab	3.8 c
600	1831 ab	192	5.2	343	17 ab	15.4 ab	29 a	3.0 d

*Means in columns followed by the same letter are not significantly different by Fisher's protected LSD values at P=0.05.
[1]Contrast of treated vs untreated significant P=0.05
[2]Lodging score at harvest 1-5: 1 = vertical; 5 = horizontal

Table 2. Effects of foliar applied Trinexepac-ethyl on seed yield, harvest components, and tiller length in Buccaneer perennial ryegrass, 1998.

Treatment	Seed Yield		Aboveground biomass	Fertile Tillers	Clean-out	Harvest index	Culm reduction	Lodging score
(g a.i./ha)	(lb/a)	(% of check)	(ton/a)	(no./sq ft)		(%)		(1-5)[2]
Untreated check	826 (b)*	100	4.8	177	19	6.7	0 b	5.0 a
Early Late								
400 0	1418 (a)	172	5.5	209	13	10.2	23 a	3.6 b
0 400	1508 (a)	183	5.4	218	15	9.4	29 a	3.4 b
200 200	1485 (a)	180	5.6	215	13	9.2	27 a	3.8 b

*Means in columns followed by the same letter are not significantly different by Fisher's protected LSD values at P=0.05, letters in parenthesis are significant at probability values P<0.10.
[2] Lodging score at harvest 1-5: 1 = vertical; 5 = horizontal

PERENNIAL RYEGRASS RESPONSE TO FOLIAR APPLICATION OF BAS 125 11 W PLANT GROWTH REGULATOR, 1998

T.B. Silberstein, W.C. Young III and T.G. Chastain

Introduction

Perennial ryegrass grown for seed is prone to lodging at the high fertility rates used to maximize seed production. Lodging of the crop can result in increased problems from disease and can reduce the efficacy of pollination. Use of manufactured plant growth regulators (PGRs) to control stem elongation and optimize seed production in cool season grasses had some success in the mid 1980s. Research developed during this period was based on the use of a residual, soil applied PGR in the triazole family (paclobutrazol) that gave reliable control of lodging and was able to improve seed yields. However, due to the longevity of this chemical in the soil, and difficulties in funding registration of chemicals for use on minor crops, use of this family of chemicals is not allowed.

Recent development of new foliar applied PGR type chemicals that readily breakdown in the environment and are effective at controlling rapid stem elongation are being studied to assess their potential for use in grass seed production systems. This experiment was conducted to examine the effect of BAS 125 11 W, a foliar applied PGR manufactured by BASF Corporation on perennial ryegrass grown for seed production.

Procedure

An established stand (planted fall 1994) of 'Buccaneer' perennial ryegrass at Hyslop Crop Science Research Farm was used for this trial. The experiment was treated with 1.6 lb a.i./a diuron in the fall as well as 250 lb/a 16-20-0 fertilizer. Spring N was applied March 9 at 120 lb N/a and April 17 at 30 lb N/a. The experimental design was a randomized complete block replicated four times with five treatments as follows: an untreated check, BAS 125 11 W applied as two single treatments at ½ lb a.i./a on April 21 and May 5, and two split applications (¼ + ¼ lb a.i./a and ⅛ + ⅛ lb a.i./a) on the same dates. PGR treatments were applied at walking speed using a bicycle type 6-foot wide boom sprayer with nozzles at 18 inch spacing. The sprayer operated at 20 psi with XR TEEJET 8003VS nozzles (approx. 30 gal/a water). Plot size was 6 ft x 25 ft. The first (early) application was made at the onset of active internode elongation and during rapid leaf development. The second (late) application was made at about two palpable nodes during rapid internode elongation. Elongation and nodal development was assessed using a weighted average of tiller size and internode expansion from plant samples taken the day of or day prior to treatments.

Plots were sampled (9-inch row samples) at early bloom for fertile tiller counts, length measurements, and above ground biomass weights. Ten inflorescences were also randomly sampled for yield component analysis and spike length measurements. Harvesting was done using a 5 ft wide swather for windrowing and a Hege 180 small plot combine for harvest. Combined seed samples were cleaned using an M2-B clipper cleaner for final cleanout; subsamples of clean seed were taken for 1000 seed weights.

Results

All of the treated plots significantly increased seed yield over the untreated check in Buccaneer perennial ryegrass. Yields in the treated plots were not statistically different from each other. No phytotoxic effects were observed from the foliar applications.

Aboveground biomass was not affected by the PGR treatment nor were the number of fertile tillers per unit area. Floret numbers tended to increased about 15 - 20% (P value <0.10, data not included), but this does not account for the magnitude of yield improvement. The effect on crop lodging was dramatic in relation to the check. The untreated stands were lodging by bloom and were level with the ground at harvest. In contrast, the stand in treated the plots remained upright past bloom and were well into seed fill when plots began lodging. The ¼ + ¼ lb split application gave the best lodging control and before control than a single application of ½ lb. At harvest the treated plots were still off the ground, which allowed for easier windrowing.

Cleanout levels tended to be somewhat lower in the treated plots (P value = 0.11). In addition to improved cleanout, the increase in harvest index indicates better seed set or

seed recovery in the crop. Overall tiller length and spike length was reduced an average of 31% across all treated plots (Table 1). This along with reductions in lodging indicate improved conditions for seed set, fill, and harvest.

It should be noted that this trial was conducted on a 4 year old stand and therefore results may be affected by the age of the stand as younger, and first-year, fields often yield at the levels the treated plots did in this trial. But this study shows the significant impact this product has on seed yield in older stands. Experiments will be expanded in 1999 to include new stands of perennial ryegrass, tall fescue and fine fescue to determine the impact this PGR has on seed production in these species.

Table 1. Effects of foliar applied BAS 125 11 W on seed yield, harvest components, and tiller length in Buccaneer perennial ryegrass, 1998.

Treatment		Seed yield	Seed yield	Aboveground biomass	Fertile tillers	Clean-out	Harvest index	Culm reduction	Lodging score
(lb a.i./a)		(lb/a)	(% of check)	(ton/a)	(no./sq ft)	-----	----- (%) -----	-----	$(1-5)^2$
Untreated check		826 b*	100	4.8	177	19	6.7^1	0 c	5.0 a
Early	Late								
½	0	1502 a	182	4.2	162	13	13.2	27 b	3.4 b
0	½	1621 a	196	5.9	236	16	9.9	30 ab	3.3 b
⅛	⅛	1598 a	193	5.5	199	17	9.1	29 ab	3.9 b
¼	¼	1731 a	210	4.7	214	13	12.7	39 a	2.0 c

*Means in columns followed by the same letter are not significantly different by Fisher's protected LSD values at P=0.05
[1]Contrast of treated vs untreated significant P=0.05
[2]Lodging score at harvest 1-5: 1 = vertical; 5 = horizontal

GENETIC SEPARATION OF ANNUAL FROM PERENNIAL RYEGRASS

R.E. Barker and S.E. Warnke

Introduction
Methods to distinguish between annual and perennial ryegrass have long been sought. Morphological characteristics that are often used to distinguish annual from perennial growth habit include rolled vs folded leaf vernation, rapid growth, wide leaves, light color foliage, heading without vernalization, and presence of awns (Jung et al., 1996). Laboratory tests that would be more rapid than growing plants to maturity are desirable. Some of these include

electrophoresis of seed proteins (Ferguson, 1984), esterase (Griffith, 1991; Griffith and Banowetz, 1992), and seedling root fluorescence (Gentner, 1929). While seedling root fluorescence has been adopted in the USA for marketing perennial ryegrass for turf, none of these laboratory tests have been readily accepted worldwide.

The Seedling Root Fluorescence Test
Seedling root fluorescence has been used as a separator to distinguish ryegrass crops for almost 60 years. Generally, germinating seedling roots of annual or Italian ryegrass fluoresce when placed under ultraviolet light, roots of perennial ryegrass do not fluoresce. Interpretation of the test, however, has been difficult since it was first implemented because of variability in the test (Nitzsche, 1960). Because

of the variability, early researchers suggested that the test could only be used as an indicator of kind, but it should not be used as a rigid discriminator (Rampton, 1938). Yet, in 1990, the Federal Seed Act rules for testing seeds were amended to allow the seedling root test to be used as a variety descriptor in the ryegrasses (AOSA rules, 1994). This action made the test more rigid than originally intended because when the fluorescence level for a variety is established, any test showing values above that level are automatically classified as annual ryegrass.

One source of variation associated with the test is that some fluorescence is not readily visible (hidden) while the seedling root is still on the filter paper. It was not recognized until the rules change in 1990 that the test should have been completed by removing all seedlings from the filter paper (Colbry, 1963). For many years, roots with faint fluorescence intensity were ignored when standard or production tests were conducted. While lifting seedlings to observe faint fluorescence on the filter paper does reduce some human judgement errors in making decisions about intensity, removal of seedlings in production laboratories is time consuming.

We found that there is far more variation in the fluorescence test because of other factors than that expressed by the small contribution of not lifting roots with hidden fluorescence (Barker et al., 1997; Floyd and Barker, 1997). We provided data (Barker et al., 1999) that were instrumental for the AOSA Seed Testing Rules to be changed by eliminating lifting starting in October 1998.

It would be far better if alternative tests to seedling root fluorescence were developed based on more stable biological characteristics than fluorescence. Such tests need to be fast, inexpensive, readily available, and easy to implement.

Alternative Tests Based on DNA

The most basic way to distinguish crop kind, or even identify cultivars, would be based on genes inherent in the materials. The genetic material, DNA, is the basis of life for any organism; genes determine expression of plant traits. Genetic testing would be ideal if the exact genes that cause the difference between organisms can be identified. Knowing the differentiation genes, and where they are located on chromosomes, allows us to sequence the DNA so the building block order can be tested. Isolating DNA sequences close to the actual genes (linkage) is also beneficial to developing tests.

We have developed a DNA-based test to separate annual from perennial ryegrass (Warnke and Barker, 1998a; 1998b). The test consists of three fundamental steps that can be completed in about 24 hours. The first step is to imbibe the seeds overnight to make them soft enough to crush so DNA can easily be extracted. The second step is to introduce a master mix of chemicals containing DNA building blocks so that DNA sequences of interest can be amplified through polymerase chain reaction (PCR). The final step is simply to visualize samples that have large quanti-

ties of amplified DNA using a fluorescence dye, or other functional binding system.

Amplification, the second step, is the part of the test and the most difficult. It is difficult not because the process of amplification is hard, but because the DNA sequence most appropriate to discriminate between two genotypes must be identified. Isolation of the correct sequence takes time and considerable research effort. To be effective, the DNA sequence to be amplified needs to be part of, or closely associated to, the gene that controls the morphological separation of the genotypes. Our first example of the separation was based on first year flowering, or flowering without vernalization (Warnke and Barker, 1998a). First year flowering may not be the best genetic separation to use because there are a few perennial ryegrass plants that flower without vernalization in greenhouse tests. We believe now that photoperiod may be a more definitive separator. Annual ryegrass plants appear to be photoperiod insensitive. That is, they will produce seed heads when day lengths are shorter than 13 hr, while perennial ryegrass plants must have more than 13 hrs. Photoperiod is somewhat complicated, but has been extensively studied in crops such as barley and wheat. There appear to be relatively few genes involved, and genetic markers linked to the more important have been identified. The genes that regulate the time of flowering are divided into vernalization response genes, photoperiod response genes, and earliness *per se* genes. Of these classes of genes only the earliness *per se* genes act in a recessive manner as occurs in annual ryegrass.

One or two major dominant genes control seedling root fluorescence, while one to four major recessive genes influence earliness. The recessive gene action of earliness in annual ryegrass makes pollen contamination difficult to identify because these recessive genes will only be expressed and visualized when in a homozygous state. Pollen contamination, therefore, will not be detected for two or more generations after contamination occurred. Genetic markers that can identify pollen contamination at the time of its occurrence will reduce annual-like genetic contamination in later generations and improve the quality of the perennial ryegrass seed crop.

While we continue our attempts to find the DNA sequences that provide the best separation, we will develop a DNA-based test that is linked to the seedling root fluorescence trait. This test, while suffering some of the same problems as the seedling root fluorescence test, will be possible to complete in about 24 hr rather than two weeks, and it will demonstrate that our concept of genetic testing to detect annual ryegrass contamination in perennial ryegrass is possible.

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VALIDITY OF FLOW CYTOMETRY FOR TESTING PLOIDY LEVEL IN RYEGRASSES

R.E. Barker, J.A. Kilgore, R.L. Cook and A.E. Garay

Introduction

Of the eight recognized ryegrass (*Lolium*) species, perennial ryegrass (*L. perenne* L.) and annual or Italian ryegrass (*L. multiflorum* Lam.) are the most predominant used commercially worldwide for forage and turf. These two species represent about two thirds of the grass seed acreage in western Oregon. All naturally occurring *Lolium* taxa where chromosomes have been counted are diploid with 2n=14 (Terrell, 1968). Starting in the late 1930s, tetraploid (2n=4x=28) forms of these two species and their hybrid, intermediate ryegrass (*L. X hybridum* Hausskn.), were developed in attempts to improve forage productivity and nutritive value.

In order to sell cultivars labeled as tetraploids, determining an accurate ploidy level is important to the grass seed industry. Cultivars pure in ploidy level are necessary because crossing among plants with different ploidy levels may result in genomic instability and uneven numbers of chromosomes, often leading to infertility and lower seed yields. Morphological characteristics of grasses with different ploidy levels can be manifested in herbage moisture content, seed size, seedling vigor, forage productivity, establishment ability, milk quality for cows, cold tolerance, competitive ability, and concentration of sugars and digestible organic matter. These different morphological characteristics, however, are not always apparent in detecting ploidy level itself. Furthermore, an accurate ploidy determination, where varieties for USA domestic sale must be at least 98% of a reported ploidy level, is required for certification of cultivar purity.

Ploidy levels in grasses have traditionally been determined via microscopic counting of chromosome numbers. This process involves collecting tissues undergoing cell division, such as root tips or pollen mother cells, and arresting the cells at the metaphase stage. The cells are then stained and squashed on a microscope slide for examination. The process is very time-consuming, and the technique requires experience in preparing and squashing the cells. Accurate counting for rapid testing in seed laboratories is often

difficult because chromosomes overlap, are inadequately spread, and polyploid cells have large numbers of very small chromosomes. Such difficulties can lead to observer bias.

In recent years a new technique, flow cytometry, has emerged for ploidy determination. Flow cytometry was first used to examine cell cycles, DNA content, and ploidy levels in humans and other animals, but by 1982 the technique was also adapted for DNA content determination in plant material. Flow cytometry is now well accepted by turf- and forage-grass researchers.

