2005
SEED PRODUCTION RESEARCH
AT OREGON STATE UNIVERSITY
USDA-ARS COOPERATING
Edited by William C. Young III

Page

(continued on inside front cover)

Department of Crop and Soil Science Ext/CrS 125, 4/06

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CROPPING SYSTEM MANAGEMENT OPTIONS FOR WILLAMETTE VALLEY VOLES

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Introduction

Decreased use of field burning to dispose of perennial grass seed straw after harvest and implementation of conservation practices, including direct seeding and maximal residue management, have raised questions whether certain crop pests such as the gray-tailed vole (*Microtus canicaudus*) are worse than before these changes. This research shows the short-term effects conservation management practices had on gray-tailed vole activity in perennial forage and turf seed crops, and how vole activity can be reduced without the need for tillage before new stands are established.

The gray-tailed vole is the primary vole species found in the Willamette Valley, that was once a prairie grassland before settlement brought agriculture. Voles now inhabit grass seed and grain fields, pastures, and wild areas that make up a significant portion of the landscape. Voles construct networks of surface runways and burrows where they live. Damage to grass seed and other crops by vole grazing varies annually, but can cause substantial economic losses when population sizes peak.

Voles are territorial and may occupy a home range of a few square meters, but can also migrate to fields from bordering wild vegetated areas. Vole population sizes vary greatly with cyclic peaks occurring every four to six years. The causes of population fluctuations are not well understood, but apparently are influenced by amounts of vegetative cover, land use patterns, food availability, predation, and diseases. Voles generally avoid bare ground where increased exposure to predation exists, thus vegetative cover can affect vole predation by avian predators. Encouraging predator habitat may be a management strategy to reduce vole populations.

There are relatively few reports about the effects of agricultural practices on vole population sizes, and no information about agriculture effects on population cycles. The height of vegetation and mulch after mowing has no apparent effect on population sizes. Trampling during grazing by cattle can reduce small herbivore populations in grasslands. However, sheep grazing in pastures has no effect on vole population numbers.

Direct-seed planting is reported to increase short-term rodent damage to crops, while tillage reduces the size of populations. Even though data are scant that describe the actual impacts of neighboring wild areas on vole numbers in fields, it has been recommended that vegetation should be reduced to help reduce the reintroduction of voles into adjacent crop fields.

Vole and other small rodent population sizes are reported influenced by the kinds of crops used in a rotation sequence. Population size decreases following the harvest of beans, and reproduction is reduced after wheat harvest. Voles also show a food preference to white clover varieties that lack prussic acid, and have reduced food intake when fed herbage high in cyanogenic content. Reproduction in laboratory rats is dramatically reduced by phytoestrogens found in red clover herbage.

Methods and Materials

This study was conducted in two sites in the Willamette Valley as a part of the USDA-ARS 10-year farming systems project. The Linn County site was a poorly drained commercial field where perennial ryegrass and annual ryegrass were grown for seed. The other site was a poor to moderately well drained soil in Benton County on the Hyslop Research Farm in an area where tall fescue seed and other crops that are adapted to better-drained soil conditions are grown commercially. At both sites, twenty-four plots approximately 60-feet wide x 112-feet long arranged as four replicate blocks with six plots per block were used. Common treatment practices to the two sites were comparisons of: (i) conventional tillage versus direct seeding establishment, and (ii) minimal versus maximal post-harvest straw amounts returned to the field. The crops that were grown in the rotation cycle during the period of 1997 to 1999 were used to compare the effects of (iii) previous crops on vole activity. The non-grass seed crops grown at the Linn County site were white clover, meadowfoam, spring wheat or spring oats. At the Benton County site, the rotation crops were red clover grown for seed, meadowfoam, or spring wheat.

Gray-tailed voles have been shown to be the primary small rodent species in the south Willamette Valley. Vole activity was expressed as the number of active burrow entrance holes and used as an estimated index to the population size. The number of active burrow entrance holes within 1-m of each side of a 30-m long transect that ran diagonally across each plot were counted at both research sites 15 January 1999. The approximate area surveyed in each plot was 60 m^2. Actively used burrow entrance holes could be easily determined visually by the presence of fresh soil at the entrance mouth. The burrow entrances that did not appear active were not counted. Gray-tailed voles are active at all times of the year, but it has been shown their population size is at the lowest numbers at this time of the year. The number of active burrow entrance holes has been shown to be an index of vole population density.

Results and Discussion

Two short-term management factors were found to influence vole activity: the method of crop establishment and the kinds of crops in the rotation sequence preceding the present crop grass or clover seed crops (Figure 1). The two kinds of seed crops grown at the time of vole sampling (grass or clover), residue management amounts, and the production sites (Linn or Benton County) had no influence on vole activity. The crops grown two-crops-prior to the present crop being grown in the rotation sequence were not as influential on vole activity as the immediate prior rotation crops.

Establishment Method and Rotation Crop Effects. Direct-seeded, continuous perennial grass seed as the previous crop in the rotation sequence resulted in the greatest vole activity of all treatment combinations (Figure 1). Vole activity was reduced if continuous grass was produced using conventional tillage instead of no-till establishment. Interestingly, when meadowfoam or spring cereals were inserted into the crop rotation sequence instead of continuous grass seed, vole activity was reduced as much as with using conventional tillage establishment. Conventional tillage established cereals, as the previous rotation crop, resulted in the lowest vole activity of all treatment combinations. The use of a meadowfoam rotation crop reduced vole activity more than wheat in a direct-seeded system.

The probable reasons for the differences in vole activity are that in perennial grass seed stands, a more stable environment is provided to vole populations than annual crops provide such as autumn-planted meadowfoam or spring-planted cereals. The use of a direct-seeded, continuous grass seed system provides a relatively continuous habitat for voles that is likely conducive for maintaining habitats similar to undisturbed areas near fields.

Conversely, tillage disrupts the network of vole pathways on the soil surface as well as underground burrows, and likely causes mortality and reduces available food resources. Also, voles are weak diggers compared to other fossioral mammals, so destruction of burrow systems should cause substantial delayed colonization in fields after tillage. Because vole activity can be reduced, even in direct-seeded systems, by including meadowfoam and cereal rotation crops in the rotation sequence, an alternative vole population size management strategy is available. Possible reasons why the rotation crops have lower vole activity may be that these annual crops provide much less cover during winter and early spring than established perennial grass seed stands. Relatively little cover is left after seed harvest in summer, compared to perennial grasses that have dense crowns arranged in 12-inch-wide rows.

There are other impact considerations to grass seed production systems that should be considered in addition to suppressing vole activity by using tillage to establish crops. Even though short-term vole activity may be reduced by tillage, the disadvantages of tillage before seeding include increased costs to establish all crops, decreased perennial ryegrass and tall fescue seed yields, increased soil erosion by precipitation, and reduced available farmer recreation time. Since a relatively small amount of acreage in the south Willamette Valley is managed by direct seeding, it is unlikely that recent high vole population cycles are influence by establishment methods, but are instead due to other factors.

Residue Management Effects. The lack of effect due to residue management amount on short-term vole activity may have resulted from inadequate difference between the maximal and minimal chopped straw amounts left in fields after seed harvest. Similarly in a German study, mulching or mowing had no effect on vole population sizes in perennial grass stands. From our results, it appears that full straw chop-back may not leave enough cover to affect short-term vole activity in perennial grass seed fields.

Another factor that may influence vole activity was the amount of shattered seed left in fields after harvest. Voles depend on available food sources to maintain population sizes. Since perennial grass crops have been shown leave great amounts of seed on the ground due to seed shattering during harvest and both cereals and meadowfoam do not, less food would be available for feeding. This, along with reduced cover in the rotation crops, suggests why the grass and clover seed crops grown in the rotation sequence after these crops had lower vole activity, even when direct-seeded.

Conclusions

This research measured vole activity in one production year at two sites to determine the short-term effects of establishment method treatments, residue management amount, and crop rotation components. Vole activity was the greatest when direct-seeded establishment was used and perennial grass seed was the previous crop in the rotation sequence. Vole activity was reduced in all other treatment combinations by using conventional tillage establishment. However, by inserting meadowfoam or spring cereals into the grass seed crop rotation sequence, vole activity was reduced as much as using conventional tillage establishment. Longer-term research is needed at a landscape-level to determine how different possible management strategies identified in this short-term study may affect vole population cycles. However, this research provides some insights into management options for consideration that may reduce vole activity in perennial grass seed fields.

The Oregon State University Departments of Fisheries & Wildlife and Crop & Soil Science have begun field-level research to determine the effects of encouraging barn owl nesting near grass seed fields to determine the effects of these preditors on vole population size and levels of crop damage.

Research is also needed at the whole field level to determine whether natural phytochemical found in clover plant herbage can be used as a natural strategy to reduce vole population sizes. It is unlikely that these chemicals affected vole activity in our small-sized plots. However, at a larger field-scale, it may be possible to use cyanogenic glycosides found in white clover to reduce vole food intake that could indirectly reduce reproduction. Also, phytoestrogens found in red clover plants may directly reduce reproductive success, as has been shown in laboratory rats.

Acknowledgment:
This research was funded in part by grants from the Oregon Department of Agriculture, Alternatives to Field Burning research program (Grant no. ARF C36-0074-92).

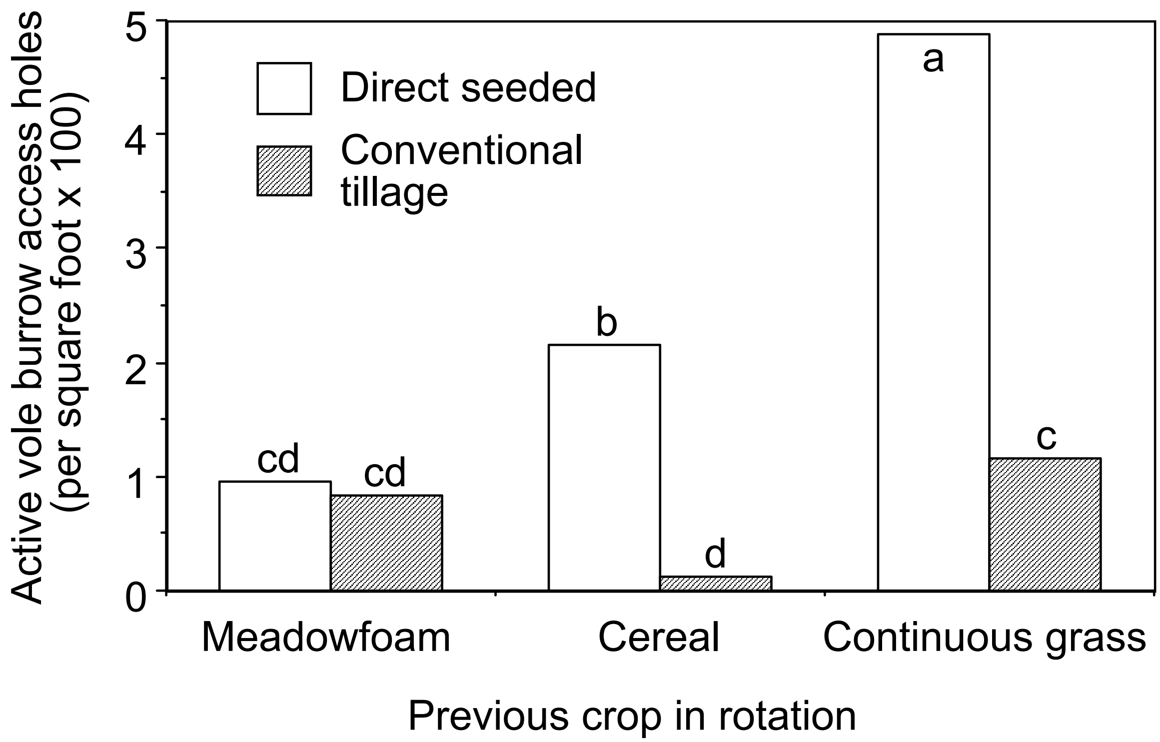


Figure 1. The effects of kinds of previous crops in the rotation sequence and establishment methods on activity measured as the number of burrow access holes in western Oregon perennial grass seed crops. Bars marked with a different letter are different at the 5% level of significance.