Flow cytometry involves the separation of intact nuclei from living plant material (usually young, fully extended leaves in the case of grasses) using a lysis buffer. After separating debris by centrifugation or filtration, the nuclear suspension is dyed with a fluorophore. The dyed suspension is then injected into the flow cytometer. Nuclei are taken into a tube via a current of water or buffer solution and passed, one by one, across a tight beam of light filtered to the absorption wavelength of the fluorophore. The light source can be either arc lamp (mercury, mercury-xenon, or xenon) or laser-based. The fluorophores bound to the nuclear material fluoresce, and the emitted wavelength is read by a series of photomultipliers. The larger the amount of DNA in the nuclei, the greater the intensity of the emitted wavelength. Data are fed into a computer, and a peak analysis program produces a histogram that conveys ploidy level and basic statistics from which the amount of DNA may be determined.

Flow cytometry has been recognized as being superior to microscopic chromosome counts (Galbraith et al., 1997) for a number of reasons. With recent technical improvements in modern flow cytometers, it is now a matter of days instead of months for a researcher to become confident with the technique. Leaf material can be collected at any growth stage, leaving the plant alive, and only a small amount of living material is necessary. User bias is virtually eliminated. Samples can be run in bulk, greatly increasing the amount of material that can be examined, and internal standards can be included for use in correcting shifting effects and determining DNA content. Furthermore, tens of thousands of cells can be counted in a single run, producing data with low statistical error.

The present study examined a large number of plants from Italian, perennial, and intermediate ryegrass seed lots using both flow cytometry and root tip chromosome counting. Our objective was to develop methodology for implementing flow cytometry in grass seed testing and verifying that, indeed, flow cytometry is accurate for determining ploidy level in ryegrass.

Materials and Methods
Three seed lots each of tetraploid Italian, perennial, and intermediate ryegrass cultivars were planted from seed into small conical pots with vermiculite. Each seed lot came from a different cultivar, except two seed lots of intermediate ryegrass (154909 and 170535) came from different production years of the same cultivar. Plants were grown in a greenhouse during the summer and fall of 1998 with a 12-16 hr photoperiod (combination sunlight and full-spectrum, high-pressure sodium lamps), in a temperature of 21°C. Plants were fertilized about every two weeks with a Peters 20-20-20 (N-P-K) combination. Flow cytometric and cytologic analysis of plants began once they had a fully expanded blade and continued through maturity.

Flow cytometry was performed on 200 plants per seed lot, essentially as performed by Galbraith et al. (1983) and Pfosser et al. (1995b). Young leaf tissue was collected by clipping relatively equal portions of blades. Leaf tissue of a tall fescue internal standard, *Festuca arundinacea* Schreb. cv. Arid, determined to have 16.69 pg DNA, was used with all scans to correct for shifting of peaks on the flow cytometer and to calculate relative DNA content of the unknown samples. Plants were examined singly or in bulk samples. Bulk samples were composed of no more than sixteen plants. If a diploid plant was detected, the bulk sample was halved and each half examined separately. In this manner the samples were narrowed down until the diploid plant of interest was isolated.

Tissues were chopped with a double-edged razor blade in 500μl of ice-cold commercial Partec buffer solution to release nuclei and allowed to wash for 1.5 min. The suspension was poured through a 30 μm filter to remove debris. Two ml of ice-cold commercial Partec DAPI solution was added (making a 1:4 buffer:DAPI ratio). The suspension was vortexed and allowed to sit for 5 min before vortexing again. The suspension was analyzed on a Partec PA flow cytometer (Partec GmbH, Otto-Hahn Straße 32, D-48161 Münster, Germany) and allowed to count for at least 20,000 cells. Means and coefficient of variance percentages of peaks were calculated by an internal peak analysis program of the flow cytometer and data values were recorded by hand. Ploidy level was determined based on position of the G1 peaks of unknowns in relation to the internal standard G1 peak.

Mean peak positions of the sample G1 peaks were normalized using the tall fescue internal standard to correct for shift. DNA content was calculated using the normalized peak values and the calculations outlined by Arumuganathan and Earle (1991) and used for relative, intraspecific comparisons.

Root tip squashes and chromosome counts were performed on at least 40 tetraploid plants of each variety and as many diploid and aneuploid plants as possible using the Feulgen technique. Young, translucent root tips were collected around midnight and placed in distilled water for 8-10 hours at 4°C. They were then fixed for 30 minutes in Carnoy's Fluid with chloroform at 4°C, treated with 5N HCl for 2 minutes at 55°C, and stained with Fuelgen's solution for 1 hour at room temperature. Root tips were washed with distilled water and frozen for later examination. Once

ready for analysis, tips were thawed and counterstained with aceto orcein (1 g orcein to 25 ml glacial acetic acid and 25 ml distilled water) for at least 5 minutes. After squashing and spreading on a slide, the chromosomes of cells in prometaphase and metaphase were counted at 1600x on a Zeiss Axioplan light microscope with a green filter. At least five cells per plant were counted and averaged. These counts were then compared against the results from the flow cytometer.

Results and Discussion
Actively dividing cells undergo a series of four temporal phases which are defined by the amount of DNA present, called the cell cycle (Galbraith, 1984). The cell cycle is comprised of a period preceding DNA synthesis (termed G1) where most cells are at any given time; DNA synthesis (S), a period prior to splitting of the cell (G2) which has twice the amount of DNA as G1; and the phase where the cell split (M). For somatic cells, the phase where the cell splits is called mitosis. Flow cytometry measures the amount of DNA present in each cell and a frequency analysis of a large number of cells reveals peaks reflecting that amount. The resulting histogram shows two defined peaks (G1 and G2), of which the G1 peak is larger because more cells are in this phase. The other phases of the cell cycle show up as little more than background noise. The major phases are present regardless of ploidy level, but tetraploid plants, having twice the DNA complement and number of chromosomes, have peaks at double that of their diploid counterparts.

A total of 381 final scans were run using flow cytometry, comprising 1794 individual plants and nine tetraploid ryegrass seed lots in composite samples of no more than sixteen plants each. Diploid contamination in tetraploid seed lots ranged from 0 to 25.5% (Table 1). As expected, DNA content of diploid plants ($\bar{x}$ = 5.74 pg) was about half the DNA content of tetraploid plants ($\bar{x}$ = 11.34 pg). Four seed lots (one Italian ryegrass, 165249, and all three intermediate ryegrasses) failed to meet the two-percent purity level required for seed certification.

Root tip squashes were performed on a total of 397 plants as a means of confirming flow cytometry results. Chromosome counts, representing at least five cells per plant and averaged over all plants in a ploidy level category ranged from 14.2 to 15.0 for diploid plants, 27.8 to 28.6 for tetraploid plants, and 30.9 for aneuploid plants (Table 2). A total of 2495 cells were counted. When testing speed is of the essence, chromosome counts of root tip cells were often inflated by chromosome overlapping and "guessing" demarcation. A careful cytogenetic analysis was not performed on most of the plants studied because techniques and conditions comparable to production testing were desired.

Three aneuploid plants were identified by flow cytometry (Tables 1 and 2). Two of these were confirmed using root tip squashes; the third had died before root tips were collected.

Identification of aneuploids using flow cytometry was determined through the appearance of bimodal peaks (Pfosser et al., 1995 a & b). The difference in DNA between the aneuploid plant and a tetraploid from the same was large enough to form distinctly different peaks, yet similar enough for the peaks to merge, forming the bimodal peak.

Confirmation of aneuploid plants was done using root tip squashes and based on the average chromosome counts. Using rapid chromosome counting techniques, variation in chromosome count averages was about 1.5 chromosomes. Any plant with an average count falling outside that range was an aneuploid suspect and was re-examined.

Flow cytometry is the better method for finding and identifying aneuploid plants because of the speed of the procedure and the ability to examine large numbers of plants. A major drawback to ploidy identification using bulk plant samples is that bulk samples may mask the presence of aneuploid plants, whereupon they would probably be classified as tetraploids. For production seed testing, the industry requires bulk sampling to increase efficiency and speed, running up to sixteen or more samples per scan. In the current study, identifying an aneuploid amongst many euploids was not confidently possible with a bulk sample larger than eight plants. Due to this problem, only one of the three aneuploids in the current study was initially identified using flow cytometry. The other two were initially identified using root tip squashes and later confirmed with flow cytometry.

Though the main goal of the present study was to investigate testing alternatives to determine ploidy level, a determination of relative DNA amounts was also performed (Table 1). While an absolute value for DNA content could not be obtained because of the A-T bias of DAPI dye, for the purposes of ploidy determination in grass seed testing and intraspecific comparisons of relative DNA amounts, DAPI is a suitable choice. With the exception of one of the aneuploids (seed lot 170535), DNA content (and peak position) correlated well with the root tip counts and served well in further distinguishing aneuploidy.

Misclassification errors (i.e. where data indicates that a plant is of a certain ploidy level and is later shown to be of the other) differed depending on the technique. Including the detection of aneuploids, misclassification errors from root tip squashing occurred 1.1% of the time (4 out of 363 plants). Such mistakes may have occurred due to severe overlap of chromosomes, mislabeling, or investigator bias. In contrast, flow cytometry had a misclassification error rate of 0.3% (5 out of 1794 plants) due to erroneously cutting the leaf of a neighboring leaf for the bulk sample and large bulk samples obscuring aneuploids. The difference of 0.8% seems small, but it is highly important when attempting to make the 2% purity level for certification purposes.

Overall, flow cytometry was shown to be the superior technique for ploidy determination. Though the initial cost of a flow cytometer and accessories may seem daunting, the speed, accuracy, and efficiency of the method should more than pay for it in the long run. It can take months for a microscopist to become confident in performing root tip squashes and counts. Even an experienced researcher, counting the chromosomes of five cells per plant, can examine no more than 20 plants in a good day. Yet with less than a week of training, a previously untrained researcher, working alone, can confidently determine the ploidy level of over 400 plants in a good day.

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Table 1. DNA content of nine ryegrass seed lots as determined by flow cytometry.

Seed lot	Diploid		Tetraploid		Other		%number Diploids
	No. of plants	DNA content[†]	No. of plants	DNA content	No. of plants	DNA content	
		(pg)		(pg)		(pg)	(%)
Italian ryegrass							
172338	2	5.62	198	11.03	0	--	1.0
163303	0	--	200	11.13	0	--	0.0
165249	7	5.91	192	11.91	1	14.32	3.5
Intermediate ryegrass							
167773	51	5.51	148	11.18	1	16.69	25.5
154909	10	5.89	190	11.35	0	--	5.0
170535	13	5.87	186	11.26	1	10.11	6.5
Perennial ryegrass							
167258	0	--	200	11.39	0	--	0.0
172003	1	5.65	199	11.48	0	--	0.5
169515	0	--	194	11.35	0	--	0.0

[†]Calculated DNA content per cell estimated by method of Arumuganathan & Earle (1991), averaged over individual or bulk samples within a seed lot.

Table 2. Chromosome counts in root tips from plants in nine ryegrass seed lots.

Seed lot number	Diploid		Tetraploid		Other	
	No. of plants	Chromosome count	No. of plants	Chromosome count	No. of plants	Chromosome count
Italian ryegrass						
172338	2	14.2 ± 0.1	40	28.0 ± 0.1	0	- -
163303	0	- -	40	27.8 ± 0.1	0	- -
165249	6	14.8 ± 0.3	34	28.2 ± 0.2	†	- -
Intermediate ryegrass						
167773	15	14.3 ± 0.1	40	28.6 ± 0.2	1	30.9 ± 0.6
154909	7	14.6 ± 0.2	40	28.4 ± 0.2	0	- -
170535	10	14.3 ± 0.1	40	28.4 ± 0.1	1	30.9 ± 0.8
Perennial ryegrass						
167258	0	- -	40	28.4 ± 0.2	0	- -
172003	1	15.0 ± 0.5	40	28.6 ± 0.1	0	- -
169515	0	- -	40	28.0 ± 0.1	0	- -

†Individual died before root tip squashes could be performed.

LABORATORY TRIALS TO DETERMINE EFFICACY OF VARIOUS BAITS FOR SLUG CONTROL

G.C. Fisher, J.T. DeFrancesco and R.N. Horton

A laboratory trial was conducted to observe the response of the gray garden slug, *Deroceras reticulatum*, Mueller, to three molluscidal baits. Bait treatments consisted of GWN-1450 (2% methiocarb), CP Snail and Slug Bait® (1.75% thiodicarb), and Deadline Bullets® (4% metaldehyde). An untreated control was included for comparison.

Adult and large juvenile slugs were collected from a commercial field of perennial ryegrass and confined with lettuce for 48 hours. Food was then withheld for 48 hours prior to the onset of the experiment.

Slugs were confined in cages in the laboratory throughout the length of the trial. Cages consisted of plastic buckets (2.5-gallon capacity, 10-inch diameter) that were fitted with screened lids. Water-soaked paper towels placed on the bottom of each cage provided high relative humidity. In addition, a small plastic card, shaped into a tent, was put in each cage to provide shelter. Cages were kept indoors at ambient temperatures, which ranged from 36 to 66°F. Treatments were arranged in a completely randomized experimental design with five replicates. Each cage contained 15 live slugs at the time treatments were introduced.

Baits were applied at 1.0 gram of product per cage on May 18, 1998 and remained in the cages until termination of the trial on May 28, 1998. In addition to the baits, 2.25 grams of fresh carrot, cut into pieces and put on small plastic trays, were added to each cage on a daily basis. Every 24 hours the carrots were removed, oven-dried and weighed to determine consumption by the slugs.

Efficacy of the treatments was evaluated by two different methods: percent slug mortality and quantity of carrot consumed (indicating efficacy of bait as a feeding deterrent). Every 24 hours for 10 days, the numbers of dead slugs were recorded and removed from each cage. At the same time, carrot pieces were removed and replaced with 2.25 grams of fresh carrot pieces. The carrots were then oven-dried and weighed to determine the amount of dry weight consumption. Previous replicated testing and calculations revealed that 2.25 grams fresh carrots weigh 0.3 grams after being oven dried. This figure (0.3 grams) was used to determine amount of carrots consumed each day by the slugs remaining in the cages.

Results and Discussion:
1. Mortality

Statistically significant differences between treatments occurred on all evaluation dates, except the first day after treatments were applied (Table 1). Having no significant difference between treatments on Day 1 was not unexpected. A certain amount of time is needed for feeding and digestion before effects of bait are observed. GWN-1450 provided the quickest control; almost 50% mortality occurred by Day 4. In contrast, 50% mortality occurred on Day 6 for the Deadline Bullets® and on Day 7 for the CP Snail and Slug Bait®. GWN-1450 and Deadline Bullets® caused significant mortality, starting on Day 2, compared to the untreated control. CP Snail and Slug Bait® did not cause significant mortality until Day 6. All treatments were comparable to one another by Day 8. The untreated

control had 1.3% mortality by Day 3 and reached 8% mortality by Day10; cause of mortality in the untreated control was undetermined.

All baits absorbed water upon contact with the moist paper towel lining on the bottom of the cages. GWN-1450 bait did not swell appreciably but the CP Snail and Slug Bait® and the Deadline Bullets® swelled to at least twice their dehydrated size within minutes. Mold appeared on the Deadline Bullets® and CP Snail and Slug Bait® on Day 7; GWN-1450 bait remained free of mold throughout the trial period.

II. Carrot Consumption

Baits may protect plants due to slug mortality as well as through reduced plant consumption. After feeding on bait, slugs may cause less damage to the target crop. The untreated control had statistically significant more carrot consumption on Day 1 and Day 2 than did any of the bait treatments (Tables 2 and 3). Slugs had free choice to eat either baits or carrots and by the end of Day 1, it appears that they ate a little of both. Slugs apparently ate no carrots in any of the treatments during Day 2. Carrot consumption was variable in and between treatments from Day 3 through Day 10, being significantly greater in the untreated control only on Day 4 and Day 7 (Tables 2 and 3).

Table 1. Effect of baits on slug mortality in caged laboratory trial, 1998.

| Treatment | Percent mortality[1] | | | | | | | | | |
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10
					(%)					
GWN-1450	1.3	17.3 a[2]	37.3 a	49.3 a	58.7 a	73.3 a	77.3 a	77.3 a	77.3 a	78.7 a
CP S&S Bait	1.3	4.0 b	6.7 b	14.7 bc	17.3 bc	36.0 b	53.3 b	58.7 a	65.3 a	65.3 a
Deadline Bull.	2.7	13.3 a	25.3 a	32.0 ab	37.3 b	50.7 b	61.3 ab	64.0 a	70.7 a	77.3 a
Untreated	0.0	0.0 b	1.3 b	1.3 c	1.3 c	2.7 c	5.3 c	8.0 b	8.0 b	8.0 b

[1] Based on 0% at Day 0.
[2] Means followed by the same letter within a column do not differ significantly at P≤ 0.05; no letter indicates a non-significant ANOVA.

Table 2. Effect of baits on individual slug feeding (carrot pieces) in caged laboratory trial, 1998.

| Treatment | Amount of carrots consumed per day (mg)[1] | | | | | | | | | |
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10
					(mg/day)					
GWN-1450	1.38 a[2]	0.00 a	3.31	0.00	5.54	6.18	0.00	0.00	2.37	7.30
CP S&S Bait	3.43 a	0.00 a	2.97	0.67	2.21	5.51	2.83	5.00	11.52	0.00
Deadline Bul.	1.43 a	0.00 a	0.00	1.11	2.54	1.67	0.00	11.25	14.00	12.00
Untreated	9.33 b	6.67 b	3.33	3.43	4.71	2.00	3.53	2.25	2.15	1.48

[1] Dry weight
[2] Means followed by the same letter within a column do not differ significantly at P≤ 0.05; no letter indicates a non-significant ANOVA.

Table 3. Effect of baits on slug feeding (carrot pieces) in caged laboratory trial, 1998.

Treatment	Amount of carrots consumed per day (mg)[1]									
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10
	(mg/day)									
GWN-1450	20 a[2]	0 a	30 ab	0 a	40	20	0 a	0	10	30
CP S&S Bait	50 a	0 a	40 b	10 a	30	50	20 b	10	50	10
Deadline Bul.	20 a	0 a	0 a	10 a	20	10	0 a	20	30	20
Untreated	140 b	100 b	50 b	50 b	70	30	50 c	30	30	20

[1] Dry weight

[2] Means followed by the same letter within a column do not differ significantly at P≤ 0.05; no letter indicates a non-significant ANOVA.

SEASONAL DEVELOPMENT OF MEADOWFOAM FLY, *SCAPTOMYZA APICALIS* HARDY (DIPTERA: DROSOPHILIDAE) IN THE WILLAMETTE VALLEY

S. Panasahatham, G.C. Fisher,
J.T. DeFrancesco and D.T. Ehrensing

Abstract
Seasonal development of the meadowfoam fly (MFF) was studied in commercial meadowfoam fields in the Willamette Valley from December 1996 through June 1998. Numbers of adults caught at weekly intervals on yellow sticky cards defined flight peaks and seasonal occurrence of this insect. Larval populations in plants were monitored through the crop season with Berlese funnels.

Fly activity over the growing season was similar in both years. A small flight was detected on traps during the first two weeks of September 1997, about one month before meadowfoam fields were seeded. In both years flies were most numerous in early to mid March. Thereafter, numbers of flies trapped fluctuated within and between fields. The last flies were captured at the end of June.

No other host plants have been identified

Introduction
Meadowfoam, *Limnanthes alba* Hartweg ex. Bentham (Limnanthaceae) is native to northern California, southern Oregon and Vancouver Island, British Columbia. The unique long chain fatty acid oil in the seed is used in machine lubricants as well as by the cosmetic industry (Jolliff et al., 1981).

MFF is apparently the only insect that significantly damages meadowfoam in the Willamette Valley. Larvae tunnel into shoots, leaf petioles, stems and flower buds. Seed yield loss has been observed in both experimental plots and commercial fields heavily infested with MFF (Ehrensing et al. 1990).

Seasonal population trends of MFF in the commercial meadowfoam fields were described over two growing seasons from December 1996 to August 1998.

Materials and Methods
Larvae and their population levels were monitored monthly from seeding to harvest. Eight samples of ten plants each were randomly taken beginning in December from each of five fields in 1996-97 and three fields in 1997-98. Larvae were extracted from plants using Berlese funnels.

Eggs and puparia observed on plant samples were recorded. Yellow sticky traps were used to monitor adults through the season in each of the fields. Traps were placed in fields about one month before meadowfoam was seeded and monitored through harvest. Six traps were placed in each field at the height of one foot from the ground. Each week traps were replaced and numbers of flies were recorded.

Results
Overall, patterns of larval and adult populations were similar from field to field in both seasons. Larvae were first detected in meadowfoam samples in early January. Numbers increased sharply after mid February. Larval densities peaked between early and mid April. The greatest larval populations observed approached 25/crown in one field during April in 1998. Larval numbers declined as bloom increased through early June. No larvae were extracted from plant samples after full bloom (Figure 1).
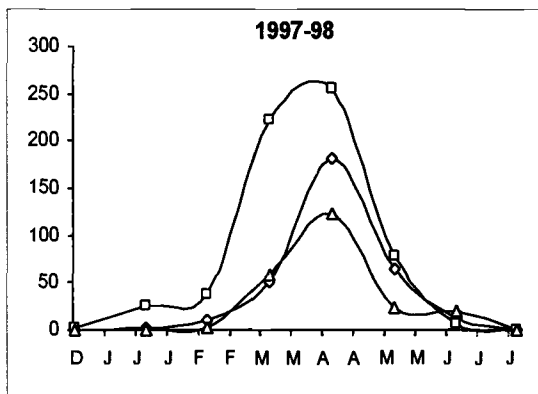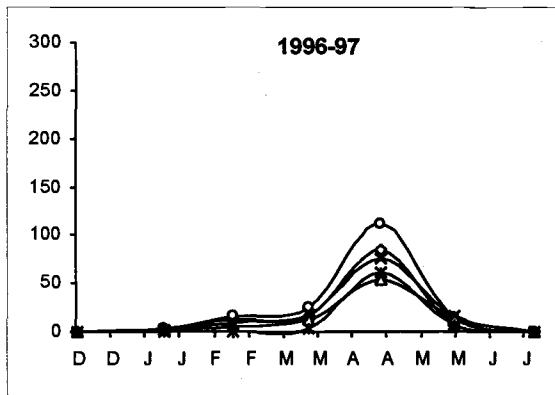
Figure 1. Averages larval densities (10 plants/sample, n=10) of *Scaptomyza apicalis* Hardy in five meadowfoam fields in 1996-97 and three fields in 1997-98 in the Willamette Valley, OR.

Larvae feed on above ground meristem tissue of the crowns and stems during the vegetative growth stage. Later, they tunnel into flower buds.

Brown puparia are usually attached to various plant structures on the lower half of the plants. A few puparia were found attached to dry stems after plants were harvested in late July 1998.

In 1997, the first fly was caught in early September well before meadowfoam was seeded. Small peaks occurred in the first half of September in every study sites following the first rains of late summers. Numbers declined through mid January. Populations increased rapidly in late January and peaked in March. Populations fluctuated widely and gradually declined when plants bloomed (Figure 2). The last flies were caught in late June of both years.
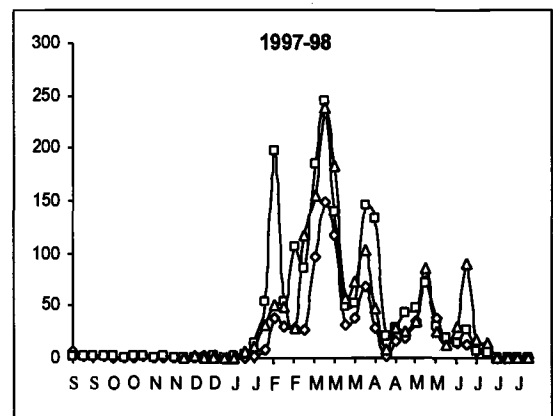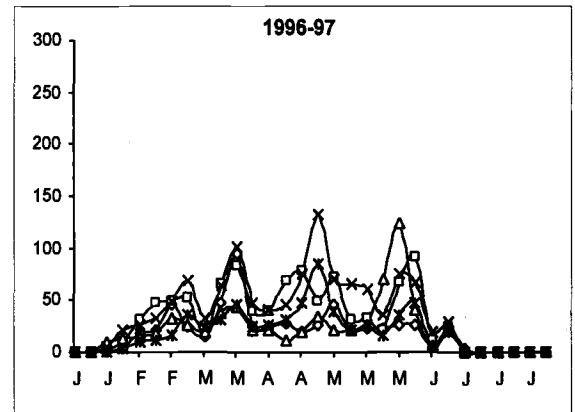
Figure 2. Average of adult *Scaptomyza apicalis* Hardy on yellow sticky traps (n=6) in five commercial meadowfoam fields in 1996-97 and three fields in 1997-98 in the Willamette Valley, OR.

Adults appear to remain in meadowfoam fields throughout their lives, seemingly quite dependent on free moisture on plants or the soil surface. They readily fly short distances on calm, warm days but are rather inactive under the canopy or on the ground on cold, cloudy days. Females did not seem to have a preferred oviposition site on meadowfoam during plant vegetative growth. However, most eggs were deposited on or near flower buds later in the season.

To date, natural biological controls have not been found.

Discussion

Meadowfoam fly occurs in all meadowfoam fields in the Willamette Valley. Egg laying flies are present at plant emergence in September, but at low numbers. Flies became abundant beginning in January. Larval populations build up in the late winter through spring and are capable of reducing plant stands, bloom and seed yield.

Meadowfoam (*Limnanthes* spp.) appears to be the only host for meadowfoam fly. Biological controls are glaringly absent. Surveys of native *Limnanthes* populations are being conducted for MFF and natural enemies. The hope is to identify and release effective biological controls into the Willamette Valley correlated from native populations of *Limnanthes* infested with MFF. Until then, growers may control meadowfoam fly with dimethoate insecticide (OR 24c) in late winter. A spray should be applied when daily fly catches on yellow sticky traps average 3 to 5 per trap.

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EFFECTS OF NITROGEN FERTILIZER RATES AND INSECTICIDE USE ON MEADOWFOAM TO CONTROL THE MEADOWFOAM FLY, *SCAPTOMYZA APICALIS* HARDY

S. Panasahatham, G.C. Fisher,
J.T. DeFrancesco and D.T. Ehrensing

Abstract

Relationships of nitrogen fertilizer and insecticide treatment on larval density of *Scaptomyza apicalis* Hardy, flower production, seed set, and seed yield of meadowfoam, *Limnanthes alba* (cv. Floral) were evaluated from September 1997 to August 1998. Combinations of five levels of urea (0, 20, 40, 60 and 80 lb/a, applied once in late February) and two levels of oxydemeton-methyl insecticide at 0.5 lb a.i./a, monthly intervals from February to May, versus no insecticide treatment were arranged in a randomized complete block design with four replications. Larval densities of each treatment were monitored at monthly intervals throughout the experimental period. Flight activity of meadowfoam fly (MFF) was monitored at weekly basis by using yellow sticky traps from October 1997 to September 1998. Flower production of meadowfoam was determined by counting flowers and opening buds in 0.1 m² portion of each plot at full bloom. Mean number of seeds set per flower were determined two weeks

prior to harvest. The final seed yields were obtained by harvesting and cleaning seed from each plot with a small plot harvester. Results showed that effects of fertilizer and insecticide were independent of each other in regard to larval density, flower density and seed set. Interaction was detected for seed yield. N fertilization increased larval density, but reduced flower density and seed yield. Insecticide application significantly reduced larval densities, but flower densities, and seed set were not statistically different from unsprayed plots. Any application rate of nitrogen fertilizer tended to reduce seed yields in plots unsprayed with insecticide. Interestingly, seed yield was only increased substantially with insecticide use in the plots receiving N at 20 lb/a. Larval density was not correlated with flower density and seed yield. However, flower density was positively correlated with seed yield ($r = 0.52, p = 0.01, n = 40$).

Introduction

The meadowfoam fly (MFF), *Scaptomyza apicalis* Hardy (F. Drosophilidae) is thus far the only insect pest of significance on meadowfoam. Larval feeding damages both vegetative and reproductive tissues of meadowfoam, *Limnanthes alba* Hartweg ex. Bentham. Early season injury results from large numbers of larvae feeding on and damaging crown tissue. Young plants die in the heavily infestations. Other plants display symptoms including severe stunting, loss of vigor and reduced flower production. Later season damage results in destroyed stems and flower buds. Significant loss of seed in experimental plots damaged by MFF have been reported (Fiez, et al., 1991 and Jolliff, et al., 1981). Up to 50% loss of seed yield is suspected in fields heavily infested with MFF (Ehrensing et al., 1990).

Rate of nitrogen fertilizer has been suspected to directly correlate with insect damage on meadowfoam. Higher infestation rates with correspondingly lower seed yields were observed in plots and fields with highest nitrogen rates. Jolliff et al. (1993) raised concern about effects of nitrogen fertilizer use on meadowfoam and fly damage. Nitrogen fertilizer applications elevate plant tissue N content, which in turn attracts greater numbers of insect in many plants (Harbaugh et al., 1983). Hart and Young (1986) reported plant tissue N concentrations from 1.5 to 1.7 gm/kg at bloom of meadowfoam (cv. Mermaid) were associated with greatest yields. Concentrations from 1.2 to 1.4 gm/kg were associated with lower yields. Concentrations above 1.8 gm/kg were generally associated with lowest yields.