CONTROL OF ANNUAL BLUEGRASS IN SEEDLING PERENNIAL RYEGRASS

C.M. Cole, R.P. Affeldt, B.D. Brewster, J.B. Colquhoun and C.A. Mallory-Smith

Introduction

Annual bluegrass (*Poa annua* L.) has developed resistance to certain herbicides in many Willamette Valley grass seed fields. Diuron (Karmex, Direx) has been a widely used herbicide in establishing new seedings and controlling weeds in established stands of perennial ryegrass for four decades. Herbicide resistance probably developed from the repeated use of this compound, and as a consequence produced resistance to other herbicides such as metribuzin (Sencor), ethofumesate (Nortron), and terbacil (Sinbar). Without adequate control with diuron at seeding or with ethofumesate in seedling stands, annual bluegrass control in seedling stands is restricted to glufosinate (Rely) applications at the three-tiller stage of perennial ryegrass growth. This research was undertaken to seek leads on potential treatments for annual bluegrass control in seedling stands of perennial ryegrass that are in the one-tiller stage of growth, when the annual bluegrass would theoretically be easier to control than at later growth stages.

Methods

The study site was at the Hyslop Research Farm near Corvallis. The experiment was designed as a randomized complete block with four replications and 8 ft by 35 ft plots. The Woodburn silt loam soil had a pH of 5.9 and an organic matter content of 2.2%. 'Cutter' Perennial ryegrass was carbon-seeded at 12.5 lb/A in 8-inch rows with a John Deere Powerdrill on September 16, 2004. A CO_2 backpack sprayer fitted with XR8003 nozzle tips was used to apply the treatments in 20 gallons of water per acre at 20 psi. Diuron was applied at 2.4 lb a.i./a to all plots except the untreated check on September 16. The postemergence treatments were applied on October 15, when the majority of the perennial ryegrass had attained the one-tiller stage of growth and the annual bluegrass ranged from one to three leaves. The annual bluegrass at this site was not herbide resistant. A reduced rate of glufosinate was compared to the maximum labeled rate, both alone and in combination with other herbicides. Flufenacet (Define), ethofumesate, pendimethalin (Prowl H_20), and sulfentrazone (Spartan) were included in the post-emergence applications. No adjuvant was used.

Visual evaluations of crop injury and annual bluegrass control were conducted in the fall, and seed yield was obtained at crop maturity. The perennial ryegrass was swathed and threshed with small-scale equipment and the seed was cleaned on a M2B Clipper Cleaner.

Results

Good to excellent control of this herbicide-susceptible strain of annual bluegrass was obtained by all treatments that contained postemergence applications (Table). The postemergence treatments were about 10% to 15% better than the diuron alone. The lower rate of glufosinate was about equal in efficacy on these fall-germinating annual bluegrass plants as most of the other postemergence treatments. Ethofumesate and pendimethalin were considerably less injurious to the perennial ryegrass than was sulfentrazone. When combined with glufosinate, sulfentrazone injury ratings in December exceeded 90%. However, these seemingly dead plants recovered to produce considerable seed. The combination of flufenacet with the lower rate of glufosinate caused little more injury to the ryegrass than glufosinate alone. Treatments that contained the lower rate of glufosinate tended to have lower injury ratings and higher seed yields than those containing the higher rate. Rain during the spring and severe vole predation during spring and summer caused high variation and considerable loss in ryegrass seed yield, so data from only two replications are reported here. There are no statistical differences among the ryegrass yields. In spite of the amazing recovery from sulfentrazone injury, further research with this compound on perennial ryegrass is not warranted. Low rates of the other compounds deserve further research.

Table 1. Visual evaluations of annual bluegrass control and perennial ryegrass injury, and perennial ryegrass seed yield following herbicide applications on a seedling stand in 2004 at the Hyslop Research Farm, 2005.

Treatment[1]	Rate	Annual bluegrass control	Perennial ryegrass		
			Injury		
		Dec. 2	Oct. 22	Dec. 2	Seed yield[2]
	(lb a.i./a)	---------------------	(%)	----------------------	(lb/a)
untreated check	0	0	0	0	390
diuron check	2.4	81	13	0	390
glufosinate	0.188	93	50	19	520
glufosinate	0.375	97	69	39	270
flufenacet	0.15	90	11	20	480
glufosinate + flufenacet	0.188 + 0.15	92	41	25	660
glufosinate + flufenacet	0.375 + 0.15	93	75	48	520
ethofumesate + flufenacet	0.75 + 0.15	91	11	30	590
pendimethalin + flufenacet	2.0 + 0.15	90	9	53	500
glufosinate + pendimethalin	0.188 + 2.0	96	56	5	420
glufosinate + pendimethalin	0.375 + 2.0	95	74	24	760
ethofumesate + pendimethalin	0.75 + 2.0	96	15	5	430
sulfentrazone + flufenacet	0.25 + 0.15	94	89	85	300
glufosinate + sulfentrazone	0.188 + 0.25	95	99	94	520
glufosinate + sulfentrazone	0.375 + 0.25	98	98	99	430
ethofumestate + sulfentrazone	0.75 + 0.25	90	91	68	420
glufosinate + ethofumesate	0.188 + 0.75	96	61	10	450
glufosinate + ethofumesate	0.375 + 0.75	95	73	26	380
LSD 0.05		7	12	14	N.S.

[1]All plots except the untreated check received diuron at 2.4 lb a.i./a on September 16, 2004.
[2]Seed yields are averages of only two replications because of vole predation.

WILD CARROT CONTROL IN TALL FESCUE WITH CHLORSULFURON

C.M. Cole, R.P. Affeldt, B.D. Brewster, J.B. Colquhoun and C.A. Mallory-Smith

Introduction

Wild carrot (*Daucus carota*) continues to be a significant management problem in Willamette Valley grass seed production. We have experimented with many herbicide treatments with varying success; however, one of the more effective experimental treatments in several tall fescue trials has been chlorsulfuron (Glean, Telar). DuPont Crop Protection, the manufacturer of chlorsulfuron, is in the process of labeling this compound for use in tall fescue, but the registration is still uncertain.

Methods

A study was conducted in Linn County to evaluate chlorsulfuron application rates and timings for wild carrot control efficacy and crop tolerance in a third-year field of 'Falcon IV' turf-type tall fescue. The trial was conducted as a randomized complete block with four replications and 8 ft by 40 ft plots. Treatments were applied with a CO_2 backpack sprayer on three dates in 2004: August 27, October 15, and December 3. The spray volume of 20 gallons per acre was applied through XR8003 flat fan nozzle tips at 20 psi. Three rates of chlorsulfuron were applied on each date; lower rates were used in the two later applications because previous research indicated less crop tolerance in the fall than in the summer. Methylated seed oil was added to each treatment at a rate of 1 percent of the spray volume. The Awbrig silty clay loam soil was wet on all three application dates. The wild carrot was mostly in the flowering stage in August and October, while in December most plants were in the rosette stage up to 4 inches in diameter.

Visual evaluations of crop injury and wild carrot control were conducted through the fall and winter months. The tall fescue was swathed and threshed at crop maturity with small-scale equipment and the seed was cleaned on a M2B Clipper Cleaner. Seed samples from each treatment were tested for one thousand seed weight and percent germination after cleaning. The total germination period was 14 days.

Results

Visible crop injury tended to be greatest in the December treatments and at the higher application rates, but degree of injury varied considerably within application dates (Table 1). Wild carrot control was greater than 90% with all treatments. The lowest rate was equally effective as the highest rate at the first two application dates, but the highest rate was slightly more effective in the December timing.

Seed yield was generally good (Table 2), but was somewhat variable - partly because of vole predation. Clean seed yields in the first two timings at the highest chlorsulfuron application rates were about equal to those in the untreated check. The reason for the high rate of clean out in yield from the lowest rate of the first application timing is not clear. Chlorsulfuron treatments did not adversely affect seed weight or percent germination.

Table 1. Visual evaluations of tall fescue injury and wild carrot control in 2005 following chlorsulfuron applications in 2004.

Chlorsulfuron rate	Application date	Tall fescue injury		Wild carrot control	
		Feb. 3	Mar. 11	Feb. 3	Mar. 11
(lb a.i./a)	(2004)	------------ (%) ------------		------------ (%) ------------	
0		0	0	0	0
0.023	August 27	25	20	99	99
0.047	August 27	14	5	99	99
0.071	August 27	26	14	99	99
0.012	October 15	18	8	90	99
0.023	October 15	21	10	95	99
0.035	October 15	10	20	93	99
0.012	December 3	25	25	90	93
0.023	December 3	29	23	91	95
0.035	December 3	36	35	90	98
LSD 0.05		8	8	3	2

Table 2. Tall fescue seed yield, 1000 seed weight, and percent germination following chlorsulfuron applications, 2005.

Chlorsulfuron rate	Application date	Tall fescue seed yield		1000 seed wt.	Germination
		Dirt weight	Clean weight		
(lb a.i./a)	(2004)	----------------(lb/a)	-----------------	------ (g) ------	---- (%) ------
0		2500	2210	2.2	83
0.023	August 27	2400	1660	2.2	90
0.047	August 27	2410	2160	2.3	91
0.071	August 27	2490	2310	2.3	88
0.012	October 15	1910	1540	2.4	90
0.023	October 15	2170	1880	2.3	92
0.035	October 15	2400	2150	2.3	91
0.012	December 3	1970	1680	2.2	88
0.023	December 3	2080	1790	2.3	90
0.035	December 3	1860	1580	2.3	93
LSD 0.05		430	630	0.2	8

EXPLORING ALTERNATIVES TO ENHANCE WEED CONTROL DURING GRASS SEED CROP ESTABLISHMENT

L.R. Schweitzer, M.E. Mellbye, G.A. Gingrich and S.G. Elias

Carbon banding that is often used for weed control during stand establishment of grass seed crops usually provides sufficient weed control, but is costly, cumbersome and sometimes inadequate. This project was initiated to explore new technologies to supplement or replace the current practice of carbon banding.

In commercial seed production in the Willamette Valley, it is commonly observed that cleaner stands are obtained when non-selective herbicides are used for "sprout sprays" before emergence of the crop seedlings. This is true for both spring and fall plantings, and for carbon band planting. The objective of this project is to delay germination of the grass seed crop 6-8 days in order to improve weed and volunteer control. The benefit would be to provide a larger window to control volunteers and weeds tolerant of diuron used in carbon band plantings.

Research was conducted with perennial ryegrass (PRG) and tall fescue (TF) seed crops. Experimental treatments include several novel technologies to delay crop seed germination:

a) Coating seeds with inert materials to restrict imbibition and germination
b) Coating seeds with "intelligent polymers" to control imbibition.
c) Using plant growth regulators to retard germination or induce temporary seed dormancy

Progress

The benefit of delaying sprout spray. A field trial was established at the Hyslop Crop Science Farm in 2004 to evaluate the control of volunteer annual ryegrass in an herbicide timing trial. No coated or treated crop seed was used. The experiment was set up to demonstrate and quantify the additional volunteer control obtained "if" a short delay in emergence of the crop could be achieved. The herbicide glyphosate (Roundup original) was used at a rate of 1.5 qt/a. Plots were arranged in a randomized complete block design with four replications. Approximately 200 lb/a of annual ryegrass was broadcast and harrowed in into the seed bed, which was then planted to Gulf annual ryegrass at 17 lb/a. Emergence of the drilled seed was used to begin the herbicide application timings, which took place 2, 8, 13, and 22 days after initial emergence of the drilled crop was observed.

The herbicide applications after crop emergence represented the effect of delaying the sprout spray assuming a seed coating or chemical treatment would delay crop germination. All delayed herbicide timings increased volunteer control over a normal sprout spray at early crop emergence (Table 1). While a delay of two days provided a reduction in volunteer count, longer delays provided a significantly greater level of control. We conclude that a crop seed germination delay of approximately one week is probably necessary to achieve our stated objective. The results define a more specific target for continuing research efforts.