The objectives of this experiment were to determine the effects of MFF damage on meadowfoam with different nitrogen fertilizer rates and with and without insecticide applications plots on infestation levels of MFF and seed yield.

Materials and Methods

The experiment was conducted on meadowfoam (cv. Floral) at Oregon State University's Hyslop Farm near Corvallis from September 1997 to August 1998. Meadowfoam was seeded at 30-35 lb/a with 6" row spacing

in early October. Combinations of five levels of 46-0-0 nitrogen fertilizer (0, 20, 40,60 and 80 lb/a) with and without oxydemeton-methyl insecticide (Methasystox-R 2EC) applications to plots were arranged in a randomized complete block design with four replications on 9 ft by 20 ft plots. Nitrogen fertilizer was topdressed to the appropriate plots in late February. Insecticide was applied at 0.5 lb. ai/a at monthly intervals from late February to May. Honeybees were placed adjacent to fields at approximately five hives per acre at 20% bloom.

Nine yellow sticky traps were placed throughout the study site to monitor fly activity from September 1997 to July 1998. Numbers of flies trapped were observed and recorded weekly. Larval densities were obtained from plant samples at monthly intervals. Samples of 5 plants each were taken from each plot a week after each insecticide application from February to May 1998. Larvae were extracted from plants using Berlese funnels. Data from the four collection dates were pooled for statistical analysis. Flower density at full bloom and seeds set per flower two weeks before harvesting were recorded in a 0.1 m^2 portion of each plot. Seed was harvested on July 12, 1998 and soon cleaned and weighed. Each data set was analyzed by two-way ANOVA with FPLSD values used for mean separations. Then, a two-way factorial was used in order to partition fertilizer and insecticide main effects and interactions. Correlation analysis on larval densities, flower densities and seed yields were performed.

Results and Discussion

The effects of nitrogen fertilizer and insecticide applications on larval density, flower density, and seed set were independent of one another (Table 1). However, interactions occurred in seed yields (Table 1). Even though insecticide applications reduced larval density by 54% (Figure 1), they had no effect on meadowfoam flower density, or seed set per flower (Table 3 and Figure 3). Increasing rates of N fertilization were positively associated with increasing larval densities. However they decreased flower density and seed yield (Table 3, Figure 3 and Figure 4). Seeds set/flower was unaffected by N rate. (Table 4). In unsprayed plots, larval density in 80 lb/a N fertilizer was 28% higher than the unfertilized plots (Figure 1). Flower density and seed yield of fertilized plots were lower than unfertilized plots, up to 61 and 16%, respectively (Table 3, Figure 3 and Figure 4). Average seed set ranged from 2.11 to 2.66 seed/flower in all plots. No significant differences were observed between or among treatments (Table 4). Interaction of nitrogen fertilizer and insecticide was significant as judged by seed yield. Plots with fertilizer generally produced less seed than plots without fertilizer. Insecticide applications increased seed yield in fertilized plots over unfertilized plots for only one N rate, 20 lb/a. Larval density was not correlated with meadowfoam flower density and seed yield (Table 2). But flower density and seed yield were correlated ($r = 0.52$, $p = 0.01$, n = 40) (Table 2).
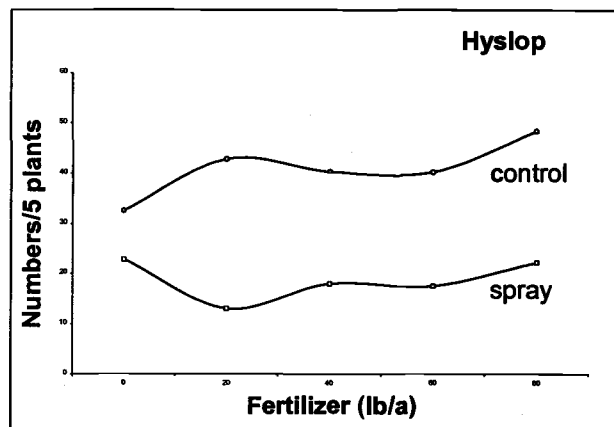

Figure 1. Average larval densities of *Scaptomyza apicalis* Hardy in plots with different nitrogen fertilizer rates and insecticide treatments at Hyslop Farm from February to May 1998 (5 plants/sample, n=4).

Table 1. Analysis of variance for main effects and treatment interactions of nitrogen fertilizer rate and insecticide application effects on *Scaptomyza apicalis* Hardy larval density, meadowfoam (cv. Floral) flower density, seed set and seed yield at Hyslop Farm of crop year 1997-98.

Treatments	Larval density	Flower density	Seed set/ flower	Seed yield
	(no./5 plants)	(0.1 m^2)	(0.1 m^2)	(lb/a)
Fertilizer rates	**	**	NS	**
Insecticide	**	NS	NS	NS
Interactions	NS	NS	NS	**

**, NS = significantly different at $p = 0.01$, and not significantly different, respectively.
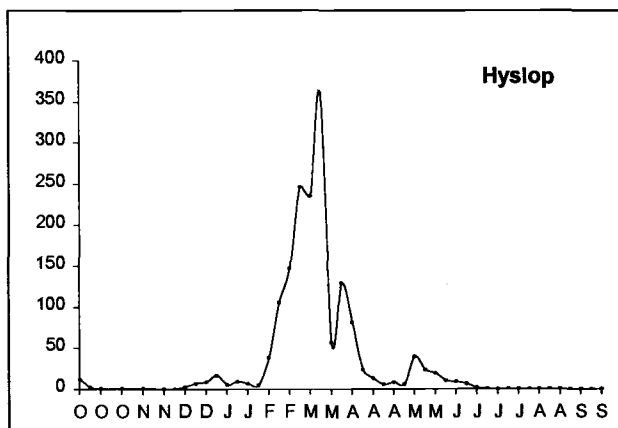
49

Figure 2. Average numbers of *Scaptomyza apicalis* Hardy flies collected at weekly intervals on yellow sticky traps (n=9) at Hyslop Farm from October 1997 through September 1998.

Table 2. Correlation among larval density of *Scaptomyza apicalis* Hardy, flower density and seed yield of meadowfoam (cv. Floral) at Hyslop Farm of crop year 1997-98.

	Flower density	Seed yield
	(*r*)	(*r*)
Larval density	-0.2230 (NS)	-0.0085 (NS)
Flower density		0.5231 (**)

**, NS = significantly different at p = 0.01, and not significantly different, respectively.

Table 3. Mean flower density and seed yield of meadowfoam (cv. Floral) in plots of different N fertilizer rates and with and without insecticide (oxydemeton-methyl) collected at Hyslop Farm of 1997-98.

Treatments[1]	Flower density	Seed yield
(Fertilizer/Insecticide)	(no./0.1 m^2)	(lb/a)
0	1,264 ab^2	661 a
0/IA	1,351 a	617 ab
20	998 bc	585 b
20/IA	1,136 abc	651 a
40	860 c	602 ab
40/IA	928 c	622 ab
60	907 c	589 b
60/IA	909 c	575 b
80	457 d	581 b
80/IA	545 d	489 c

[1] = Fertilizer (lb/a)/ Insecticide applied (IA) at 0.5 lb/a, monthly interval.
[2] = Means with the same letter are not significantly different (ANOVA-LSD, p = 0.01, n = 4).

Flight activity was generally greatest from February through May. There were four possible peaks. The highest peak was detected in early March (Figure 2). A small peak was detected in October, prior to seedling emergence. Flight activity and larval density gradually decreased as bloom progressed (Figure 1 and Figure 2).
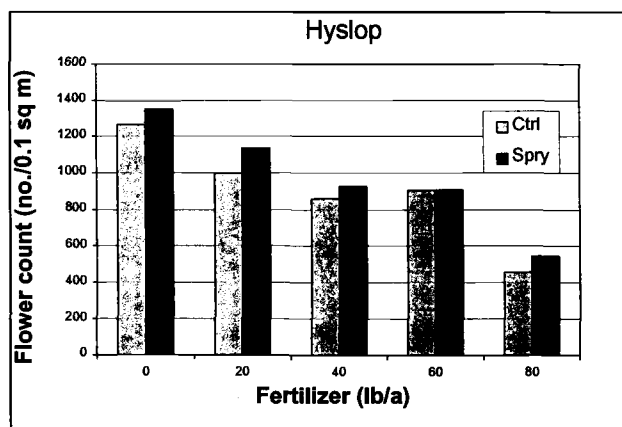

Figure 3. Mean flower density of meadowfoam, *Limnanthes alba* (cv. Floral) in plots of different fertilizer rates, with and without insecticide sprays collected from 0.1 m^2 at Hyslop Farm of 1997-98.
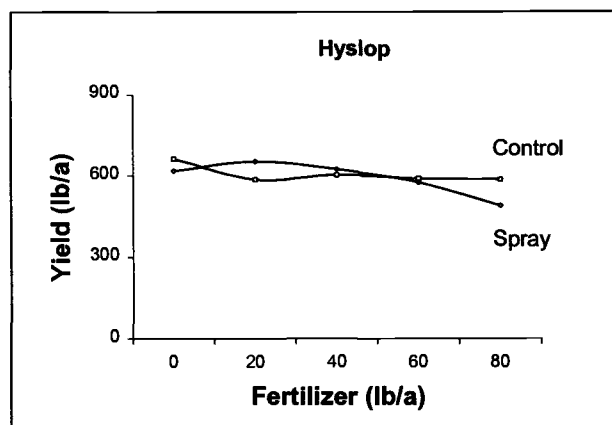

Figure 4. Mean yield of meadowfoam, *Limnanthes alba* (cv. Floral) in plots of different fertilizer rates, with and without insecticide sprays at Hyslop Farm of 1997-98.

Conclusion

Meadowfoam is sensitive to excessive nitrogen fertilization. Treatments with increasing nitrogen rates showed detrimental effects on all yield components. Lodging from excessive nitrogen application (as reported in Mermaid cultivar) was not observed in this experiment. Stands with higher nitrogen rates were distinctively thinner with plants possessing fewer branches than those of the lower rates. Fertilization rates beyond 0 lb/a generally decreased seed yield, except in the 20 lb/a with insecticide application. The significant increase in fly infestations at higher nitrogen rates suggests this insect was preferentially attracted to plants high in N content. Given that seeds set per flower in all treatments were not significantly different suggested that the odd of being pollinated were probably about equal in flowers of different treatments. Interestingly, the use of multiple sprays prior to bloom actually decreased yields in fertilized plots. This suggests that suppression of insect infestation by insecticide did not overcome effects of excessive N application. Moreover, the combination effects of fertilizer and insecticide accelerated the reduction of seed yield. The inverse relationship between nitrogen fertilizer rate and seed yield agrees with previous reports (Jolliff, et al., 1993). However, seeds set/flower was unaffected by nitrogen rate or insecticide.

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Table 4. Distribution and percentages of the seeds set per flower of different fertilizer rates and insecticide treatments on meadowfoam, *Limnanthes alba* (cv. Floral) collected at Hyslop Farm on June 28, 1998.

Treatments[1]	Distribution of seeds set/flower							Average[2] (seed/flower)
	0	1	2	3	4	5	> 5	
	--(%)---							
0	11.16	13.97	18.60	21.32	24.38	10.41	0.16	2.6570
0/IA	18.89	14.48	13.80	18.67	15.61	18.44	0.11	2.5339
20	13.99	16.65	15.08	12.78	26.66	14.84	0.00	2.6598
20/IA	17.68	21.17	14.86	17.57	17.12	11.60	0.00	2.3007
40	20.03	15.18	16.23	14.53	21.33	12.70	0.00	2.4005
40/IA	13.87	15.31	20.10	22.37	19.98	8.25	0.12	2.4450
60	16.94	13.58	17.66	20.73	18.10	12.99	0.00	2.4847
60/IA	14.99	21.48	15.52	18.97	17.90	11.14	0.00	2.3675
80	15.97	14.93	22.05	14.24	18.05	14.76	0.00	2.4774
80/IA	21.22	16.56	21.22	19.29	14.31	7.40	0.00	2.1109
								NS

[1] = Fertilizer (lb/a)/Insecticide application (IA) at 0.5 ib/a, monthly interval.
[2] = (n = 4).

CONTROL OF *SCAPTOMYZA* FLY IN MEADOWFOAM WITH INSECTICIDES

G.C. Fisher and J.T. DeFrancesco

The *Scaptomyza* fly is an insect pest found in commercial meadowfoam fields throughout the Willamette Valley. This Pomace Fly is in the Drosophilidae family and has been tentatively identified as *Scaptomyza apicalis* Hardy, with the unofficial common name of the Meadowfoam fly. Larval infestations have caused extensive damage to plant crowns and flower buds in some fields. This fly appears to have at least two generations per year in commercial meadowfoam of Western Oregon. We have targeted late winter as an opportune time to apply sprays; populations of the fly begin to build at this time.

A trial was established at Hyslop Research Farm in 1998 to evaluate the effect of various insecticides and time of application for larval control, flower density and seed yield. Treatments included bifenthrin (Capture 2EC®) at 0.1 lb a.i./a, dimethoate (Dimethoate 400®) at 0.5 lb a.i./a, imidacloprid (Provado 1.6E®) at 0.31 lb ai/a, and oxydemeton-methyl (Metasystox-R®) at 0.5 lb a.i/a applied on 1/10/98, 2/15/98 or on both dates. Treatments were applied with a CO_2 backpack sprayer, equipped with a 3-nozzle boom (tips = 8002 flat fan), at 40 psi in 30 to 40 gallons of water per acre.

Numbers of larvae per plant were determined by randomly cutting at the soil line five plants per plot on 3/13/98. Larvae were extracted from plants over a four day period using Burlese funnels. Flower counts were made on 5/15/98 in each plot. Flowers and viable floral buds were recorded from a 0.5 ft² area in each plot. Plots were harvested on 7/13/98; seed was cleaned and weighed.

Results and Discussion:

Bifenthrin, a synthetic pyrethroid, gave the greatest reduction in meadowfoam fly larvae and produced the most uninjured flowers and flower buds (Table 1). Plant vigor in the bifenthrin plots was good, as judged by overall growth and canopy height; bloom was quite uniform.

Larval populations within the trial area were quite low for all treatments when evaluated in mid-March (<2.5 larvae per crown in the more heavily infested plots). Seed yield for all treatments, even the untreated control, were not significantly different from one another. The trend, however, was for greater seed yield in sprayed plots.

In 1999, bifenthrin will be further evaluated in relation to timing and number of spray applications. An EUP (Experimental Use Permit), will allow performance evaluation on larger blocks in commercial fields of meadowfoam.

Table 1. Effect of insecticides on *Scaptomyza* fly population, flower density, and seed yield in meadowfoam, Hyslop Research Farm, 1998.