Table 1. The effect of delaying the "sprout spray" (glyphosate) on control of volunteer annual ryegrass at Hyslop Farm, Corvallis, Oregon, 2005.

Roundup Application (1.5 qt./a Roundup original + 0.5% NIS v/v)			Volunteer ryegrass control	
Timing relative to ryegrass crop emergence	Days from crop emergence	Date	Feb. 8 Visual rating (% control)	Feb. 24 Certification count[2] (seedlings/16 ft.)
Check	Pre	Oct. 5	0%	410 a
Pre-emergence and pre-plant (All treatments received this application)				
Sprout spray[1]	0	Oct. 25	27% a	175 b
Short delay	2	Oct. 27	73% b	62 c
Moderate delay (of about a week)	8	Nov. 3	94% c	19 c
Long delay (of about 2 weeks)	13	Nov. 8	97% c	34 c
Very long delay (4 weeks)	22	Nov. 17	99% c	19 c

[1]Can begin to view ryegrass crop rows planted emerging to ½ inch. This timing selected as the latest a commercial application of Roundup would be applied to a fall planted crop.

[2]Certification count conducted by Oscar Gutbrod with the OSU Seed Certification Service. In this procedure all the seedling ryegrass ("volunteers") were counted in a 16 sq. ft. area. Assuming 6 inch rows and 12-14 crop seedling/ft of row, the total ryegrass allowed is 4-5 plants/16 sq/ft. (5 is about = to 1% for certified generation production standards).

Seed coating. Initial experiments proved that tall fescue and perennial ryegrass grass seed can be coated with build-up ratios up to at least 18x weight increase with no loss of germination capacity. However, since minimal germination delay was observed in the early coating series using typical coating components and techniques, additional shell coats of two different polymers were added to help impede imbibition. Lab germination tests indicated promise for these treatments, so a preliminary field emergence trial was planted in fall of 2004. These trials showed a 1-2 day delay of emergence, but not enough to achieve effective weed control before crop establishment. The extra polymer shell coatings seemed more effective for perennial ryegrass than for tall fescue in these trials.

Collaboration with Landec, Inc. for trial coatings with their Intellicoat© technologies has not been successful to date. Their commercial coating products that are temperature-sensitive or imbibition-inhibitors are geared for the major corn and soybean crops; they are not readily inclined to explore applications for more minor acreage crops.

Meadowfoam seed meal additive. Since meadowfoam seed meal apparently has germination inhibitory activity, we explored potential use in delaying grass seed germination. Finely ground meal bi-product from meadowfoam seed oil extraction was added during the coating process at different rates, and to inner or outer coating layers for evaluation of germination delaying potential.

Higher rates of ground meadowfoam seed meal added to grass seed coatings did delay germination rate in lab germination tests and greenhouse soil emergence trials. However, increasing application rates to achieve significant germination delay (up to 2 days or more) appeared to cause root-stubbing abnormalities for both crops (and some seed death for tall fescue). These detrimental effects were not observed in greenhouse soil emergence tests, so may not be a problem in field planting. A late spring 2005 field trial attempt failed for lack of moisture so will be repeated.

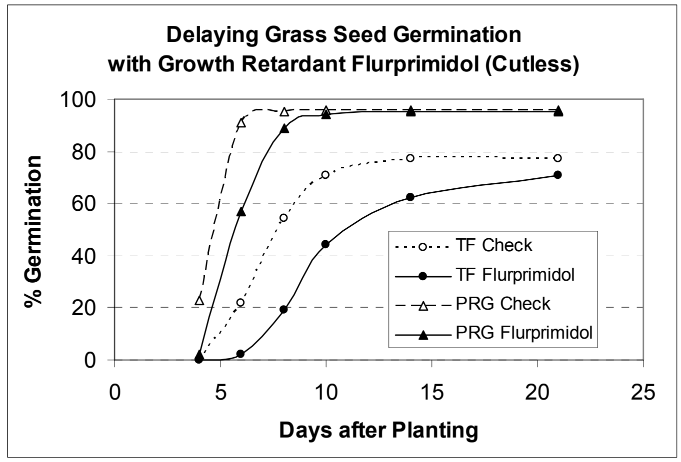
Growth regulators to retard germination. Two plant growth retardants Paclobutrazol (trade name, Trimmit 25C FV) and Flurprimidol (trade name, Cutless 50W) are reported to have germination retarding effects. We soaked PRG and TF seeds in solutions of Paclobutrazol or Flurprimidol at three concentrations (200; 500; and 1000 mg/L) for 8, 16, and 24 hours at room temperature. After soaking, seeds were air dried in the laboratory before evaluating in a standard lab germination test with daily observations of germination rate and seedling development. Seeds were not coated.

Both chemicals delayed germination (about 2 days for TF and 1 day for PRG) at the concentrations and soak times used in these preliminary trials.

Flurprimidol was relatively more effective in delaying germination of PRG than Paclobutrazol, whereas both chemicals had similar effect on delaying the germination of TF. The retardant treatments had no effect on total germination of PRG, but reduced TF final germination by 12-20%.

Seedlings from retardant treated seeds were relatively smaller than the untreated controls for both TF and PRG. Also, seedling growth of TF was not as uniform within each treatment compared to the PRG. These effects will need to be evaluated in field grow-outs.

Figure 1. Example of germination delay using a plant growth regulator.



Summary
In the search for enhanced weed control in grass seed crop establishment, a realistic germination delay "target" is being confirmed and incremental steps achieved toward delaying germination of crop seeds to allow weed kill-off before crop emergence.

Additional work is underway to optimize growth retardant concentrations and application methodology. Then retardant treated seeds will be coated to determine whether additive effects can achieve sufficient germination delay to enhance weed control options before crop emergence. Successful combination treatments will be evaluated in small plot field emergence trials and the most promising advanced to grower field trials.

Acknowledgement:
The authors want to acknowledge the input provided by Phil Rolston, AgResearch, New Zealand on the design of the herbicide timing trial used in this project.

GIS ANALYSIS OF CROP ROTATION AND STAND AGE ON GRASS SEED WEEDS

G.W. Mueller-Warrant, G.W. Whittaker and W.C. Young III

Introduction

Successful weed control has long been recognized as a critical component of grass seed production, and many management decisions are based on current needs to control weeds or past failures. Approximately half of all grass seed grown in Oregon is certified through the Oregon Seed Certification Service (OSCS) as meeting established standards for seed source, field isolation, crop management, land history, prohibited weeds, and seed conditioning. Pre-harvest seed crop field inspection reports from 1994 through the present are stored by the OSCS in a relational database along with general information provided by growers during field signup, and these data have been used to create special reports of field contaminants by county and crop kind along with annual summaries of new plantings and fields signed up for certification. A Geographic Information System (GIS) version of the OSCS data would provide a powerful tool for examining the impact of crop rotation and stand establishment practices on weed demographics. More accurate assessments of spatial and temporal trends in weed prevalence and severity could assist researchers, seed growers, and regulatory agencies in quickly identifying newly emerging weed problems and better understanding the extent and severity of all weed problems.

Our general objective was to use the extensive record of weed species presence and severity that had been generated by routine operations of the OSCS from 1994 to 2003 to produce composite pictures of the behavior of weeds, crops, and growers over this time period, and develop an overall view of the sustainability of the grass seed industry. To accomplish this general objective, we converted a subset of data in the OSCS's non-spatial database into a GIS. Once this had been accomplished for all data from Linn County, we proceeded to examine changes in weed demographics over the past decade. Our specific objectives were: (1) to document the actual cropping sequence patterns used in certified grass seed production, (2) to measure length of time out of certified grass seed production as affected by choice of previous or follow-on crop species, (3) to monitor possible changes over this 10-year period in stand life of certified grass seed crops, (4) to measure changes in weed species presence and severity as affected by crop rotation and by length of time out of certified grass seed production, and (5) to measure effects of stand age on weed severity.

Procedures

Access to the OSCS's database was granted under provisions that no confidential business information would be publicly released and all copies of data containing confidential business information would be destroyed or returned to the OSCS upon conclusion of the analyses. Information covering the period from 1994 through 2003 consisted of 58,011 single crop year records. Data were organized by years and imported into a series of Microsoft Excel spreadsheets. A composite list of all 207 weeds found in any of the 58,011 inspections was first generated, and then this list of weeds was used to search the "Contaminants" column text string for information on each individual weed. Where ambiguity existed in weed names used by OSCS field inspectors (e.g., some inspectors used the generic term "brome" while others identified particular species within the genus *Bromus*), the weeds in question were grouped together before further analysis. In addition to *Bromus* spp., we also grouped two or more *Agrostis* spp., *Amaranthus* spp., *Avena* spp., and *Rumex* spp. In cases where a given weed was absent (i.e., it had not been observed during inspection) it was assigned a value of 0, with trace, many, and excessive ratings being converted into arbitrary values of 1, 2 and 3, corresponding approximately to logarithmic differences in weed densities. A multiple year composite spreadsheet was generated that identified all years for which a given certification number had been used. Data from each of the 10 individual years as well as the multiple-year composite were then exported from Excel in text file format suitable for importation into Arc-GIS.

A shapefile of agricultural field boundaries or common land units (CLU) was obtained from the USDA-FSA field office in Tangent, OR. The CLU as provided to us lacked any information on farming operations, conservation practices, crop species, and land ownership. An Arc-GIS map was created containing several layers useful in assigning certification field numbers to the CLU polygons. NDVI rasters [(Band4 – Band3)/(Band4 + Band3)] derived from late summer Landsat images for the period from 1993 through 2003 were useful in differentiating bare/worked ground from established perennial crops, and in some cases, one crop from another, particularly tall fescue from perennial ryegrass. Knowledge of when a crop had been planted was useful in choosing among several candidate fields of similar size. Accumulation of tentative assignments of certified fields within a single TRS section was useful in restricting remaining possibilities for location of any not yet assigned certified fields. Field CLU polygons were edited as necessary to subdivide larger areas into several smaller fields or merge smaller fields into a single larger one based upon personal knowledge of current field boundaries. No attempt was made to verify the validity of the field locations with growers due to concerns over possible disclosure of confidential business information. While some errors in georeferencing field locations were likely made, possible discrepancies were generally limited to swapping of nearly identically-sized fields within a one-square-mile section. Cropping sequence patterns were primarily identified by the assignment of multiple certification field numbers with non-overlapping production years to the same CLU boundary polygon. Upon conclusion of field identification for Linn County, the data were exported to Excel for further summarization and statistical analysis.

Chi-square tests for independence vs. interaction of classification factors in contingency tables were used to test statistical significance. Time between old and new certified grass seed stands was characterized by the arithmetic mean, the median, and the proportion of cases replanted immediately (i.e., replanted in the first fall after the final harvest of the old stand). Stand duration was characterized by the arithmetic mean and the standard deviation. Tendency of weeds to carryover from the final harvest of an old stand into any harvest of a new stand was tested by chi-square for independence of the simple presence or absence of a weed species and by correlation and linear regression of severity index values for each weed before and after rotation. In addition to the previously described values of 0, 1, 2, and 3 for denoting weed severity, we added a value of 4 to represent cases in which a species had been previously grown as the crop (e.g., annual ryegrass and Kentucky bluegrass). Regression analysis was also used to test for effects of length of time between destruction of old stands and planting of new stands on change in severity of weeds.

Results

Cropping sequence. We identified a total of 545 cases in Linn County over the 10-year period in which a new certified grass seed crop was planted on land previously used to grow another certified grass seed crop. Not surprisingly, the three most commonly grown grasses, both as previous crops and as follow-on crops, were perennial ryegrass, tall fescue, and annual ryegrass, accounting for a total of 74 and 84% of old and new crops, respectively. When looking at all crop sequences, growers showed a strong tendency to replant fields to the same crop they had previously grown. The majority of these cases, however, simply represented replanting of fields to the same variety that had previously been grown. Excluding cases in which fields were replanted to the same variety, 378 old stands were replaced with different crops or different varieties of the same crop. Within these cases, growers actually changed crop species more often than expected for complete independence in choice of prior and follow-on crops, indicative of the challenge of reducing volunteer crop density below that allowed by certification rules. Unusually frequent transitions included Colonial bentgrass to Chewings fescue, tall fescue to annual ryegrass, orchardgrass to annual ryegrass, creeping bentgrass to perennial ryegrass, and annual ryegrass to tall fescue. Possible reasons for the popularity of these particular transitions include available herbicide treatment options (e.g., use of Poast and Fusilade to control Colonial bentgrass in Chewing fescue) and differential first-year seed production potential (e.g., very low seed yields during the establishment year for tall fescue and orchardgrass vs. very high yields for annual ryegrass).

Time between certified grass seed crops. Striking differences occurred among crop species when length of time out of grass seed was analyzed relative to new crop being planted. On one extreme, 78% of new annual ryegrass fields were planted in the first fall after final harvest of previously grown grass seed crops. In contrast, only 27% of all other grass seed crops were planted in the first fall. On average, growers waited longer between grass seed crops to plant orchardgrass or tall fescue than perennial ryegrass or Chewings fescue. When time out of grass seed was analyzed on the basis of previously grown crop, evidence that some crop species were easier or harder to remove than others was clearly present. For example, 62% of old creeping bentgrass fields were replanted to some grass seed crop in the first fall, while only 7% of Colonial bentgrass fields were. Average time until replanting was 1.64 years for tall fescue and orchardgrass, but only 0.89 years for all of the fine fescues (red fescue, sheep fescue, hard fescue, Chewings fescue). Average time until replanting for fields previously growing perennial ryegrass was 2.32 years (median time 1.75 years), implying that growers usually employed two winters of alternative (non-grass seed) crops and/or fallow before replanting grass seed crops in fields previously growing perennial ryegrass. The OSCS land history requirement for changing certified perennial ryegrass varieties is a two year minimum.

Stand age at final grass seed harvest. One of the major concerns expressed by grass seed growers during the 1991 to 1997 phase-down in field burning was that stand lives of their crops might be shortened in the absence of burning, either through changes in crop growth patterns and seed yield potential or through increases in pest problems. In an attempt to quantify possible changes in stand age that might be related to the phase-down in field burning, we compared stand life for certified fields that reached their final year of production during three sets of 3-year periods (1994 to 1996, 1997 to 1999, and 2000 to 2002) by crop species. Several species appeared to show shortened stand life over this time period, but the relatively small number of cases available for most of the crops limited our ability to test the statistical significance of the differences. For perennial ryegrass, however, 95% confidence intervals indicated that stand life decreased from 3.97 ± 0.32 years in the first 3-year period to 3.05 ± 0.34 years in the second period. Perennial ryegrass stand life in the third period averaged 3.34 ± 0.44 years, not statistically separable from either of the two earlier periods although much closer to that of the second period. In contrast to the situation with perennial ryegrass, tall fescue stand life increased from 5.55 ± 0.99 years in the first 3-year period to 7.73 ± 0.77 years in the second period. However, since some of those years of tall fescue seed production occurred before the field burning phase-down even began, the safest conclusion would simply be that there was no evidence that the field burning phase-down decreased tall fescue stand life. Grouping all fine fescues together, stand life was 5.21 ± 1.29 years in the first 3-year period and 4.12 ± 0.80 years in the third period, a trend toward decreased stand life that did not attain statistical significance. Legislation governing the field burning phase-down did allow some burning to continue, and allocated much of that to the fine fescues. Hence it is likely that many of the fine fescue fields were actually field burned during all three 3-year periods.

Carryover of weeds from previous to follow-on certified grass seed stands. Given the prominent role played by weeds in decisions by grass seed growers that stands have reached the ends of their productive lives, one would naturally expect management practices during the time out of certified grass seed to be aimed at reducing weed populations. The extent to which stand removal and eventual replanting did succeed in controlling weeds was evaluated by testing for the independence of weed species presence in fields during the final year of an old stand and any year of a new stand. Of the 36 weeds most commonly found in grass seed fields, 20 failed this chi-square test of independence at the P = 0.01 level, and two more at slightly higher probability levels, providing evidence that grower management practices during the time out of grass seed had not fully erased past weed problems. Tests of linear correlation of weed severity from the final year of an old stand to any year of a new stand provided similar evidence that these 22 weeds tended to carryover from one stand to the next. Correlation coefficients measure the strength of this carryover effect, and correlations were highest for a number of weeds long recognized as serious problems in grass seed. The weed with the strongest correlation between stands (r = 0.436) was western wildcucumber, a perennial noted for regenerating from its massive taproot. The next strongest correlations occurred for annual bluegrass and roughstalk bluegrass (0.352 and 0.341), grassy weed species often present as several percent of the total seed harvested in highly infested stands. Other weeds or crops carrying over at moderate levels (r >= 0.15) include *Agrostis* spp., quackgrass, *Avena* spp., *Bromus* spp., field bindweed, orchardgrass, tall fescue, common velvetgrass, German velvetgrass, Kentucky bluegrass, and *Rumex* spp. The remaining eight weeds showing low (0.05 <= r <= 0.131) but still statistically significant tendencies to carryover from one stand to the next were mayweed chamomile, Canada thistle, annual ryegrass, perennial ryegrass, lowland cudweed, ladysthumb, rattail fescue, and wheat. Weeds whose presence (or severity) in old and new stands appeared to be truly independent included *Amaranthus* spp., shepherd's-purse, common catsear, wild carrot, field horsetail, catchweed bedstraw, sharppoint fluvellin, prickly lettuce, pineapple-weed, Himalaya blackberry, common groundsel, wild mustard, perennial sowthistle, and reed canarygrass. It is interesting to note that only one of these 14 independent weeds was a grass (reed canarygrass), while 15 of the 22 weeds carrying over to significant extents from old to new stands were grasses. We also analyzed our data by pooling the change in severity from old stands to new stands for the 22 weeds whose presence carried over to develop a metric of the overall effectiveness of stand removal/replanting in controlling weeds. Using this composite score, 24% of fields were cleaner after rotation than they had been before it, 32% were weedier, and 44% stayed about the same. Whether fields were cleaner or weedier after rotation was non-randomly distributed among growers, and reasons for differences in effectiveness of their rotations could be a valuable focus of future research.

Planting date**.** Early fall (September through October) was the preferred planting time for certified grass seed crops, accounting for 61% of new stands, while spring planting (March through June) accounted for an additional 29%. Grower disuse of summer (July through August) planting was likely a consequence of the limited availability of irrigation, while winter (November through February) planting would be restricted by excessive rainfall and poor soil physical condition. Weeds differed dramatically in their response to planting date, as indicated by the wide range in ratios of first-year weed severity index for early fall vs. spring plantings. On one extreme, wheat was over 5 times as severe with early fall than spring planting, whereas on the other extreme, Himalaya blackberry was over 6 times as severe with spring than early fall planting. Testing against an arbitrary cutoff of 50% greater severity, the 13 weeds worse with early fall than spring planting were *Amaranthus* spp., *Avena* spp., *Bromus* spp., shepherd's-purse, field bindweed, field horsetail, tall fescue, catchweed bedstraw, common velvetgrass, annual ryegrass, roughstalk bluegrass, pineapple-weed, and wheat. Testing against an equivalent cutoff of 33% lower severity, the seven weeds less of a problem with early fall than spring planting were common catsear, orchardgrass, sharppoint fluvellin, lowland cudweed, Himalaya blackberry, perennial sowthistle, and reed canarygrass. The 16 other weeds were relatively unaffected by planting date.

Time out of grass seed production. To further analyze the impact of management practices on the fate of weeds during transitions from one certified grass seed crop to another, we took the difference in weed severity in the first crop of a new stand minus the final crop of the previous stand and regressed this change in severity against length of time between grass seed crops, limiting our analyses to cases where stands were replanted to new certified grass seed crops within the first 3.3 years after removal of the old stands. Slopes of change in severity vs. time out of grass seed were significant at the P = 0.05 level for eight weeds, and were significant at the P = 0.1 level for six additional weeds. Of these 14 weeds, slopes were positive in 10 cases, indicating that these weeds increased in severity with length of time out of grass seed, and negative in four cases. The four weeds that decreased in severity the longer fields were out of grass seed were annual ryegrass, roughstalk bluegrass, reed canarygrass, and lowland cudweed. The four weeds increasing most rapidly with time out of grass seed were field bindweed, common groundsel, wheat, and wild carrot. Increases in field bindweed likely represent poorer control of this weed in alternate crops such as white clover and wheat than in grass seed crops. Increases in common groundsel may reflect the tendency of that weed to proliferate under fallow in the absence of crop competition. Increases in wheat almost certainly represent volunteer plants present following production of wheat as a rotational crop between grass seed stands. Wild carrot is an increasingly common weed of grass seed crops, and its tendency to increase in severity with time out of grass seed suggests the need to critically examine weed control practices during the entire rotational period out of grass seed.

The intercept in the regression of change in severity vs. time out of grass seed provides a measure of the direct impact of the acts of taking an old grass seed crop out of production and establishing a new one, regardless of how short or long the period between grass seed crops was. Intercepts differed from zero for

10 cases at the P = 0.05 level, and two more cases at slightly higher probability levels. In 10 of these 12 cases intercepts were negative, implying a reduction in severity of these weeds during destruction of old stands and/or establishment of new stands. Ranked in order of decreasing strength of this effect, the weeds negatively impacted by stand removal and replanting were tall fescue, field bindweed, Canada thistle, orchardgrass, *Bromus* spp., roughstalk bluegrass, German velvetgrass, quackgrass, Kentucky bluegrass, and perennial sowthistle. The two weeds whose severity was increased by stand removal and replanting were annual ryegrass and *Avena* spp. Increases in severity by annual ryegrass were likely consequences of its cosmopolitan distribution in soil seedbanks and its vigorous growth under conditions of low competition from crop seedlings during establishment of new stands. Increases in severity by *Avena* spp. over time could arise from use of tame oat as a crop and the presence of wild oat as a weed in cereal crops. Both intercepts and slopes of regression of change in severity vs. time out of grass seed were significant for four weeds: roughstalk bluegrass, annual ryegrass, field bindweed, and orchardgrass. Both of the coefficients were negative in the case of roughstalk bluegrass, implying that benefits of stand removal/replanting in controlling this weed were present initially and increased with time out of grass seed. The positive intercept and negative slope for annual ryegrass suggest that growers risk increased problems with this weed whenever they remove old grass seed stands and plant new ones, problems that can be diminished through effective control in alternative crops grown between the grass seed stands. The negative intercept and positive slope for field bindweed and orchardgrass suggest that these weeds are set back by stand removal practices but often find opportunities to proliferate in the alternative crops grown between grass seed stands.

Year-to-year changes in severity of weeds in established grass seed stands. Weeds of grass seed crops can be viewed as falling into several major categories. Some are poorly suited for survival within grass seed stands, diminish in severity as stands age, and occur in early years of new stands primarily because of their adaptation to the various rotational crops grown and/or fallow practices used between grass seed stands. On the other extreme, some weeds flourish within grass seed stands, increase in severity as stands age, and are often the real reason that growers take older stands out of production. A third major category are the opportunists, weeds whose presence primarily reflects loss of individual crop plants and stand uniformity to factors other than competition from these weeds. There were 14 weeds whose severity decreased when averaged over 6,936 year-to-year comparisons in 2,745 established grass seed stands. Most of the annual broadleaves fell in this category of weeds diminishing with stand age, including *Amaranthus* spp., mayweed chamomile, shepherd's-purse, catchweed bedstraw, ladysthumb, pineapple-weed, common groundsel, and wild mustard. Wild carrot, generally considered a biennial when allowed to grow undisturbed, also diminished in severity with stand age. Annual grasses decreasing in severity as stands aged consisted of *Avena* spp., annual ryegrass, rattail fescue, and wheat. The only perennial grass that decreased in severity as stands aged was perennial ryegrass, a species generally viewed as being a short-lived perennial in most environments.