Treatment	Application date	No. larvae per plant[1]	Percent control[2]	Number of flowers	Seed yield[4]
			(%)	(no./0.5 sq. ft.)	(lb/a)
Imidacloprid	1/10/98	1.8	0	326 a[3]	492.5
Metasystox-R	1/10/98	1.0	41	306 a	610.1
Dimethoate 400	1/10/98	2.4	0	396 a	595.5
Bifenthrin	1/10/98	1.3	24	326 a	634.1
Imidacloprid	2/15/98	1.3	24	348 a	471.0
Metasystox-R	2/15/98	1.5	12	376 a	617.0
Dimethoate 400	2/15/98	1.8	0	302 a	586.3
Bifenthrin	2/15/98	0.25	88	560 b	559.4
Imidacloprid	1/10/98 & 2/15/98	2.2	0	331 a	597.0
Metasystox-R	1/10/98 & 2/15/98	1.0	39	415 a	564.0
Dimethoate 400	1/10/98 & 2/15/98	1.4	15	380 a	648.5
Bifenthrin	1/10/98 & 2/15/98	0	100	614 b	640.8
Untreated Control	- - - -	1.7	- - - -	296 a	500.9

[1] Average of 5 plants per plot, 3/13/98

[2] Percent control is the population reduction when compared to the untreated check.

[3] Means within a column followed by the same letter do not differ significantly at P≤ 0.05; no letter indicates a non-significant ANOVA

[4] Cleaned seed weight

NUTRIENT UPTAKE FOR ROUGH BLUEGRASS, 1998

M.D. Butler, J.M. Hart and N.A. Farris

Rough bluegrass (*Poa trivialis*) was first grown in central Oregon in the mid-1970s. The crop consisted of the single cultivar, 'Saber', with relatively few acres until the mid-1980s. Since then, new varieties, which include 'Laser', 'Cypress', and 'Saber II' were introduced. Plantings steadily increased to approximately 5,300 acres in 1998. Cultural practices for rough bluegrass are substantially different from Kentucky bluegrass. Rough bluegrass is a shallow-rooted crop with a high water requirement. As harvest nears, growers maintain high moisture levels to cause the crop to lodge and keep the heads moist to reduce shatter and seed loss.

This research project was initiated to determine the nutrient uptake for rough bluegrass that would be used to assist growers in determining rate and timing of fertilizer applications to maximize their economic return. The 1998 growing season was the second year of a multi-year project conducted on commercial fields at two locations north of Madras, Oregon. Second year fields of the cultivars 'Cypress' and 'Saber II' were chosen for the study. The 'Cypress' location was fairly sandy soil with sprinkler irrigation, while the 'Saber II' location was on loamy soil using furrow irrigation. Row spacing at both locations was 15 inches apart.

Aboveground plant biomass samples were collected bi-weekly from April 16 to June 23. Two feet of two adjacent rows from three predetermined locations per field were clipped, dried, and weighed. A subsample was taken for analyses of nutrient content. The concentration of N, P, K, and S are given in Table 1.

Table 1. Aboveground plant biomass accumulation and nutrient concentration for Saber II and Cypress rough bluegrass, 1998.

Sampling Date	Biomass	N	P	K	S
	(lb/a)			(%)	
Saber II					
April 16	2715	4.67	0.44	2.97	0.33
April 29	2642	4.63	0.52	3.39	0.39
May 13	4491	2.77	0.41	3.12	0.29
May 26	7709	1.97	0.34	2.52	0.21
June 9	8700	1.51	0.27	2.21	0.19
June 23	12024	1.61	0.26	1.78	0.21
Cypress					
April 16	2706	4.63	0.47	2.95	0.37
April 29	3190	3.83	0.48	3.42	0.35
May 13	4387	2.49	0.41	2.74	0.24
May 26	7394	2.28	0.35	2.39	0.23
June 9	7946	1.82	0.31	1.78	0.19
June 23	7999	1.87	0.29	1.46	0.18

Nutrient concentration decreased as plant biomass increased. Concentration of N, P, K, and S was similar for both sites early in the growing season and at harvest. Biomass was the similar for both sites at the initial sampling date, but the site planted with the cultivar Saber II produced approximately 25% more biomass than the site planted with the cultivar Cypress. A biomass of 4 to 6 tons per acre at harvest is comparable to many other species of grass grown for seed.

Table 2. Nutrient uptake for Saber II and Cypress rough bluegrass, 1998.

Sampling date	N	P	K	S
	----------------- (lb/a) -------------------			
Saber II				
April 16	125	12	80	9
April 29	118	13	86	9
May 13	150	19	141	14
May 26	164	27	204	17
June 9	147	27	208	17
June 23	187	30	222	22
Cypress				
April 16	123	12	76	10
April 29	126	15	104	11
May 13	120	19	127	12
May 26	181	28	188	18
June 9	146	24	153	15
June 23	163	25	128	16

Nitrogen uptake at both sites was surprisingly high at the first sampling date (Table 2). More than two-thirds of the N was in the aboveground biomass when less than 25% of the biomass was accumulated. The early accumulation of N is important to growers. They should consider having most, if not all, fertilizer N applied by early April if the growth in 1998 is typical of most years. Applications in May and June are likely not an effective influence on yield.

Nitrogen accumulation in the aboveground biomass was between 150 and 200 lb/a. Last year's report contained an error when an amount of 300 lb/a was reported. When the error was corrected, N accumulation for both years was between 100 and 200 lb N/a.

Potassium accumulation was similar in amount to N, 150 to 225 lb/a, but occurred later than N accumulation. Accumulation of P and S were similar, between 15 and 25 lb/a. In contrast to the early accumulation of N, accumulation of P, K, and S did not reach near maximum until late May.

EVALUATION OF FUNGICIDES FOR POWDERY MILDEW AND STRIPE RUST CONTROL IN KENTUCKY BLUEGRASS IN CENTRAL OREGON, 1998

M.D. Butler, N.A. Farris and R.J. Burr

Kentucky bluegrass remains a valuable component of the agricultural industry in central Oregon despite acreage declined to 5,400 acres in 1998 as acres of rough bluegrass has increased to 5,300. The level of powdery mildew and stripe rust infection is dependent on weather conditions in the spring. Powdery mildew (*Erysiphe graminis*) typically appears earlier in the spring when temperatures are between 60 and 70°F under humid conditions. The appearance of stripe rust (*Puccinia striiformis*) usually follows powdery mildew during late spring when temperatures have increased and free moisture is available.

Several new fungicides are expected to be available which may have activity on powdery mildew and stripe rust. The objective of this research was to evaluate these new products against those historically used on Kentucky bluegrass in central Oregon.

Plots 10 ft x 22 ft were replicated four times in a randomized complete block design. Treatments were applied with a CO_2-pressurized, hand-held boom sprayer at 40 psi and 20 gal/a water. TwinJet 8002 nozzles were used to improve fungicide coverage. Silwet at 1 qt/100 gal was applied with all treatments. Plots were evaluated pre- and post-treatment using a rating scale of 0 (no symptoms) to 5 (total coverage).

Two fungicide evaluations for powdery mildew control in Kentucky bluegrass were conducted in a commercial 'Geronimo' field near Madras, Oregon. Tilt at 4 fl oz/a, Tilt at 4 fl oz/a plus Microthiol at 2 lb/a, Folicur at 4 fl oz/a, Bayleton at 4 fl oz/a, Quadris at 6 and 12 fl oz/a, and Microthiol at 5 lb/a were applied to the first set of plots April 17, 1998. Plots were evaluated prior to treatment April 16, and following treatment on April 28, May 5 and May 14.

The second set of plots for powder mildew control were conducted in the same commercial field adjacent to the first set of plots. Fungicide applied May 22 were Tilt at 4 fl oz/a, Stratego at 10 fl oz/a, Folicur at 4 fl oz/a, Quadris at 12 fl oz/a, Flint at 2.75 oz/a and BAS 500 00 F at 9 fl oz/a. Plots were evaluated prior to treatment May 21, and following treatment on June 11, June 17, and June 25.

Fungicide evaluations for stripe rust were conducted in a 'Sodnet' Kentucky bluegrass field at the Central Oregon Agricultural Research Center, Madras location. Fungicides were applied on May 28. Treatments were the same as the second powdery mildew trail. Plots were evaluated prior to treatment May 28 and following treatment on June 9, June 16, and June 25.

The effect of fungicides on the level of powdery mildew is provided in Table 1 for the early trial, and Table 2 for the later trial. In the first trial Tilt in combination with Microthiol provided the best control, followed by Tilt alone, Bayleton, Microthiol, and Folicur. Quadris did not reduce powdery mildew at either rate.

In the second powdery mildew trial the best control was provided by Rally, followed by Flint. Treatments of the other fungicides including Stratego, did not significantly reduce the level of disease compared to the untreated plots.

At the time of the second trial, disease levels were quite advanced and plant growth was substantial, making good fungicide coverage more difficult.

The effect of fungicides on the level of stripe rust is provided in Table 3. Stripe rust was significantly reduced by the numbered compound BAS 500 00 F, Stratego, Tilt, and Flint. Fungicides were applied when disease levels were already quite high, rather than as a preventive treatment.

Table 1. Severity of powdery mildew on Kentucky bluegrass near Madras, Oregon following fungicide application April 17, 1998 using a rating scale of 0 (no disease) to 5 (leaves totally covered).

Treatments[2]	Rate	Powdery mildew severity			
		Pre-treat. 4/16/98	Post-treat. 4/28/98	Post-treat. 5/5/98	Post-treat. 5/14/98
	(product/a)	-----------------------------------(0-5)[1]-----------------------------------			
Tilt	4 oz	2.9	1.3 c[3]	0.8 cd	1.1 b
Tilt	4 oz				
+ Microthiol	2 lb	2.6	1.6 c	0.6 d	0.7 c
Folicur	4 oz	2.6	1.7 bc	1.3 bc	1.4 b
Bayleton	4 oz	2.3	1.3 c	0.7 d	1.2 b
Quadris	6 oz	2.6	2.4 ab	2.6 a	2.6 a
Quadris	12 oz	2.7	2.3 ab	2.4 a	2.4 a
Microthiol	5 lb	2.7	1.8 bc	1.6 b	1.3 b
Untreated	---	2.6	2.8 a	2.8 a	2.5 a
		NS			

[1]Rating scale was 0-5, with 0 = no mildew and 5 = the leaves completely covered.
[2]Treatments applied with 1 qt/100 gal Silwet.
[3]Mean separation with Student-Newman-Keuls Test at $P \leq 0.05$.

Table 2. Severity of powdery mildew on Kentucky bluegrass near Madras, Oregon following fungicide application May 22, 1998 using a rating scale of 0 (no disease) to 5 (leaves totally covered).

Treatments[2]	Rate	Powdery mildew severity			
		Pre-treat. 5/21/98	Post-treat. 6/11/98	Post-treat. 6/17/98	Post-treat. 6/25/98
	(product/a)	---(0-5)[1]---			
Tilt	4 oz	2.5	2.4	1.9 ab[3]	2.3 ab
Flint	10 oz	2.2	2.2	2.4 a	2.2 ab
CGA-279202	2.75 oz	2.3	2.5	2.5 a	2 b
Folicur	4 oz	2.2	2.1	2.5 a	2.1 ab
Quadris	12 oz	2.3	2.6	2.5 a	2.4 ab
BAS 500 00F	9 oz	2.4	2.6	2.5 a	2.5 a
Rally	6 oz	2.2	2.2	1.7 b	1.6 c
Untreated	---	2.2	2.5	2.5 a	2.5 a
		NS	NS		

[1]Rating scale was 0-5, with 0 = no mildew and 5 = the leaves completely covered.
[2]Treatments applied with 1 qt/100 gal Silwet.
[3]Mean separation with Student-Newman-Keuls Test at $P \leq 0.05$.

Table 3. Severity of stripe rust on Kentucky bluegrass near Madras, Oregon following fungicide application May 28, 1998 using a rating scale of 0 (no disease) to 5 (leaves totally covered).

Treatments[2]	Rate	Stripe rust severity			
		Pre-treat. 5/28/98	Post-treat. 6/9/98	Post-treat. 6/16/98	Post-treat. 6/25/98
	(product/a)	---(0-5)[1]---			
Tilt	4 oz	2.6 ab	2.7	2.4	1.7 bc
Stratego	10 oz	3.2 a	3.0	2.2	1.5 c
Flint	2.75 oz	2.8 ab	3.0	2.5	1.7 bc
Folicur	4 oz	2.9 ab	3.0	2.7	2.1 ab
Quadris	12 oz	2.6 ab	2.9	2.5	1.8 abc
BAS 500 00F	9 oz	3.0 ab	3.0	2.4	1.5 c
Rally	6 oz	2.9 ab	3.2	2.5	2.1 ab
Untreated	---	2.5 b	3.2	2.7	2.3 a
		NS	NS		

[1]Rating scale was 0-5, with 0 = no rust and 5 = the leaves completely covered.
[2]Treatments applied with 1 qt/100 gal Silwet.
[3]Mean separation with Student-Newman-Keuls Test at $P \leq 0.05$.

EVALUATION OF FUNGICIDES FOR CONTROL OF ERGOT IN KENTUCKY BLUEGRASS, 1998

M.D. Butler, N.A. Farris, S.C. Alderman and F.J. Crowe

Ergot, caused by the fungus *Claviceps purpurea*, is an important flower-infecting pathogen in grass seed production regions of the Pacific Northwest. Of the grass species grown for seed in Oregon, Kentucky bluegrass is particularly affected by ergot. Traditional control has been through open field burning, which has partially suppressed the disease.

Previous fungicide evaluations in central Oregon during 1992 to 1997 indicate excellent ergot control with Punch, for which there are no plans for registration in the United States. Tilt and Folicur have provided suppression of ergot. As a result of this research, and similar fungicide evaluations by William Johnston at Washington State University, ergot suppression was added to the Tilt label in 1995 through a Special Local Need 24(c) registration. Folicur was recently registered for use on grass seed as well.

During the 1998 season fungicides evaluated for control of ergot were conducted on 'Coventry' Kentucky bluegrass at the Central Oregon Agricultural Research Center, Powell Butte location. The plot area was infested with ergot at 1 sclerotia/ft^2 on March 12. Sclerotia were place in a freezer for 2 weeks to break dormancy prior to distribution. Single and double applications of Tilt, Folicur, Quadris, Stratego, Flint, BAS 500 00F, and Rally were evaluated during the 1998 season. Fungicides were applied at the following rates, Tilt at 6 oz/a, Folicur at 6 oz/a, Quadris at 12 oz/a, Stratego at 10 oz/a, Flint at 2.75 oz/a, BAS 500 00F at 9 oz/a and Rally at 6 oz/a.