The 22 other weeds all showed tendencies to increase in severity as stands aged. Weeds classified as opportunists (or very slow invaders restrained by efficacy of commonly used herbicides) on the basis of the small size of their average year-to-year changes in severity would consist of common catsear, field horsetail, common velvetgrass, sharppoint fluvellin, lowland cudweed, annual bluegrass, and *Rumex* spp. Annual bluegrass also exhibited unique behavior relative to stand age, decreasing in severity from first crop to second crop to a greater extent than any other weed, but then consistently increasing in severity with time in all older stands. The simplest explanation for this pattern was that annual bluegrass: (1) exploited open space available between crop rows in new plantings, (2) was crowded out by vigorous crop regrowth during the second growing season (August through July) of young stands, and (3) then exploited open space that gradually became available over time as older stands thinned out for a wide variety of reasons. Based on average year-to-year change in severity, the most aggressive weed of Linn County grass seed fields was roughstalk bluegrass. Its average yearly increase in severity was 64 and 65% higher than the next two most rapidly increasing weeds, tall fescue and Canada thistle. Ranked in order of decreasing aggressiveness, the 10 most serious weeds after roughstalk bluegrass, tall fescue, and Canada thistle were *Bromus* spp., *Agrostis* spp., orchardgrass, Kentucky bluegrass, German velvetgrass, perennial sowthistle, prickly lettuce, quackgrass, western wildcucumber, and reed canarygrass. The two species that would be ranked as least successful of the 15 weeds invasive in grass seed crops were field bindweed and Himalaya blackberry. Availability of several highly effective herbicide treatments for their control in grass seed crops was probably responsible for limiting their proliferation relative to that of roughstalk bluegrass. Reasons for the relatively large year-to-year increase in severity of Canada thistle are not obvious, especially given the excellent control that Stinger/Curtail provides.

Implications for the Grass Seed Industry

Research needs identified during our analysis of 10-year trends of grass seed weeds include both long-recognized problems and newly emerging concerns. Foremost among the long-recognized problems were control of roughstalk bluegrass, annual bluegrass, annual ryegrass, and other volunteer crops. While Canada thistle has long been on state lists of prohibited noxious weeds, our finding that it was the third most aggressively spreading weed of grass seed crops was surprising, and indicates a need for research to determine why and how this is occurring. Wild carrot is already the focus of considerable research, and our findings suggest that poor control in rotational crops and fallow periods between grass seed stands may be a key to its recent success as a weed.

EVALUATION OF THE NITROGEN MINERALIZATION SOIL TEST TO REFINE SPRING NITROGEN RATE DETERMINATION IN WESTERN OREGON GRASS SEED PRODUCTION

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Before application of plant nutrients, grass seed producers need to determine, if a nutrient is needed and how much to apply. Soil testing is used to choose the rate of phosphorus, potassium, calcium, magnesium, boron, zinc, or lime. Soil testing to predict nitrogen rate was practical only for arid and semi-arid environments until recently, when an in-season test for nitrate in moist cool environments was developed in the eastern US (Magdoff et al., 1990).

Assessment of nitrogen status for western Oregon cool season crops such as wheat needed a different approach than the in-season nitrate test developed in the eastern US. Recent work at OSU has provided wheat growers a test to refine their spring nitrogen rate (Christensen et al., 2004). From a soil sample in January, the nitrogen mineralization soil test (Nmin) has the ability to accurately predict nitrogen fertilizer needs in spring. Some growers have successfully reduced spring nitrogen rates by 50% using the test. Several growers of both wheat and grass for seed are so enthusiastic about the Nmin test in wheat that they asked for a similar test to be used in grass seed production.

Our objective was to evaluate the Nmin test as a method to refine spring nitrogen rate for perennial ryegrass, tall fescue and annual ryegrass in western Oregon. We wanted to know in which situations spring nitrogen rates can be reduced without reducing seed yield.

Field scale plots with non-replicated N rates of 0, 60, 120 and 180 lb/a were established in fields of perennial ryegrass and tall fescue. Eight tall fescue and seven perennial ryegrass sites were established with plots 20 to 25 ft wide and at least 500 ft long. Table 1 provides site information for tall fescue and perennial ryegrass. Annual ryegrass data is not included since extremely wet spring weather created conditions that suppressed annual ryegrass seed yield. The highest seed yield at any site was less than 1300 lb/a, an uncharacteristically low yield for these sites. No relationship existed between the Nmin soil test and N or yield measurements, additional evidence that factors other than N limited seed yield.

Spring nitrogen application was made by OSU using an Orbit Air plot fertilizer applicator. Seed yield was measured by the grower swathing a single pass through the middle of each treatment, threshing seed with a commercial combine, and weighing seed in a Brent Yield Cart.

Table 1. Management information for field sites in 2005.

Site No.	Location	Species	Variety	Stand age	Straw management	Soil series	Treatment application
				(years)			(date)
3	Shed	Perennial ryegrass	Barennium	2	Full straw	Amity	3/15
7	Greenberry	Perennial ryegrass	Evening Shade	2	Full straw	Dayton	3/9
10	Macleay	Perennial ryegrass	Top Hat	3	baled	Nekia	3/10
11	St. Paul	Perennial ryegrass	Greenville	2	baled	McBee	3/10
13	Dayton	Perennial ryegrass	Keystone	1		Aloha	3/11
14	McCoy	Perennial ryegrass	MVS124	1		Woodburn	3/11
1	Harrisburg	Tall fescue	Jessup	5	baled	Malabon Holcomb	3/9
4	Shedd	Tall fescue	Reserve	3	Full straw	Woodburn	3/9
8	Monroe	Tall fescue	Fawn	3	baled	Chehalis	3/9
9	Monroe	Tall fescue	Justice	1		Chehalis	3/9
12	Mt. Angel	Tall fescue	Biltmore	4	Full straw	Amity	3/10
15	Suver	Tall fescue	Tulsa 2	3	Full straw	Woodburn Dayton	3/11
16	Rickreall	Tall fescue	Cavalcade	4	Full straw	Coburg Cove	3/11
17	Dayton	Tall fescue	JT3	6	baled	Aloha	3/11

In addition to field or dirt seed yield, clean seed yield, weight of 1000 seeds, aboveground biomass and nitrogen uptake at harvest were measured. Soil was tested for NO_3-N, NH_4-N, and Nmin from a 12 inch deep sample taken in January. Tables 2, and 3 provide N soil test results.

Table 2. Perennial ryegrass soil test N results, 2005.

Site	NO_3-N	NH_4-N	Nmin
	-------------------- (ppm)	---------------------	
3	2.2	4.2	40.5
7	4.0	4.1	22.2
10	3.3	2.1	40.3
11	7.3	1.7	52.7
13	4.6	2.6	16.2
14	7.7	2.2	27.1

Table 3. Tall fescue soil test N results, 2005.

Site	NO_3-N	NH_4-N	Nmin
	-------------------- (ppm)	---------------------	
1	5.0	2.3	38.4
4	3.4	2.9	17.0
8	3.9	3.6	19.2
9	5.3	3.8	25.7
12	2.0	1.4	33.5
15	3.9	4.4	28.9
16	3.5	6.3	28.8
17	9.1	3.1	17.5

Results and Discussion

Cool season grass grown for seed in western Oregon requires a spring application of nitrogen fertilizer for optimum production. Determining the amount of N to apply is the focus of this research. Rather than approaching the problem from the perspective that inadequate N results in reduced yield, the problem will be addressed from identification of sites for which N rate can be reduced without a reduction in yield. N in excess of crop need is an expense growers are unable to bear in competitive global seed market with sharply rising N cost.

When the project was initiated, we hoped to treat the three grass species as a single group. This approach would simplify recommendations and data collection. These data show the interpretation of the Nmin soil test to be different for tall fescue and perennial ryegrass. Therefore, the data will be presented by grass species.

Progress for Tall Fescue and Perennial Ryegrass

Grass seed obtains nitrogen from two sources, soil and fertilizer. Soil nitrogen is provided in available mineral form, (nitrate or ammonium-N), or mineralizable N, i.e. nitrogen that will become available during the growing season. Both available and mineralizable nitrogen are measured for predicting spring fertilizer N rate using the "Nmin" soil test developed at OSU. Most of the N supplied from soil for cool season grass production in the Willamette Valley is mineralizable.

Calibration of the Nmin test is a multi-step process. We did not find a relationship between Nmin and grass seed yield. Grass seed yield is related to nitrogen uptake, thus, the Nmin soil test to be of value should be related to N uptake. Perennial ryegrass requires 175 to 225 lb N/a from soil and fertilizer to produce optimum seed yield (Figure 1). Tall fescue requires slightly less N to be supplied than perennial ryegrass, approximately 125 to 175 lb/a (Figure 2).

Figure 1. Relationship between perennial ryegrass seed yield and nitrogen supply. Nitrogen supply is the sum of N applied as fertilizer in the spring and N uptake from treatments with no spring fertilizer N applied.

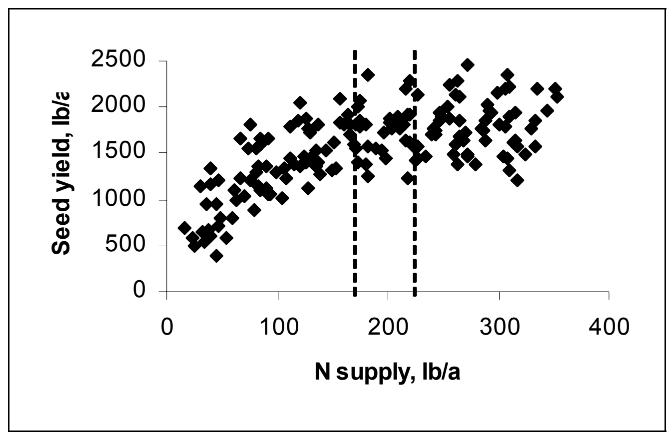
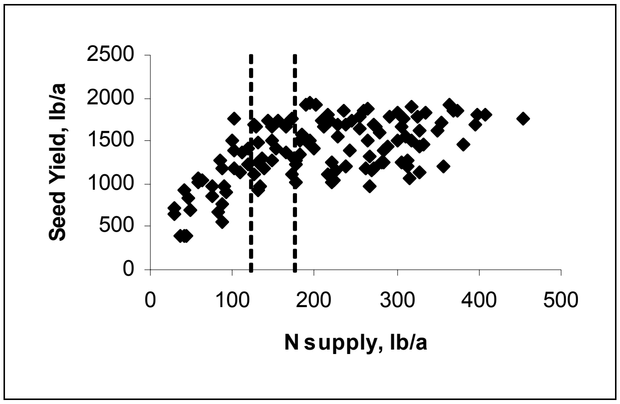


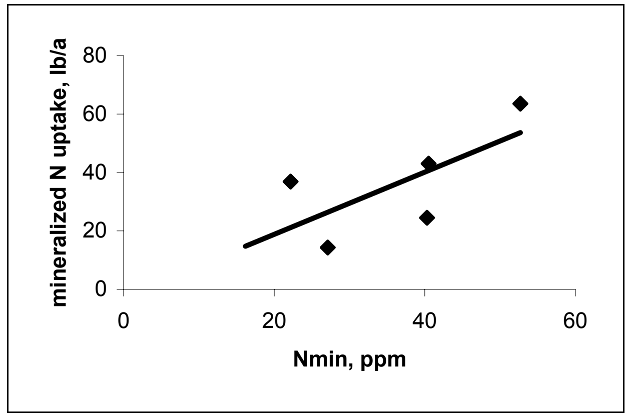
Figure 2. Relationship between tall fescue seed yield and nitrogen supply. Nitrogen supply is the sum of N applied as fertilizer in the spring and N uptake from treatments with no spring fertilizer N applied.