Plots 10 ft x 20 ft were replicated four times in a randomized complete block design. Materials were applied using a 9-foot CO_2 pressurized boom sprayer with TwinJet 8002 nozzles at 40 psi and 20 gal/a water. Silwet at 1 qt/100 gal was applied in combination with all fungicides. Treatments were applied on June 12 and June 23, 1998. The first treatments were applied at the initiation of anthesis, followed by the second 11 days later.

One hundred panicle samples were randomly collected from each plot on July 15. Number of panicles with sclerotia, total sclerotia per sample, seed weight, and percent germination was determined for each plot.

Disease levels were moderate, with an average of 3 sclerotia per panicle in the untreated plots (Table 1). There were no significant differences between treatments at the 95 percent confidence level. The trend, however, indicates that fungicides applied twice generally provided greater disease control than single treatments. This is supported by earlier studies. Quadris applied twice at 12 oz/a was associated with the lowest number of infected panicles and lowest total number of sclerotia. Seed germination appeared to be reduced following two applications of Folicur. This is supported by earlier studies where germination has been significantly reduced following Folicur treatments. Although sample weight was lowest for the double Quadris treatments, a reduction in seed weight following application of Quadris is not supported by 1997 data.

Table 1. Evaluation of fungicides applied for ergot control to 'Coventry' Kentucky bluegrass at the Central Oregon Agricultural Research Center, Powell Butte, OR, 1998.

Fungicide treatments	Rate of product June 6	June 23	Infected panicles	Total sclerotia	Sample weight	1000 seed weight	Seed germination
	----------(fl oz/a)---------		---(no./100 panicles)---		------- (grams)------		(%)
Tilt[1]	6 oz		50	193	6.2	0.40	77
Tilt	6 oz	6 oz	40	94	6.8	0.38	84
Folicur	6 oz		50	223	6.2	0.37	73
Folicur	6 oz	6 oz	37	122	6.6	0.37	61
Quadris	12 oz		57	174	6.4	0.40	84
Quadris	12 oz	12 oz	33	58	6.0	0.37	80
Stratego	10 oz		53	199	6.7	0.38	72
Stratego	10 oz	10 oz	55	199	6.7	0.40	75
Flint	2.75 oz		56	193	6.4	0.38	73
Flint	2.75 oz	2.75 oz	54	181	6.4	0.39	82
BAS 500 00F	9oz		48	148	6.8	0.38	73
BAS 500 00F	9 oz	9 oz	46	114	6.4	0.39	68
Rally	6oz		69	336	6.3	0.41	85
Rally	6 oz	6 oz	48	137	6.4	0.38	85
Untreated	---		56	299	7.2	0.40	82
			NS[2]	NS	NS	NS	NS

[1] Silwet at 1 qt/100 gal applied with all fungicides
[2] There were no significant differences between treatments with Student-Newman-Keuls at $P \leq 0.05$

EVALUATION OF HERBICIDES FOR CONTROL OF ROUGH BLUEGRASS AND INJURY TO KENTUCKY BLUEGRASS, 1998

M.D. Butler and N.A. Farris

Research to evaluate herbicides for control of rough bluegrass in Kentucky bluegrass was initiated in 1993. A wide variety of herbicide combinations were screened early in the process. In subsequent years, the objective has been to evaluate treatments with the most promise, and fine-tune application rates and timings for the most effective herbicide combinations. In addition, several new herbicides have been evaluated, as they have become available.

The objective of the research this year was to determine the best timing and rate of a spring application of Beacon following a fall application of Sinbar plus Karmex or Beacon plus Karmex. Timings evaluated were a single treatment in March or April, or a split application made in both March and April. A new herbicide, Milestone, was included in the evaluation at two application rates.

Plots were place in three commercial grass seed fields to evaluate control of 'Cypress' and 'Saber II' rough blue-grass and injury to 'Crest' Kentucky bluegrass. Treatments included a November 4 application of Sinbar at 0.5 lb/a plus Karmex at 2 lb/a and Beacon at 0.38 oz/a plus Karmex at 2 lb/a alone or followed by a spring application of Beacon. Beacon was applied either March 30, April 24, or both at 0.76 oz/a following Sinbar plus Karmex and at 0.38 oz/a following Beacon plus Karmex. New product evaluations included a November 4 application of Milestone at 2 oz/a and 4 oz/a.

Treatments were applied with a CO_2 pressurized, hand-held, boom sprayer at 40 psi and 20 gal/a water. Plots 10 ft x 20 ft were replicated three times in a randomized complete block design. A nonionic surfactant was applied at 1 qt/100 gal in combination with all herbicides.

A visual evaluation for percent reduction in biomass to established plants was conducted March 24 on rough bluegrass. Pre-harvest evaluations of percent reduction in seed set were conducted on both rough bluegrass and Kentucky bluegrass June 4.

The effect of herbicide applications for control of rough bluegrass is provided in Table 1, and reduction in yield to Kentucky bluegrass is shown in Table 2. In comparing fall applications alone, Sinbar plus Karmex provided better control of rough bluegrass than Beacon plus Karmex. Bea-

con applied in either March or April provided greater control of rough bluegrass following the fall application of Sinbar plus Karmex than following Beacon plus Karmex. However, the least injury to Kentucky bluegrass was with Beacon applied in March following Beacon plus Karmex in November. There were no consistent differences between March and April applications of Beacon. Beacon applied as a split application in March and April did not increase control of rough bluegrass, but may have caused slightly less injury to Kentucky bluegrass.

Table 1. Effect of herbicides applied November 4, 1997 alone or followed by Beacon applied March 30 and/or April 24 to rough bluegrass. Crop reduction was evaluated March 24, 1998 and yield reduction was evaluated June 4, 1998.

	Treatments	Rate	Crop reduction[1]		Yield reduction[2]	
			Fuzzy	Saber II	Fuzzy	Saber II
		(product/a)	----------------------------------- (%) -----------------------------			
1.	Sinbar	0.5 lb	83 a[3]	50 ab	60 ab	30
	+Karmex	2.0 lb				
2.	Beacon	0.76 oz	60 a	47 ab	45 b	10
	+Karmex	2.0 lb				
3.	Sinbar	0.5 lb	87 a	47 ab	97 a	60
	+Karmex	2.0 lb				
	Beacon (Mar)	0.76 oz				
4.	Sinbar	0.5 lb	87 a	60 ab	93 a	37
	+Karmex	2.0 lb				
	Beacon (Apr)	0.76 oz				
5.	Sinbar	0.5 lb	82 a	57 ab	98 a	33
	+Karmex	2.0 lb				
	Beacon (Mar)	0.38 oz				
	Beacon (Apr)	0.38 oz				
6.	Beacon	0.38 oz	33 b	32 ab	55 ab	33
	+Karmex	2.0 lb				
	Beacon (Mar)	0.38 oz				
7.	Beacon	0.38 oz	22 bc	15 b	65 ab	3
	+Karmex	2.0 lb				
	Beacon (Apr)	0.38 oz				
8.	Milestone	2.0 oz	15 bc	12 b	35 bc	20
9.	Milestone	4.0 oz	85 a	80 a	35 bc	40
10.	Untreated	---	0 c	0 b	0 c	0
						NS

[1]Data based on visual evaluation of reduction in biomass.
[2]Data based on visual evaluation of reduction in seed set.
[3]Mean separation with Student-Newman-Keuls ($P \leq 0.05$).

Table 2. Effect of herbicides applied November 4, 1997 alone or followed by Beacon applied March 30 and/or April 24 to Kentucky bluegrass. Yield reduction was evaluated June 4, 1998.

Treatments	Rate	Yield reduction[1] Crest Kentucky bluegrass
	(product/a)	(%)
1. Sinbar	0.5 lb	53 a[2]
+Karmex	2.0 lb	
2. Beacon	0.76 oz	57 a
+Karmex	2.0 lb	
3. Sinbar	0.5 lb	60 a
+Karmex	2.0 lb	
Beacon (Mar)	0.76 oz	
4. Sinbar	0.5 lb	53 a
+Karmex	2.0 lb	
Beacon (Apr)	0.76 oz	
5. Sinbar	0.5 lb	43 a
+Karmex	2.0 lb	
Beacon (Mar)	0.38 oz	
Beacon (Apr)	0.38 oz	
6. Beacon	0.38 oz	13 b
+Karmex	2.0 lb	
Beacon (Mar)	0.38 oz	
7. Beacon	0.38 oz	50 a
+Karmex	2.0 lb	
Beacon (Apr)	0.38 oz	
8. Milestone	2.0 oz	33 a
9. Milestone	4.0 oz	40 a
10. Untreated	---	0 b

[1]Data based on visual evaluation of reduction in seed set.
[2]Mean separation with Student-Newman-Keuls ($P \leq 0.05$).

Milestone at 4 oz/a compared to 2 oz/a provided more control of rough bluegrass, but also more injury to Kentucky bluegrass. Early plant injury to rough bluegrass declined later in the season causing less reduction in seed set.

The most effective treatment for control of rough bluegrass continues to be a fall application of Sinbar at 0.5 lb/a plus Karmex at 2 lb/a followed by a Beacon application in late March or early April.

RESISTANCE TO BEACON IN DOWNY BROME

G.W. Mueller-Warrant, C.A. Mallory-Smith and P E. Hendrickson

Introduction

Downy brome (*Bromus tectorum*) is widely distributed throughout the western United States and is a major weed of Kentucky bluegrass grown for seed in the Pacific Northwest. Prior to the recent registration of primisulfuron (Beacon), growers relied on terbacil (Sinbar), metribuzin (Sencor or Lexone), and high rates (2 lb/a) of dicamba (Banvel) for control of downy brome. While terbacil is relatively effective if applied at maximum labeled rates preemergence to downy brome and moved into the soil with irrigation or timely rainfall, Kentucky bluegrass tolerance is quite marginal. Growers often damage their stands with treatments that achieve only partial weed control. While metribuzin has better crop safety than terbacil, downy brome control is extremely variable from year to year. Efficacy of dicamba is strongly dependent on downy brome size in late fall and severity of winter weather. Dicamba treatments often result in total weed control failures. Neither terbacil, metribuzin, nor high rates dicamba can be used in seedling stands of Kentucky bluegrass. Because of problems with all three of these older herbicides, growers were eager to adopt use of primisulfuron on Kentucky bluegrass grown for seed. We included this herbicide in many of the treatment combinations in long-term residue management by herbicide treatment studies conducted in Kentucky bluegrass grown for seed at Madras and La Grande, OR. Because resistance to ALS inhibitors has sometimes developed within a few years of use, we saved samples of downy brome seed from several treatments with and without primisulfuron over the duration of these studies.

Materials and Methods

Kentucky bluegrass was seeded in 1992 at Madras and La Grande, and no grass control herbicides were applied before the first grass seed harvest in 1993. Post-harvest residue management treatments (field burn, bale/flail chop/rake, and 'vacuum sweep') were applied annually to the 60 by 135 ft main plots from 1993 through 1996, and herbicide treatments were generally reapplied to the same 9 by 60 ft. subplots from fall 1993 through fall 1995. However, a few herbicide treatments were altered during that period because of excessive crop damage or excessive downy brome density. Herbicides were applied with a pull-type plot sprayer supplying 26 gal/a at 30 psi through 8003 flat fan nozzles. All primisulfuron treatments included 0.25% R-11 surfactant. Average time between the two applications was 8 weeks. In the 1996-97 growing season, 3 out of 15 plots in each residue management block were untreated checks. The other 12 plots received an early fall treatment of primisulfuron plus terbacil followed

by a late fall treatment of either primisulfuron plus terbacil or primisulfuron alone where Kentucky bluegrass stands were thin. Downy brome growth at the early fall applications ranged from the 1-leaf to 4-leaf stage, while it ranged from the 4-leaf to the 12-tiller stage at the late fall applications. Weed density was measured by counting all downy brome plants present in a 7-ft-wide strip centered each plot. In cases where downy brome density exceeded 1000 plants/plot, sub-sampling was used. A swather was used to cut 5-ft-wide strips out of the centers of the plots, after which the adjacent edges of the plots (2 ft + 2 ft) were swathed together. Windrows were picked up and threshed with a plot combine when dry. Seed from each plot was bagged.

Samples of downy brome seed were collected during the cleaning of Kentucky bluegrass seed harvested from 1994 to 1997, and a 55-plot subset of these samples was screened in the greenhouse for resistance to 0.0352 lb/a (0.75 oz product/a) primisulfuron plus 0.25% surfactant applied at the 2-leaf growth stage. Greenhouse-grown downy brome was treated using a compressed-air spray chamber supplying 27 gal/a at mid-canopy height at 30 psi. In the rate response study, primisulfuron was applied at 0.0312, 0.0625, 0.125, 0.25, 0.375, 0.5, 0.75, 1, 1.5, 2, 3, 4, 6, 8, 16, and 32 times the standard 0.0352 lb/a rate. The greenhouse screening trial was conducted twice. Because quantities of seed from the 1994 and 1995 harvests were extremely limited, only seed from the 1996 harvest was used in the first study. The second study was conducted with seed from all three years, exhausting the seed supply for many of the plots. Results from the two studies were similar, and only data from the second study are shown.

Field Observations
Primisulfuron provided 81 to 94% control of downy brome when split-applied in early and late fall (Table 1). A split-application of primisulfuron plus terbacil tank-mixes provided 98 to 100% control for the first two years, dropping to 97% control at Madras in the third year. By 1996, downy brome control in several plots treated with various combinations of primisulfuron and terbacil for three consecutive years was noticeably lower. Whether downy brome survival in those plots was due to sprayer skips, different weather patterns, or increased herbicide resistance was not clear. The replication to replication variability in downy brome density in primisulfuron plus terbacil treatments in the 1995-96 growing season was high, with counts per plot ranging from 0 to 572 for one treatment. Downy brome density in 11 of 36 plots at Madras treated with the most effective combinations of primisulfuron plus terbacil was at least 10 times higher than in the other 25 plots, strongly suggesting that herbicide resistance was developing. Since successful reproduction is the most critical step in evolution, we classified downy brome in individual field plots as resistant if its density increased over the previous year. This definition says that a weed is resistant if it can increase in abundance from year to year when treated with the same herbicide. Because our pattern of swathing and combining (centers of plots and pooled edges of plots) redistributed weed seed passing through the combine, effective downy brome density for the previous year in the neighborhood of each plot was calculated as one-half of the density observed in that plot plus one-quarter of the density observed in each of the two neighboring plots. This calculation ignores the effects of seed shattering within a plot before combining and those of seed blowing between plots at any time.