Perennial Ryegrass

Now that the relationship between N uptake and seed yield has been established, the next step needed to implement use of the Nmin soil test is to relate the Nmin test to N uptake. We know that nitrate-N and ammonium-N are available for plant growth. The amount of N we estimate these N forms supply for plant growth was subtracted from the total N uptake. For example, the nitrate-N for the surface foot of Site 3 was 2.2 ppm and the ammonium-N was 4.2 ppm (Table 2). Their sum is 6.6 ppm. We multiplied 6.6 ppm x 3.6 to convert ppm to pounds N per acre. The result is 22 lb available N. The total N uptake in the unfertilized plot was 66 lb/a (Table 5), the estimated available N, 22 lb/a, was subtracted from the total N uptake, 66 lb. giving 44 lb N/a from mineralized N. The N from the mineralized source was plotted against the Nmin soil test value from a 0 to 12 inch sample taken in January (Figure 3). The figure shows that each ppm of mineralized N produces about 1 pound of N in perennial ryegrass.

Figure 3. The relationship of Nmin soil test from 0 to 12 inches in January to Perennial ryegrass N uptake estimated to be from mineralized soil N, 2005.



If correct, we should be able to estimate N rate needed from Nmin soil test. To test the procedure, we will use data from three perennial ryegrass Nmin plots in 2004 (Table 4). Table 4 shows the test is reasonably consistent with N rate information. Unfortunately, the Nmin rates calculated fell between the increments used in the N rate work. The procedure correctly predicted sites 2 and 3 needed a higher N rate than did Site 1.

Table 4. Evaluation of Nmin soil test for perennial ryegrass, 2004.

Site	Available N	Nmin soil test	Expected available N	Calculated spring N need	Optimun N rate applied
	(lb/a)	(ppm)	-----------------------------	(lb/a)	------------------------
1	43	33	76	149	120
2	25	34	59	166	180
3	25	32	57	168	180

The calculated rate is the difference between 225 and the expected available N. The number, 225, is the N supply from Figure 1 that provides consistent top seed yield. The right hand column, "optimum N rate," is the N rate from the incremental addition of N (0, 60, 120, 180 lb/a) producing the maximum economic yield in 2004.

Perennial ryegrass data from 2005 (Table 5) shows the Nmin soil test above 50 ppm (Site 11) before N rate can be reduced without reducing seed yield. Site 11 is the only field with an Nmin soil test above 50 ppm. The lack of more sites with "high" Nmin results is severe a limitation to the test and serves to create cautionary statements about use of the test until more data is collected.

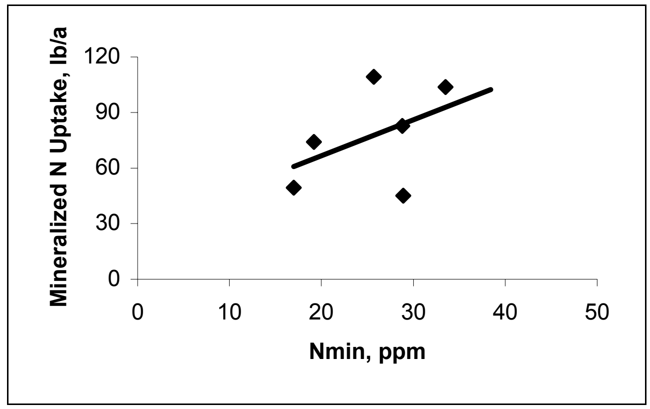
Table 5. The influence of N rate on perennial ryegrass biomass, N concentration, N uptake seed yield, and seed weight measurements. 2005.

Site	N rate	Nmin	N	N uptake	Seed yield
	(lb/a)	(ppm)	(%)	(lb/a)	(lb/a)
3	0	40.5	0.76	66	1673
	60		1.01	125	2126
	120		1.39	144	2019
	180		1.42	182	2331
7	0	22.2	0.73	66	1553
	60		0.94	108	1793
	120		1.03	170	2051
	180		1.02	176	2213
10	0	40.3	0.58	44	847
	60		0.76	92	1022
	120		1.24	123	1020
	180		1.15	153	1308
11	0	52.7	1.01	96	1423
	60		1.07	170	1489
	120		1.27	144	1479
	180		1.58	183	1506
13	0	16.2	1.10	181	1386
	60		1.27	179	1622
	120		2.17	371	1607
	180		1.96	313	1872
14	0	27.1	0.80	50	1283
	60		0.68	82	1782
	120		1.21	148	1934
	180		1.56	166	2126

Tall Fescue

Data collected in 2005 does not provide same relationship for with tall fescue as perennial ryegrass. For tall fescue, the relationship between Nmin soil test and "mineralized N for uptake" is shown in Figure 4. The figure shows that each ppm of mineralized N produces about 2 pounds of N in tall fescue.

Figure 4. The relationship of Nmin soil test from 0 to 12 inches in January to tall fescue N estimated to be from mineralized soil N, 2005.



If correct, we should be able to estimate N rate needed from Nmin soil test. To test the procedure, we follow the same procedure as done for perennial ryegrass, using data from two tall fescue Nmin plots in 2004 (Table 6). Table 6 shows the test is not consistent with N rate information.

Table 6. Evaluation of Nmin soil test for tall fescue, 2004.

Site	Available N	Nmin soil test	Expected available N	Calculated rate	Optimum N rate application
	(lb/a)	(ppm)	------------------------------	(lb/a)	-------------------------
1	39	55	174	0	120
2	16	33	108	67	120

The calculated rate is the difference between 175 and the expected available N. The number, 175, is the N supply from Figure 2 that provides consistent top seed yield The right hand column, N rate, is the N rate from the incremental addition of N (0, 60, 120, 180 lb/a) producing the maximum economic yield in 2004.

We assumed that low Nmin test values were necessary for calibration of the procedure. The Nmin test from two tall fescue fields was low, below 20 ppm. These values did not provide the expected data as N uptake for both sites was more than 100 lb/a without addition of any fertilizer N, Table 7.

Use of the Nmin soil test for prediction of spring N rate in tall fescue is not recommended since we do not know the relationship of the test and N uptake or seed yield.

Table 7. Tall fescue biomass, N concentration, N uptake, seed yield, and seed weight data, 2005.

Site	N rate	Nmin	N	N uptake	Seed yield
	(lb/a)	(ppm)	(%)	(lb/a)	(lb/a)
1	0	24.8	0.81	57	1268
	60		0.87	66	1308
	120		1.11	113	1503
	180		1.33	129	1317
4	0	22.4	0.91	72	1127
	60		0.98	106	1401
	120		1.18	150	1235
	180		1.66	191	1237
8	0	31	0.87	101	1144
	60		0.87	68	1366
	120		1.33	131	1036
	180		1.79	200	1218
9	0	19.5	1.23	142	2874
	60		1.72	244	2591
	120		1.98	239	2786
	180		2.04	303	2707
12	0		0.99	116	1468
	60		1.37	192	1570
	120		1.58	230	1526
	180		1.77	222	1527
15	0	24.4	0.97	75	837
	60		1.32	121	836
	120		1.17	92	492
	180		1.68	175	611
16	0	32.3	0.86	118	1945
	60		1.29	202	2117
	120		1.39	192	2023
	180		1.67	217	1634
17	0	15.6	1.59	190	1558
	60		1.53	151	1493
	120		1.94	212	1343
	180		1.51	179	1393

Summary

The data collected in 2004 and 2005 may allow use of the Nmin soil test to predict spring N rate for perennial ryegrass. No relationship that can be used to predict spring N rate for tall fescue has been developed. The deeper rooted tall fescue may be more efficient at using site N than perennial ryegrass.

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RESPONSE OF SEED YIELD TO SWATHING TIME IN ANNUAL AND PERENNIAL RYEGRASS

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

Seed moisture content is probably the best indicator of the physiological maturity in grass seed crops for determining when swathing (windrowing) is to be done for harvesting seed. Since grass seed crops do not pollinate and mature over a uniform time period, there is a wide range of seed maturity within a crop stand. In order to optimize the time to swath grass seed crops, there is a balance between cutting too early and too late. Cutting too early at high moisture content shortens the seed fill period and can cause reduced seed size and increase the number of immature seed. Cutting too late at low moisture content can decrease yield through losses due to seed shattering (Klein and Harmond, 1971; Andersen and Andersen, 1980). Both of these extremes can have an impact on seed quality as well as seed yield. For annual ryegrass, there is very little information for the Willamette Valley on what would be the best cutting time for maximizing seed yield and seed quality. Previous work in the U.K. has identified the range of moisture contents for optimizing harvested seed yield in direct combined annual ryegrass (Hides et al., 1993). Research was also done in the Willamette Valley of Oregon for tall fescue (Andrade et al., 1994) as well as perennial ryegrass, orchardgrass, and fine fescues (Klein and Harmond, 1971). There is also some evidence in research by Andersen and Andersen (1980) on several grass species that the crop is able to continue development as it dries in the windrow. How much this continued development benefits seed yield is not well known.

In addition to using seed moisture content as a factor to determine when to swath, many growers cut their crops under high humidity conditions either at night or early morning to take advantage of dew on the crop as a means to reduce seed shatter. Swathing under high humidity conditions lets the grower delay swathing to allow more time for the later maturing portion of the crop to continue seed fill and hopefully increase harvested seed yield. Though this is a common practice in some areas of seed production in the Willamette Valley, there is little applied research available that quantifies any beneficial effect that high humidity conditions have on seed yield.

This is the second year of trials to address these questions, two experiments were begun in 2004 (one in perennial ryegrass and one in annual ryegrass) to help determine optimum swathing times. The perennial ryegrass trial was done on-farm in a first-year stand of perennial ryegrass using grower equipment. This trial was designed to compare harvest at different seed moisture contents and verify recommendations previously available. This also provided an opportunity to compare the efficacy of more modern harvest equipment than was used in previous studies by Klein and Harmond over 30 years ago.

A second trial was conducted at the Hyslop Research Farm in Corvallis, Oregon. This trial was designed to measure two factors: seed moisture content and the impact of dew on the crop at swathing. This information will be used to provide annual ryegrass growers previously unavailable guidelines to help determine the best times to begin harvest. The results presented here are from a second year of data.

Materials and methods

Perennial ryegrass.

On-farm research plots were established in June 2005 at Lindsay Farms near Shedd, Oregon. The field was planted to perennial ryegrass (var. Fiesta III) in late May 2004 for a first crop in 2005. The site received 200 lb/a of a fertilizer blend (11-0-30-12) in the fall, 2004. Spring 2005 fertility included 250 lb/a of 15-10-10 the first week of March and a single application of 285 lb/a of 40% ureasol (40-0-0) the first week of April for a total spring nitrogen of 150 lb/a. The crop was treated with Palisade® plant growth regulator at a rate of 1.5 pt/a late April. In addition, fungicides were applied three times during the growing season to control rust. Plots were swathed on July 8, 14, 16 and 20 depending on seed moisture content, then all plots were combined on July 29. Two treatments were done on the July 20 swath date – an early morning time when the dew was on the crop and later in the day after the crop dried out in order to compare the effect of dew moisture on a crop harvest lower than optimum seed moisture content. Harvested seed yield was determined using a Brent® yield cart to weigh combined plots and sub-samples were also obtained at the same time for cleanout, seed size, and germination tests. Cleanout was determined by using an M2-B clipper cleaner, seed size was measured by taking 1000 seed weights from combine run samples and germination tests were done according to OSTA rules. Seed shattering caused by swathing was estimated following swathing by taking quadrat measurements randomly in several places within the plots in both the open stand and under the windrow. Experimental design for the trial was set up as a 5 treatment randomized complete block with four replications. Analysis was done using Statistix® statistical software.

Annual ryegrass.

Research plots were established at Hyslop Research Farm in the fall of 2004 using conventional plowing and planting. The new planting was fertilized with 275 lb/a of 16-16-16 (45 lb N/a) pre-plant incorporation. Spring fertilizer was applied on March 17 for a total N application of 137 lb/a plus 30 lb/a S. Experimental design was set up as a 5 x 2 factorial with seed moisture content and dew as the two main factors replicated four times. There were five seed moisture contents (50, 45, 40, 35, and 30%) at two dew levels (dew present and no dew present) for a total of 10 treatments. Analysis was done using Statistix® statistical software. Plots were swathed using a modified JD 2280 swather and combined July 15 with a Hege 180 plot combine.