Uniform application of split-applied primisulfuron plus terbacil at the Madras and La Grande test sites in the fall of 1996 helped to clarify the situation. Downy brome density in the untreated checks increased by 33-fold at Madras and 47-fold at La Grande (Table 2). In 100 plots at each site, the primisulfuron plus terbacil treatment performed as it had in the first two years of the study, controlling of 99% of the downy brome. In the other 44 treated plots at each site, downy brome density increased an average of 9-fold at Madras and >3-fold at La Grande, or control relative to the untreated checks of 73% at Madras and 93% at La Grande. When the same data were grouped by previous year treatment rather than by plot, 20 treatments at Madras and 25 treatments at La Grande showed no signs of resistance, and achieved 99% control of downy brome. However, 16 treatments at Madras and 11 treatments at La Grande did show resistance, with downy brome densities increasing an average of 6-fold and 3-fold, respectively. Interestingly, only one of the 16 treatments showing resistance at Madras came from the field burn residue management treatment, while the other 15 treatments were nearly equally divided between 'vacuum-sweep' and bale/flail chop/rake residue management.

Greenhouse Screening
A 55-plot subset of samples of downy brome seed collected from Kentucky bluegrass seed harvested from 1994 to 1996 was screened in the greenhouse for resistance to 0.0352 lb/a primisulfuron applied at the 2-leaf stage. Progression of symptoms on downy brome treated with primisulfuron included a rapid cessation of growth and a gradual discoloration of the treated leaves, followed by the appearance of healthy, new tillers at the base of the plant within two to three weeks after treatment for the resistant biotypes. Plants that did not begin to regrow within three to four weeks after treatment eventually died. Because all downy brome plants from Madras and La Grande were initially injured by primisulfuron, resistance was simply measured as the ability to survive and regrow. Average downy brome survival increased from 5.9% for seed harvested in 1994, to 7.7% for 1995, and to 19.7% for 1996 (Table 3). Of particular concern was the increase over time in plots where primisulfuron failed to achieve 88% or better control. There were 2 such plots out of 51 tested for the 1994 seed, 8 out of 50 for the 1995 seed, and 19 out of 55 for the 1996 seed.

Dose response curves were generated for seed harvested from three plots (410, 301, and 344) at Madras in 1996, and the $LD_{98\%}$ for the most resistant type (plot 344) was 7-fold greater than for the most susceptible type (Fig. 1). $LD_{98\%}$ for plot 301 was 2-fold greater than plot 410. Plot 344, the most resistant type, had a 6-fold increase in downy brome density in the field from 1995 to 1996 (data not shown). The two resistant biotypes in seed from the 1994 harvest came from plots 236 and 238, which were centered only 18 ft. apart, suggesting a possible common origin for the resistance sometime prior to 1994.

BROTE rate response to primisulfuron
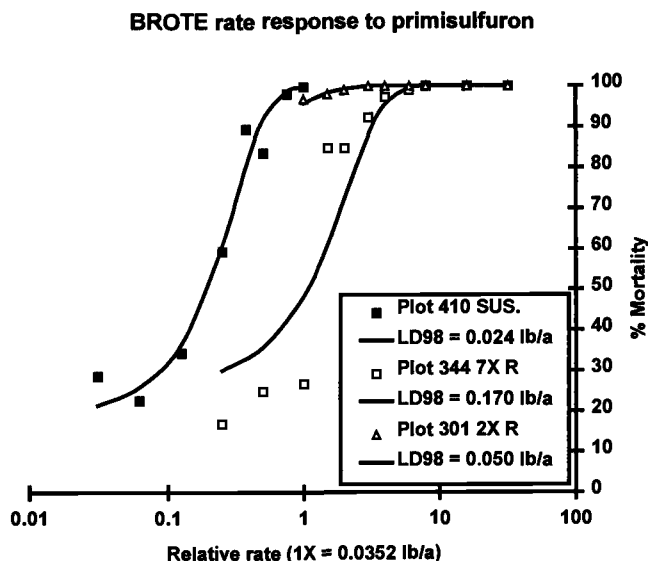
Figure 1.   Response to primisulfuron rates by downy brome seed archived from the 1996 harvest of three plots at Madras, OR. Logistic regressions of mortality versus rate (solid lines). Note logarithmic rate axis. Rates ranged from 32X to 1/32X the standard 0.75 oz product/a treatment.

Resistance Mechanism
ALS activity in the three biotypes used in the dose response trial plus another known susceptible was similarly inhibited by imazapyr (Arsenal) and chlorsulfuron (Glean) (Dale Shaner, pers. comm.), implying that resistance was not target-site based. Other greenhouse studies showed that primisulfuron-resistant biotypes were cross resistant to sulfosulfuron (Maverick). Phytotoxicity of sulfosulfuron on the resistant types was dramatically increased by tank-mixing with an organophosphate insecticide, implying that resistance was based on metabolic degradation of sulfonyl-urea herbicides.

Conclusions
Primisulfuron use in Kentucky bluegrass grown for seed rapidly selected downy brome biotypes with resistance to herbicide. The speed with which populations of this weed evolved resistance suggests that grass seed growers must be vigilant if they hope to continue using this herbicide. Cross resistance to sulfosulfuron suggests that wheat growers also will need to worry about resistant downy brome. Because this resistance evolved within a controlled test plot, we know more about the factors leading to this case of herbicide resistance than is usually known.

Edge effects probably played a major role in the increase in resistance over time. Effective and ineffective treatments were often adjacent, with the spray pattern edge of an effective treatment providing a gradually decreasing rate of herbicide into the first 6 inches of an adjacent plot. Full rates of primisulfuron were needed to control even the most susceptible type, with survival rapidly increasing below the 0.5X rate. The harvest technique helped move weed seeds between adjacent plots. Tank-mixes of herbicides with alternate modes of action are often suggested as ways to slow the development of resistance. Such tank-mixes were present in these field trials, and were overcome by the resistance that downy brome developed. However, it is possible that the resistance evolved in the boundaries between neighboring treatments, and uniform applications of primisulfuron plus terbacil over an entire field might have remained effective much longer than they did as individual treatments within a larger test. The extremely high density of downy brome in the untreated checks and in those treatments that never were effective may have aided the rapid evolution of resistance by providing a large gene pool in which primisulfuron could select a resistant biotype.

Ongoing Studies and Future Plans
The dose response curves are being repeated for the three biotypes and for one additional plot from Madras, two plots from La Grande, and a putative target site mutant collected in the Columbia River Basin by Dr. Dan Ball. Preliminary results confirm the dose-response curves shown in Figure 1, and strongly suggest that the Columbia River basin biotype does possess target site resistance. Seed produced in the greenhouse from the first two greenhouse trials will be tested to determine whether the percent of resistant progeny has increased in the primisulfuron survivors. We hope to determine whether the seed from the field plots consists of a mixture of susceptible and resistant types. Seed from the 1997 harvest is available for nearly all of the 180 plots at each field site. We plan to screen this seed to produce a detailed map of the distribution of resistance across the 2.5 acre area of each site. These 9 ft by 60 ft grid maps will then be analyzed for spatial patterns, potentially locating the initial sources of resistance.

Table 1. Control of downy brome in Kentucky bluegrass grown for seed using primisulfuron alone or with split-applications of primisulfuron + terbacil.

Location	Timing	Rate	1993-94	1994-95	1995-96
		(lb a.i./a)	------------------(% control)-------------------		
Madras					
Primisulfuron / Primisulfuron	Early fall / Late fall	0.0176 / 0.0176	82	94	91
Primisulfuron + terbacil* / Primisulfuron + terbacil*	Early fall / Late fall	0.0176 + 0.375 / 0.0176 + 0.375	98	99	97
La Grande					
Primisulfuron / Primisulfuron	Early fall / Late fall	0.0176 / 0.0176	81	92	83
Primisulfuron + terbacil* / Primisulfuron + terbacil*	Early fall / Late fall	0.0176 + 0.375 / 0.0176 + 0.375	100	98	99

*Terbacil rate in 1995-96 was reduced to 0.3 lb/a due to crop injury from terbacil carryover.

Table 2.   Response of downy brome in Kentucky bluegrass grown for seed to split-applications of primisulfuron plus terbacil in 1996-97 following various herbicide treatments for previous three years.

Downy brome population increases over previous year's population (by category)	Madras	LaGrande
	----------------(ratio 1997 to 1996)----------------	
Untreated checks	33.2X	47.1X
Treatments where resistance had developed	6.1X	3.1X
No. of treatments with apparent resistance	16	11
Control relative to untreated checks	82%	93%
Treatments without resistance	0.4X	0.5X
No. of treatments without resistance	20	25
Control relative to untreated checks	99%	99%
Plots where resistance had developed	8.9X	3.4X
No. of plots with apparent resistance	44	44
Control relative to untreated checks	73%	93%
Plots without resistance	0.3X	0.3X
No. of plots without resistance	100	100
Control relative to untreated checks	99%	99%

Treatments or plots were classified as having resistance if the ratio of downy brome density in 1997 to 1996 exceeded 1.

Table 3.   Response of archived BROTE seed to primisulfuron.

Response of BROTE at 2-leaf stage to 0.0352 lb/a primisulfuron	Year of seed production		
	1993-94	1994-95	1995-96
	------------------------ (no. of plots in each category)------------------------		
archived seed not viable	7	0	0
100% mortality	26	19	18
95-99% mortality	8	17	9
88-95% mortality	8	6	9
80-88% mortality	0	2	1
70-80% mortality	0	3	4
50-70% mortality	2	2	7
<50% mortality	0	1	7
Total no. of samples tested	51	50	55
Total no. of seedlings treated	1393	4303	3972
% of seedlings surviving	5.9	7.7	19.7

Primisulfuron was first applied in the 1993-94 growing season. BROTE seed was collected during cleaning of Kentucky bluegrass seed, and samples from selected treatments at Madras and LaGrande were archived in cold storage.

PRIMISULFURON EFFECTS ON ROTATIONAL CROPS IN CENTRAL OREGON

P.E. Hendrickson, C.A. Mallory-Smith and B.D. Brewster

Introduction

Primisulfuron (Beacon) is registered in the Pacific Northwest for use in Kentucky bluegrass (*Poa pratensis* L.). This sulfonylurea herbicide controls annual and perennial grasses, including downy brome (*Bromus tectorum* L.), a major weed problem in central Oregon. Primisulfuron has a short to moderate soil persistence with a half-life of about 1 to 8 weeks under field conditions. Because sulfonylurea herbicides often have soil residuals that can injure subsequent rotational crops, studies were conducted to determine which crops might be injured following primisulfuron use.

Materials and Methods

Two experiments were conducted in Central Oregon to evaluate the tolerance of rotational crops to primisulfuron. Experiment 1 was conducted at the Central Oregon Agricultural Research Center (COARC) near Madras, OR, and consisted of two similar field trials to simulate planting a field with a different crop after losing a seedling stand of Kentucky bluegrass. Trial 1 was established in 1996 and Trail 2 was established in 1997. Experiment 2 (Trials 3 to 5) was conducted in established fields of Kentucky bluegrass near Madras and Culver, OR. Primisulfuron application data are presented in Table 1 and the soil characteristics are presented in Table 2.

The treatments were applied in 20 gpa of water at a pressure of 19 psi with a plot sprayer. A crop oil concentrate was added to all treatments at a rate of 1% v/v. Treatments were replicated four times in a randomized complete block design.

Table 1.   Primisulfuron application data.

Rate	Date of application	
	Trial 1,3,4,5	Trial 2
(lb a.i./a)		
0.038	11/1/96	11/5/97
0.076	11/1/96	11/5/97
0.019 + 0.019	11/1/96 + 3/27/97	11/5/97 + 4/8/98

Table 2.   Soil characteristics at each location.

Trial	Location	Soil texture	Soil pH	Organic matter (%)
1	COARC	Madras sandy loam	6.5	1.4
2	COARC	Madras sandy loam	6.8	1.4
3	Madras	Madras loam	4.9	1.8
4	Madras	Madras loam	5.4	2.2
5	Culver	Agency loam	5.6	1.8

Experiment 1: Plot dimensions were 8 ft by 20 ft and 8 ft by 10 ft for spring and fall planted crops, respectively. The seedling Kentucky bluegrass was killed with glyphosate in early spring, and the area was rototilled in the direction of primisulfuron application to restrict soil mixing among plots. Row spacing and planting dates for the two trials are presented in Table 3.

Table 3.   Crops and planting dates for Experiment 1 in 1997 and 1998.

Crop	Planting date	
	Trial 1	Trial 2
Alfalfa	5/30/97	6/12/98
Canola	5/30/97	6/12/98
Spring wheat	5/30/97	6/12/98
Sugarbeets	5/30/97	6/12/98
	6/12/98	
Kentucky bluegrass	9/18/97	8/18/98
Peppermint	10/9/97	10/1/98
Winter wheat	10/9/97	10/1/98

The front half of each trial was seeded to alfalfa, canola, spring wheat, and sugarbeets in the spring following primisulfuron application, and was irrigated as needed. The back half of each trial was not irrigated during the summer, and was planted to Kentucky bluegrass, peppermint, and winter wheat in the fall. Crop rotation restrictions following primisulfuron applications to corn is 3 months for winter wheat, 8 months for alfalfa and spring-seeded small grains, and 18 months for canola, sugarbeets, Kentucky bluegrass, and peppermint (Anonymous 1999). Dry soil and limited rainfall during fall planting in Trial 2, resulted in poor stand establishment. Alfalfa, canola, spring wheat, and sugarbeets will be planted in Trial 2 in the spring of 1999. Only sugarbeets were seeded in Trial 1 in the spring of 1998. The crops were seeded perpendicular to the direction of herbicide application and the plots were hand-weeded.

Above-ground fresh weight yields were obtained from 12 ft of row in each plot about 5.5 weeks after planting the spring crops and 7 months after planting the fall crops. The data are presented as a percent of the untreated check while the mean separation procedures reflect differences observed in the fresh weights.

Experiment 2: Plot dimensions were 8 ft by 25 ft. The Kentucky bluegrass was harvested from 62.5 ft^2 per plot in July 1997. Carrots, spring wheat, and winter wheat were seeded in Trials 3, 4, and 5, respectively. The winter wheat and carrots were seeded in the fall of 1997, while the spring wheat was seeded in the spring of 1998. Visual estimates of percent crop injury were recorded for the three trials.

Results

Experiment 1: Injury from soil residues of primisulfuron varied with the crop in Trial 1. Canola, spring wheat, and sugarbeets planted in May 1997 were injured with sugarbeets suffering greater than 50 percent reduction in fresh weight at the 0.038 lb a.i./a rate (Figure 1). Alfalfa seeded in May 1997 and sugarbeets seeded in June 1998 were not significantly affected. There were no significant reductions of the fresh weights of crops planted in the fall of 1997 (Figure 2).

Fresh weight reductions of spring-planted crops in Trial 2 were greater than in Trial 1 (Figure 1). Fresh weights were reduced by an average of 71, 84, 76, and 100 percent for alfalfa, spring wheat, canola, and sugarbeets, respectively. Environmental factors known to increase the probability of phytotoxic residues of sulfonylurea herbicides persisting in the soil include low soil temperature and low soil moisture content. Rainfall from August 1996 to July 1997 was 15 in and from August 1997 to July 1998 was 14 in . In the 1996-1997 crop year, 61 percent of the precipitation was recorded between November 1 and January 31. During this period, Trial 1 was flooded with 4 in of water. In the 1997-1998 crop year, 37 percent of the precipitation was recorded in May. These factors may have contributed to the differences observed in primisulfuron persistence between the two trials.
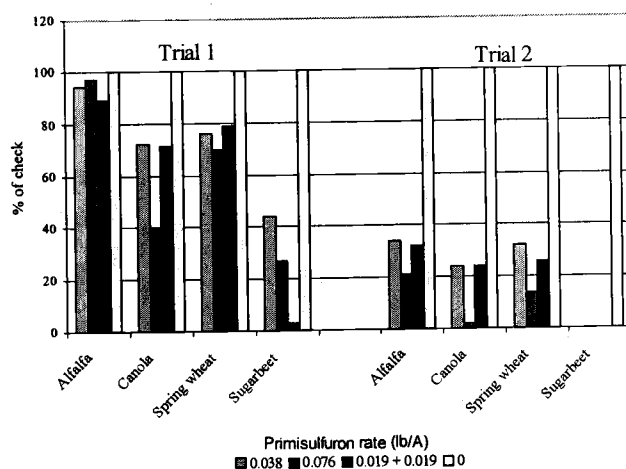

Figure 1. Fresh weights of crops planted in the spring of 1997 and 1998 in soil previously treated with primisulfuron.
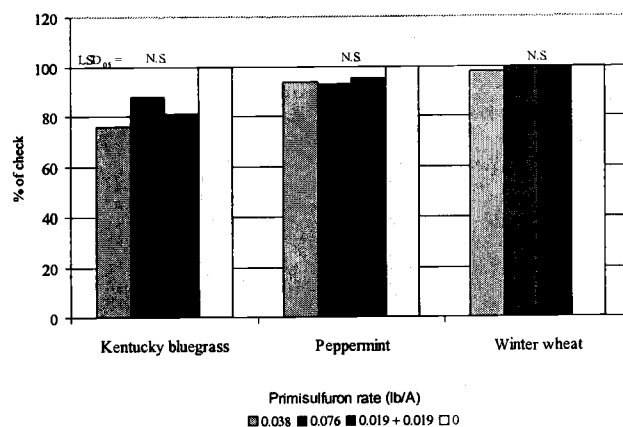

Figure 2. Fresh weights of crops planted in the fall of 1997 in soil treated with primisulfuron.

Experiment 2: No yield reductions occurred in the three established Kentucky bluegrass trials (Figure 3). The rotation crops of spring wheat, winter wheat, and carrots were not visibly injured by any of the primisulfuron treatments.
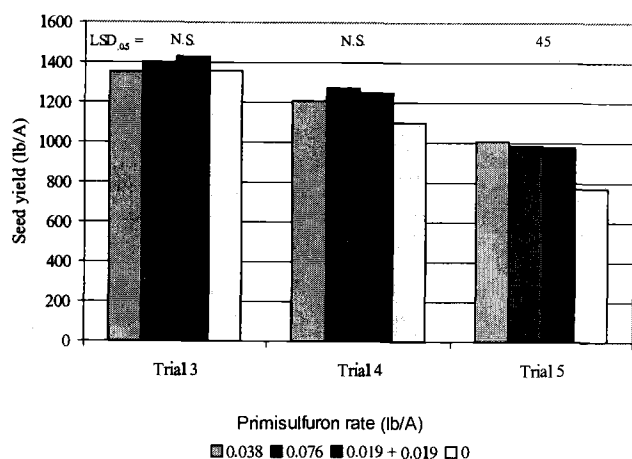
Figure 3. Effect of primisulfuron treatments on established Kentucky bluegrass seed yields.

Conclusions

Experiment 1: Crops planted in the spring after the loss of the seedling Kentucky bluegrass stand were injured in both trials. Crop injury was greater when dry weather occurred during the time between the primisulfuron application and seeding of these crops. This is consistent with the Beacon label which states that injury may occur under these conditions.

Experiment 2: Kentucky bluegrass yields were not reduced by fall applications of primisulfuron. None of the crops tested (carrots, winter wheat, and spring wheat) showed carry-over effects from primisulfuron.

Literature Cited

Anonymous. 1999. Sample labels and reference guide. Novartis Corp. Greensboro, NC. pp. 35-49.

CARRYOVER EFFECTS OF PRIMISULFURON TO ROTATIONAL CROPS IN EASTERN OREGON

D.A. Ball and D. Singh

Primisulfuron (Beacon) is registered for use in seedling and established Kentucky bluegrass under an Oregon Special Local Needs registration (24c). In Eastern Oregon, Beacon is used to control downy brome and quackgrass. Kentucky bluegrass crop injury can be avoided with proper application timing. (Ball and Walenta, 1996). Beacon is a sulfonylurea class of herbicide and has soil residual properties which may affect subsequent crops grown in rotation with grass seed. Studies were conducted to identify feasible crop rotation options following KBG seed production where Beacon is used for downy brome

management. Soil persistence of Beacon and possible carryover to sweet corn, potatoes, onions and winter wheat was studied under irrigated field conditions in the lower Umatilla Basin of Oregon and Columbia Basin of Washington. Also, sugarbeets and mint were grown in crop rotation after Kentucky bluegrass in the Grande Ronde Valley to evaluate Beacon carryover effects on those crops.

Sweet Corn & Onion

Beacon treatments were applied to an established Kentucky bluegrass stand in two commercial field locations near Paterson, WA in fall 1996 and spring 1997. Plots were 15 x 50 ft with four replications arranged in a randomized complete block design. Soil at location #1 was loamy sand (86% sand, 8% silt, and 6% clay) with 0.8 % organic matter, pH 6.7, and CEC of 9.9 meq/100g. Soil at location #2 was also loamy sand (86% sand, 8% silt, and 6% clay) with 0.73 % organic matter, pH 7.0, and CEC of 6.4 meq/100g. After Kentucky bluegrass harvest, both locations were rotated into sweet corn (var. *Golden Jubilee*) in July 1997. Plots were relocated and sweet corn was evaluated for possible carryover effects from Beacon. No significant differences in sweet corn plant height and visible crop injury (August 6, 1997) were observed from Beacon treatments applied to Kentucky bluegrass and compared to untreated check. These results were expected since Beacon is registered for use in many corn cultivars.

Both locations were subsequently rotated to dehydrating onions (March, 1998) after commercial sweet corn harvest. Plots were relocated to evaluate the influence of Beacon treatments on dehydrating onions. No visible crop injury was observed on dehydrating onions at either location. Dehydrating onion plant stand count was unaffected by Beacon treatments applied to Kentucky bluegrass compared to untreated check. No dehydrating onion yields were obtained at these two locations.

Beacon treatments were also applied to a seedling Kentucky bluegrass stand in a commercial field at a third location near Prosser, WA in fall 1996 and spring 1997. Soil at the site was silt loam (40% sand, 51% silt, and 10% clay) with 1.1% organic matter, pH 6.3, and CEC of 18.6 meq/100g. After Kentucky bluegrass harvest, the field was rotated into fresh market onions (var. *Tamara*) in April 1998. Plots were relocated and onions were evaluated for possible carryover effects. No visible injury symptoms from Beacon treatments were observed. Beacon treatments did not affect onion stand counts or ungraded onion yield.

Potatoes

Beacon treatments were applied in fall 1996 and spring 1997 to an established Kentucky bluegrass stand in a commercial field near Paterson, WA. Plots were 15 x 50 ft with four replications arranged in a randomized complete block design. Soil at the site was sandy loam (76% sand, 17% silt, and 7% clay) with 0.86% organic matter, pH 7.5, and CEC of 7.2 meq/100g. After Kentucky bluegrass

harvest, the field was rotated into sweet corn in July 1997 and subsequently into potatoes (var. *Rangers*) in April 1998. Plots were relocated and potatoes were evaluated for possible carryover effects.

No visible injury symptoms from Beacon treatments were observed. Two 10 feet rows of potatoes from the middle of the plot were harvested, weighed and graded. In the 2X rate of Beacon (1.5 oz/a) treatment applied in spring, the Cwt/a of 4-12 oz sized potatoes was reduced compared to untreated check. However, the Cwt./a of the 12-oz or larger size in the same treatment was higher than untreated check (Table 1). The high rate of Beacon applied in spring probably reduced the number of tubers, either by reducing the plant stand or by affecting the formation of tubers. Fewer tubers had reduced competition, either at plant level or between the tubers, thus potentially leading to larger tubers.

Winter Wheat
Beacon treatments were applied to an established Chewings fescue stand in 1996-97 near Echo, OR. The plots were 10 x 40 ft with four replications arranged in a randomized complete block design. Soil at the site was a sandy loam (68% sand, 23% silt, and 9% clay) with 1.4% organic matter, pH 6.7, and CEC of 10.7 meq/100g. After Chewings fescue harvest, the field was rotated into winter wheat (var. *Stephens*) in October 1997. Plots were relocated and winter wheat was evaluated for possible carryover effects. No visible injury symptoms from Beacon treatments were observed. In the 2X rate of fall Beacon treatment (1.5 oz/a) winter wheat yield was reduced compared to untreated check (Table 2).

Peppermint
Beacon treatments were applied to an established Kentucky bluegrass stand in 1996-97 in a commercial field near Imbler, OR. The plots were 8 x 40 ft with four replications. Soil at the site was sandy loam (59% sand, 30% silt, and 11% clay) with 3.56% organic matter, pH 6.5 and CEC of 17.9 meq/100g. After Kentucky bluegrass harvest, the field was rotated into peppermint (var. *Blackmitchim*) in November 1997. Plots were relocated and peppermint was evaluated for possible carryover effects. No visible crop injury symptoms from Beacon were observed. Fresh biomass samples were taken from 5 x 40 feet area with a plot swather from the middle of the plot. The established peppermint stand was highly variable which resulted in highly variable fresh biomass samples. Beacon treatments applied in Kentucky bluegrass had no significant influence on fresh biomass of peppermint compared to untreated control.

Sugarbeet
Beacon treatments were applied to a established Kentucky bluegrass stand in 1996-97 in a commercial field near Imbler, OR. Plots were 8 x 40 ft with four replications. Soil at the site was sandy loam (60% sand, 30% silt, and 10% clay) with 3.46% organic matter, pH 7.7 and CEC of 6.9 meq/100g. The field was rotated into sugarbeet (var. *Betaseed 8088*) in April 1998. Plots were relocated and sugarbeet was evaluated for possible carryover effects. Crop stand of sugarbeet in this field was quite variable. In the Beacon treatments significant visible crop injury was observed (Table 3). Unfortunately the field had to be harvested prematurely, so root yield was less than normal. Two 10 feet wide rows of sugarbeet were dug for sample per plot to determine tuber yield. Sugarbeet yields from Beacon treatments were not statistically different from untreated control due to the high variability in crop stand, and early harvest.

In conclusion, the soil persistence of Beacon did not greatly affect crop rotation opportunities investigated in these studies, with the exception of sugarbeets. None of the other crops (sweet corn, onions, winter wheat, potatoes, nor peppermint) showed significant carryover effects from Beacon applied at normal use rates. A slight carryover effect observed on potatoes and winter wheat was observed only at 2X use rate of Beacon.

References
Ball, D. A. and D. L. Walenta. 1996. Preliminary Evaluations of Primisulfuron for Downy Brome Control in Eastern Oregon Bluegrass Seed Production. 1995 Seed Prod. Res. OSU Ext/CrS 106 pg 66-67.

Table 1. Response of potato to Beacon treatments applied in Kentucky bluegrass the previous year.

Treatment*	Product rate	Date of application	Size grade of potatoes					Total yield	Specific gravity
			Unders	Culls	2 oz	4-12 oz	>12 oz		
	(oz/a)		----------------------------(Cwt/a)----------------------						
Beacon	0.375	Oct 2, 1996	90	31	22	378	74	616	1.085
Beacon	0.750	Oct 2, 1996	91	25	15	386	61	620	1.084
Beacon	1.500	Oct 2, 1996	96	20	23	370	45	579	1.083
Beacon	0.375	Feb 21, 1997	64	36	36	378	84	618	1.084
Beacon	0.750	Feb 21, 1997	91	25	18	368	55	578	1.084
Beacon	1.500	Feb 21, 1997	90	25	25	289	90	533	1.082
Beacon/Beacon	0.375/0.375	Oct 2/Nov 9, 1996	83	23	28	410	89	663	1.084
Untreated			113	37	29	381	41	603	1.083
LSD 0.05			NS	NS	NS	59	36	NS	NS

* Beacon applied with 1 qt/a crop oil concentrate (MorAct).
NS = Statistically non-significant at 5% level.

Table 2. Response of winter wheat to Beacon treatments applied in Chewings fescue the previous year.

Treatment*	Product rate	Date of application	Yield	Test wt
	(oz/a)		(bu/a)	(lb/b)
Beacon	0.375	Oct 8, 1996	102	60
Beacon	0.500	Oct 8, 1996	102	59
Beacon	0.750	Oct 8, 1996	88	59
Beacon	1.500	Oct 8, 1996	82	59
Beacon	0.750	Nov 11, 1996	104	60
Beacon	0.750	Feb 20, 1997	94	60
Beacon/Beacon	0.375/0.375	Oct 8, 1996/Nov 11, 1996	104	60
Beacon/Beacon	0.375/0.375	Oct 8, 1996/Feb 20, 1997	105	59
Beacon/Beacon	0.375/0.375	Nov 11, 1996/Feb 20, 1997	91	59
Untreated			99	59
LSD 0.05			16	NS

* Beacon applied with 1 qt/a crop oil concentrate (MorAct).
NS = Statistically non-significant at 5% level.

Table 3. Response of sugarbeet to Beacon treatments applied in Kentucky bluegrass the previous year.

| Treatment* | Product rate | Date of application | Visible crop injury | | Yield |
			June 3, 1998	Aug 12, 1998	Aug 13, 1998
	(oz/a)		------------------(%)---------------		(ton/a)
Beacon	0.375	Oct 2, 1996	52	0	14
Beacon	0.750	Oct 2, 1996	32	7	11
Beacon	1.500	Oct 2, 1996	71	35	9
Beacon	0.375	Feb 21, 1997	22	0	15
Beacon	0.750	Feb 21, 1997	35	5	13
Beacon	1.500	Feb 21, 1997	50	0	15
Beacon/Beacon	0.375/0.375	Oct 2/Nov 9, 1996	48	28	10
Untreated			0	0	16
LSD 0.05			22	NS	NS

* Beacon applied with 1 qt/a crop oil concentrate (MorAct).
NS = Statistically non-significant at 5% level.