Results

Perennial ryegrass

Plots at Lindsay Farms were swathed at four different maturities that were determined by the grower. The first date was several days prior to when the grower would normally swath, the second date was the normal grower swathing time, and the third date was a few days later than the normal swathing date. The fourth later date was chosen to give a very late swathing treatment. The seed moisture content in the plots for the four dates - July 8, 14, 16, and July 20 were 46, 38, 33, and 27% respectively. Plots were swathed at approximately 10 AM each day with the last date swath times both early (7 AM) later in the day after the dew was gone. Seed yield (Table 1) was highest on the first swath date (July 8) and gradually decreased as seed moisture dropped. Significant drops compared to the first swath date did not occur until the latest swathing date. Cleanout varied some but did not appear to be affected much by the swathing date. Seed size as measured by 1000 seed weight was not affected by the different swathing dates. Germination was good at all swathing dates and varied from 97.2 to 98.4 percent - a range of only 1.2 percent.

Table 1. Harvest components in perennial ryegrass swathed at different seed moisture contents, Lindsay Farms, 2005.

Seed moisture at swathing	Seed yield	Clean-out	1000 seed wt.	Seed germ.
[% (date)]	(lb/a)	(%)	(g)	(%)
46 (7/8)	2075 a[1]	3.7 a	2.06	98.4
38 (7/14)[2]	1963 ab	2.7 b	2.12	97.8
33 (7/16)	1955 ab	3.5 a	2.17	98.1
27 (7/20)	1922 b	3.1 ab	2.16	97.9
27 (7/20)[3]	1774 c	3.1 ab	2.12	97.2
LSD 0.05	140	0.1	NS	NS

[1] Means in columns followed by the same letter are not significantly different by Fisher's protected LSD values.
[2] Field swathing moisture content (grower norm).
[3] Field swathing without dew.

In addition to seed yield, shattered seed populations (Table 2) were estimated in the plots by counting actual seed on the ground (blank seeds were ignored). As seed moisture levels decreased, the shattered seed populations increased under the swaths. The seed densities between the swaths did not change as dramatically but indicated some pre-swathing shattering was taking place as seed moisture decreased. These plots were harvested using a draper type deck on the swather. Because of the draper deck, there were few seed shattered between the windrows and it can be concluded that the difference in losses comparing between the swaths and under the swaths were primarily caused by the swathing process and not pre-swathing shatter. This was a contributing factor to decrease in seed yield as seed moisture decreased.

A comparison of 2005 and 2004 seed yields is shown in Table 3. Both years were very similar in seed yield response. A look at both years' data show that waiting for seed moisture to drop some resulted in decreased yields. A later swath timing (27 percent seed moisture) was added in 2005 to determine how much the effect on seed yield dew can have if the crop is swathed at less than the recommended seed moisture content. Waiting until the crop matures to lower seed moisture did not result in better yields than swathing earlier. If the crop is swathed at too low of moisture content, then making use of high humidity in the morning (or night) may be helpful. Waiting until the crop dried out caused a 150 lb/a seed yield decrease on the same day.

Table 2. Seed shatter measured after swathing in perennial ryegrass swathed at different seed moisture contents, Lindsay Farms, 2005.

	Estimated shattered seed density		
Seed moisture at swathing	Between swaths	Under swaths	Weighted average
(%)	---------------- (no. sq ft)	----------------	
46	29 a[1]	609 a	222 a
38	96 ab	1740 b	644 b
33	118 b	2135 bc	790 bc
27 (+ dew)	212 c	2507 c	977 c
27 (- dew)	312 d	3981 d	1535 d
LSD 0.05	86	697	222

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

Table 3. Perennial ryegrass seed yield comparison between 2004 and 2005, Lindsay Farms.

Seed moisture at swathing		2004 yield	2005 yield	2 year average
(%)		--------------(lb/a)-------------		
46	(45)[1]	1695	2075	1885
38	(36)	1727	1963	1845
33	(29)	1662	1955	1809
27	(+ dew)	---	1922	---
27	(- dew)	---	1774	---

[1] Values in ( ) are comparable 2004 seed moistures values

Annual ryegrass

Seed Moisture and Dew. Annual ryegrass plots were swathed at the five different moisture contents listed in Table 4. Seed yield was highest at the 45 percent seed moisture. Harvesting below 45 percent seed moisture caused a rapid decline in seed yield. In addition, there was some seed moisture x dew interaction (P value between 0.05 and 0.10). The interaction, presented in Table 5, shows the benefit of swathing when humidity in the crop is high. At 50 percent moisture, there was no difference in yield due to the presence or absence of dew on the crop. However, at lower seed moistures, yield was reduced by an average of 231 lb/a, equal to an average loss of 24%.

Seed yields were down considerably this year due to heavy damage from vole populations. There were a lot of seed head missing or chewed off. However, even with vole impact, the relationships of the treatment effects were almost identical to the previous year as shown in Table 6. Shattering was visually evident when the plots were swathed under the drier conditions. Seed size (1000 seed weight) increased significantly as the crop was harvested at lower seed moistures. Factors that may contribute to this are the loss of the smaller seed at the distal end of the spikelets as they tend to shatter first and maybe continued fill of seeds that did not shatter. The largest seed are at the base (proximal) of the spikelet and do not shatter as readily, thus increasing the portion of seed that is larger and hence increasing 1000 seed weights. Germination tended to decrease at the lower seed moisture ($P < 0.10$) but it is unclear as to the cause and the difference was rather small at less than 2%. Germination averaged from 96.9 to 98.7 percent.

Table 4. Seed yield, 1000 seed weight, and germination in annual ryegrass swathed at different seed moisture contents and dew levels, Hyslop Research Farm, 2005.

Treatment	Seed Yield		1000 seed wt.		Seed germination	
	(lb/a)		(g)		(%)	
Seed moisture % (swath date)						
50 (6/24)	1220	a[1]	3.22	b	98.7	a
45 (6/29)	1241	a	3.22	b	98.4	a
40 (7/1)	958	b	3.40	a	97.4	b
33 (7/3)	774	c	3.41	a	98.0	ab
28 (7/5)	664	c	3.40	a	96.9	b
LSD 0.05 (0.10)	120		0.08		(1.1)	
Time of day						
Dew present [2]	1064	a	3.35		---	
No dew present	879	b	3.34		---	
LSD 0.05	76		NS			

[1] Means in columns followed by the same letter are not significantly different by Fisher's protected LSD values.
[2] Early morning for dew present, early afternoon for no dew present.

Table 5. Seed yield interaction in annual ryegrass swathed at different seed moisture contents and time of day at Hyslop Research Farm, 2005.

Seed moisture at swathing	Dew present[1]		No dew		Difference (dew – no dew)
(%)	-------------------(lb/a)--------------------				
50	1219	a[2]	1221	a	(2)
45	1362	a	1120	a	242
40	1009	b	908	b	101
33	901	bc	647	c	254
28	828	c	500	d	327
LSD 0.10	-------- 141 --------				

[1] Early morning - with dew present; early-mid afternoon - no dew present.
[2] Means in columns followed by the same letter are not significantly different by Fisher's protected LSD values.

Table 6. Annual ryegrass seed yield comparison between 2004 and 2005, Hyslop Farm.

Seed moisture at swathing	2004 Seed yield	2005 Seed-yield	2 year average
(%)	--------------(lb/a)-------------		
50	2575	1220	1898
45	2790	1241	2016
40	2594	958	1776
33	2386	774	1580
28	1906	664	1285
Time of day			
Dew present [2]	2567	1064	1816
No dew present	2333	879	1606

Conclusions

Seed moisture content is a useful tool in determining the range of maturity for maximizing yield in grass harvested for seed. In this second year of data the optimum time for swathing in the perennial ryegrass was 38-45% seed moisture. These data indicate that cutting a few days early does not impact yield as much as cutting a few days late. Looking at the 2 year average, swathing at the higher seed moisture tended to have higher yields than at the lower seed moisture.

In the annual ryegrass trial, the optimum seed moisture content was around 45% seed moisture, similar in both years, with losses increasing as moisture departed more than five percent from the optimum. However, some flexibility in delaying swathing time can be utilized if there is dew present on the crop.

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THE EFFECT OF EARLY FUNGICIDE APPLICATIONS ON SEED YIELD IN PERENNIAL RYEGRASS

G.A. Gingrich and M.E. Mellbye

Introduction

Stem rust is a serious disease problem in many Willamette Valley grass seed fields. Spring weather patterns, the variety being grown and the age of the stand are major factors influencing rust initiation and infection levels. Research trials the past two years have shown that seed yields can be significantly reduced when rust is not adequately controlled. Perennial ryegrass and tall fescue are particularly susceptible to rust infections and seed yield reduction. It's been estimated that Oregon grass seed growers spend approximately $15 million annually for rust control programs.

This is the third year of on-farm fungicide trials conducted to evaluate the effect various fungicide applications has on seed yields of perennial ryegrass (Table 2). In 2005 rust infections began very early in some fields and by the end of the season rust pressure was generally quite high. In addition to determining the effect of a standard rust control program on seed yields we also looked at early treatment programs and how they influenced seed production.

Methods

Results in this report were obtained from large scale, on-farm yield trials conducted on three turf type perennial ryegrass fields. Field trials were conducted at three locations: (1) a two year old field located near Gervais (var. Paragon), (2) a first year field in the Pratum area (var. Stellar), and (3) a three year old field in the Tangent area (var.Paragon). Fungicides used were:

Propiconazole (Tilt 428 GS)
Chlorothalonil (Echo)
Azoxystrobin (Amistar, Quadris)
Pyraclostrobin (Headline)
Azoxystrobin/Propiconazole (Quilt)

Fungicide applications were made using an ATV mounted sprayer with a 20 ft boom equipped with TeeJet 11002 VS nozzles at 30 psi calibrated to apply 15 gpa. Crop oil concentrate (COC) at 0.5% vv was added to each fungicide treatment. Plots were arranged in a randomized complete block design with three replications. Individual plot size was 24 feet wide by 300 to 400 feet long. Grower equipment was used to harvest individual plots and a weigh wagon was used to determine seed yield. Sub-samples of the harvested seed from each plot were collected to determine percent cleanout, 1000 seed weight and to calculate total clean seed yields.

Results

Winter weather in 2004-05 was unusually dry and warm in western Oregon. These conditions contributed to one of the earliest rust seasons in recent years. By late March, a number of early fall planted, first-year fields were showing significant levels of rust infections. These fields went on to have high rust pressure throughout the spring and 3 to 4 fungicide applications were necessary to provide adequate disease control. Both Marion County locations had the first fungicide treatments made by late April. Only in the site east of Salem, a first year field, was there much rust present at the initial fungicide application timing. Rust pressure was lower and appeared somewhat later in the two and three year old fields near Gervais and Tangent. The Tangent field didn't get its first treatment until early May (Table1). All treatments provided acceptable rust control when compared to the untreated check.

Table 2 provides details on the rust infection levels, percent cleanout, 1000 seed weight and seed yield data for each treatment. Only at the site east of Salem did all fungicide applications provide significantly higher seed yields than the untreated checks. There was no untreated check plot at the Gervais field site. A visual evaluation of rust infestation just prior to swathing showed moderate to high levels of rust in the check plots and excellent rust control in the fungicide treated plots. The percent cleanout was considerably greater in the seed harvested from the untreated plots at the Pratum and Tangent locations.

When compared to the untreated check plot the highest yielding fungicide treatments increased seed yields by nearly 270 lbs/a at the Tangent location and a whopping 1500 lbs/a at the Pratum location. At the Tangent site, with low rust pressure, the highest yield was from the early Tilt application. However the early Headline treatment provided the highest yield at the Pratum site. At this site all of the early treatments yielded significantly more seed than the standard treatment program. Seed yields were not significantly different between the early and standard treatments at the Tangent site. Rust pressure was both late and relatively light in this field.

Summary

The early fungicide treatments resulted in an increase in seed yields at only one of three locations in 2005. There were no differences among the fungicide products. The results of this study suggest a benefit to early fungicide applications only under severe and early rust pressure. A well timed fungicide program is a good investment for perennial ryegrass seed producers in western Oregon.

Acknowledgements:
Appreciation is extended to BASF Corp. and Syngenta Crop Protection, Inc. for their support of these OSU Extension Service fungicide trials. We also express our appreciation for the cooperation of the growers who allowed us to use their fields and assisted with the seed harvest.

Table 1. Treatment table: fungicide products, application rates and timing, 2005.

Treatments	Application dates and rates (product/acre)			
North Valley site (var. Stellar)	4/26/05 2-3 node	5/12/05 Late flag/boot	5/28/05 Mostly headed	6/15/05 Late anthesis
Quilt - Early treatment program	7 oz Quilt	6oz Tilt+1pt Echo	20.5 oz Quilt	6 oz Tilt
Headline - Early treatment program	6 oz Headline	6oz Tilt+1pt Echo	20.5 oz Quilt	6 oz Tilt
Amistar - Early treatment program	2 oz Amistar	6oz Tilt+1pt Echo	20.5 oz Quilt	6 oz Tilt
Tilt - Early treatment program	4 oz Tilt	6oz Tilt+1pt Echo	20.5 oz Quilt	6 oz Tilt
Standard treatment program	-	6oz Tilt+1pt Echo	20.5 oz Quilt	6 oz Tilt
South Valley site (var. Paragon)	5/2/05 1-2 node	5/28/05 Mostly headed		
Quilt - Early treatment program	7 oz Quilt	6oz Tilt+1pt Echo		
Headline - Early treatment program	6 oz Headline	6oz Tilt+1pt Echo		
Amistar - Early treatment program	2 oz Amistar	6oz Tilt+1pt Echo		
Tilt - Early treatment program	4 oz Tilt	6oz Tilt+1pt Echo		
Standard treatment program	-	6oz Tilt+1pt Echo		
North Valley site (var. Paragon)	4/20/05 1-2 node	5/11/05 Early heading	5/30/05 Mostly headed	6/20/05 Late anthesis
Quilt - Early treatment program	7 oz Quilt	6 oz Tilt	6 oz Tilt	9 oz Headline
Headline - Early treatment	6 oz Headline	6 oz Tilt	6 oz Tilt	9 oz Headline
Tilt + Echo - Early treatment	6 Tilt/1 pt Echo	6 oz Tilt	6 oz Tilt	9 oz Headline
Standard treatment program	-	6 oz Tilt	6 oz Tilt	9 oz Headline

Table 2. The effect of early fungicide treatments on stem rust severity, percent cleanout, 1000 weight and seed yield of perennial ryegrass on three Willamette Valley fields, 2005.

Treatments	Rust (Late June)	Seed yield	Additional seed[3]	Cleanout	1000 seed wt.
	(%)	(lb/a)	(lb/a)	(%)	(g)
	North Valley - Pratum area (var. Stellar -first year crop)				
Untreated check[1]	73.3	544	0	14.9	2.016
Quilt - Early treatment	3.7	1969	1425	10.4	2.127
Headline - Early treatment	1.0	2043	1499	8.8	2.149
Amistar - Early	1.7	1999	1455	9.5	2.189
Tilt - Early treatment	2.7	1904	1360	9.8	2.130
Standard treatment program[2]	3.7	1698	1154	9.6	2.022
LSD 0.05	2.3	147		5.2	0.103
	South Valley - Tangent area (var. Paragon - 3rd year crop)				
Untreated check[1]	58.0	1015	0	19.6	1.701
Quilt - Early treatment	5.8	1127	112	18.9	1.842
Headline - Early treatment	4.3	1211	196	17.8	1.878
Amistar - Early	5.2	1224	209	17.4	1.890
Tilt - Early treatment	9.3	1283	268	15.7	1.871
Standard treatment program[2]	6.3	1221	206	16.6	1.917
LSD 0.05	9.8	NS		1.9	0.072
	North Valley - Gervais area (var. Paragon - 2nd year crop)				
Quilt - Early treatment	1.5	1281	NA	8.2	1.874
Headline - Early treatment	2.0	1317	NA	6.8	1.867
Tilt + Echo - Early treatment	2.0	1374	NA	7.5	1.826
Standard treatment program[2]	6.0	1306	NA	7.8	1.855
LSD 0.05	1.9	NS	--	NS	NS

[1] The check was harvested as one strip and not included in statistical analysis for seed yield.
[2] No early fungicide treatment, otherwise the same.
[3] The additional seed yield above the untreated plots.

FIELD EVALUATION OF THE USDA RUST MODEL – YEAR II

G.A. Gingrich, M.E. Mellbye and W.F. Pfender

Introduction

Each year millions of dollars are spent on fungicide programs for rust control in grass seed fields in western Oregon. It is estimated that approximately $15 million is spent annually on control programs in perennial ryegrass and tall fescue fields alone. Timely applications of fungicides are critical in obtaining effective control and keeping application costs to a minimum.

One objective of this study was to determine the effectiveness of fungicide applications applied according to information provided by the USDA Rust Model in comparison to a traditional application program. Prior to the rust season a weather station was installed in each of the fields where the trials were conducted. Data from the weather stations was used to predict potential rust infection initiation and severity and provide information for fungicide applications. The rust model is still in the process of development, and these tests are part of the effort to test and adjust the model.

Methods

The data for this report was obtained from large scale, on-farm yield trials conducted on turf type perennial ryegrass. Trials were conducted at two locations: (1) a first year field located near Pratum (var. Stellar) and (2) on a three year old field in the Tangent area (var. Paragon). Fungicides used were:

Propiconazole (Tilt 428 GS)
Chlorothalonil (Echo)
Azoxystrobin (Amistar, Quadris)
Pyraclostrobin (Headline)
Azoxystrobin/Propiconazole (Quilt)

Fungicide applications were made using an ATV mounted sprayer with a 20 ft boom equipped with TeeJet 11002 VS nozzles at 30 psi calibrated to apply 15 gpa. Crop oil concentrate (COC) at 0.5% vv was added to each fungicide treatment. Plots were arranged in a randomized complete block design with three replications. Individual plot size was 24 feet wide x 300 to 400 feet long to allow harvest using grower equipment. A weigh wagon was used to measure seed yields from each plot. Sub-samples of the harvested seed from each plot were collected to determine percent cleanout, 1000 seed weight and to calculate total clean seed yields.

Results

In general 2005 was considered a heavy stem rust infection year and rust infections began unusually early in many first year fields. Rust started earlier and was more severe in the North Valley field test (a first-year field) than in the 3-year-old South Valley field. In both field tests the most effective fungicide treatments resulted in significant seed yield increases over the untreated check.

Table 2 shows the results of the visual evaluations of rust infection levels, seed yield, 1000 seed weight and percent cleanout. In addition, an economic analysis of the costs and returns associated with fungicide applications is shown in Tables 1 & 3.

In the North Valley test, the model treatment had significantly less rust at the end of the season than the other treatments. Yields were generally similar among treatments. Although the model treatment yield was not significantly different from the mean of the other treatments, it was significantly less than the yield of the highest-yielding treatment. The number of fungicide applications was the same for the model treatment and the other treatments, so the cost was similar among treatments. Return per dollar invested in rust management was $7.16 for the model treatment, an average of $4.63 for the non-model treatments, but $8.40 for the best non-model treatment. That is, the model gave better economic return than the average of all the non-model fungicide programs, but not as good a return as the highest-yielding non-model treatment.

In the South Valley test, final rust severity was not significantly different among fungicide treatments. The model treatment used only one fungicide application whereas the other treatments used two applications, so the rust management cost was lower for the model treatment. Yields were not significantly different among treatments, so the return per dollar invested was better for the model treatment ($5.47) than for the others (less than $1.00).

As in the previous year's tests of the rust model in large plots, the 2005 test produced results that are related to the severity of rust in the field. Where rust develops early and severely, the number of applications suggested by the rust model is similar to the number used without the model, and therefore the model produces a similar result (with respect to economic return on rust management costs) as the non-model treatments. However where rust develops later or less severely, the rust model suggests using a smaller number of sprays. Provided the smaller number of sprays protects the crop adequately (as it did in this test), the economic return on rust management costs in less severely-diseased fields is better when the rust model projections are used than when they are not. Overall then, using the rust model as a decision aid in the 2004 and 2005 tests improved economic results in some of the cases and maintained economic return in most other cases, compared to applications made without the model information.

The 2005 rust model was a provisional version, and improvements are still being made. We anticipate that the performance of the model, with respect to economic optimization of rust management, will increase in coming years. In some cases, we expect that use of the model will reduce the number of sprays. In other cases, even when the number of applications is not reduced compared to traditional application schedules, the improved model should optimize the timing, and therefore the control obtained by the fungicide applications.

Acknowledgements

Appreciation is extended to Syngenta Crop Protection, Inc. for their support of these OSU Extension Service fungicide trials. We also express our appreciation for the cooperation of the growers who allowed us to use their fields and assisted with the seed harvest.

Table 1. Treatment table: fungicide application rates, timings, and costs, 2005.

Treatments	Application dates and rates (product/acre)					
North Valley site (var. Stellar)	4/26/05 2-3 node	5/12/05 Late flag Early boot	5/26/05 Mostly headed	5/28/05 Mostly headed	5/15/05 Late anthesis	6/24/05 Late anthesis
Quilt - Early treatment program	7 oz Quilt	6oz Tilt+1pt Echo	-	20.5 oz Quilt	6 oz Tilt	-
Headline - Early treatment program	6 oz Headline	6oz Tilt+1pt Echo	-	20.5 oz Quilt	6 oz Tilt	-
Amistar - Early treatment program	2 oz Amistar	6oz Tilt+1pt Echo	-	20.5 oz Quilt	6 oz Tilt	-
Tilt - Early treatment program	4 oz Tilt	6oz Tilt+1pt Echo	-	20.5 oz Quilt	6 oz Tilt	-
Standard treatment program	-	6oz Tilt+1pt Echo	-	20.5 oz Quilt	6 oz Tilt	-
Rust model treatment	6oz Tilt+1pt Echo	9 oz Quadris	9 oz Quadris	-	-	20.5 oz Quilt
South Valley site (var. Paragon)	5/2/05 1-2 node			5/28/05 Mostly headed	6/14/05 Late anthesis	
.Quilt - Early treatment program	7 oz Quilt	-	-	6oz Tilt+1pt Echo	-	-
Headline - Early treatment program	6 oz Headline	-	-	6oz Tilt+1pt Echo	-	-
Amistar - Early treatment program	2 oz Amistar	-	-	6oz Tilt+1pt Echo	-	-
Tilt - Early treatment program	4 oz Tilt	-	-	6oz Tilt+1pt Echo	-	-
Standard treatment program	-	-	-	6oz Tilt+1pt Echo	-	-
Rust model treatment	-	-	-	-	20.5 oz Quilt	-

Note: Applications with 1/2 % COC, 30 psi, 15 pga.
Varieties: Stellar, 1st seed crop (north valley) and Paragon, 3rd seed crop (south valley).
Costs include product, COC surfactant, and application.

Costs used in economic analysis is Table 3.

Tilt	$270/gal
Quadris	$274/gal
Headline	$225/gal
Quilt	$205/gal
Amistar	$85.50/lb
Echo	$37.50/gal
COC (Crop Oil Concentrate)	$7.85/gal

Table 2. Results summary: the effect of fungicides on stem rust severity and seed yield of turf type perennial ryegrass in the north and south Willamette Valley, 2005.

	Results								
	North Valley (var. Stellar)				South Valley (var. Paragon)				Two-site average seed yield
Treatments	Rust (6-30-05)	Seed yield	Cleanout	1000 seed wt.	Rust (7-2-05)	Seed yield	Cleanout	1000 seed wt.	
	(%)	(lb/a)	(%)	(g)	(%)	(lb/a)	(%)	(g)	(lb/a)
Untreated Check[1]	73	544	6.1	2.02	58	1015	25.0	1.70	780
Non-rust model treatments									
Five treatment mean[2]	10	1923	2.6	2.12	6	1213	20.0	1.88	1568
Highest yield treatment	9	2043	1.0	2.15	9	1283	19.5	1.87	1663
Rust model treatment	2	1865	1.8	2.11		1322	18.2	1.95	1594
LSD 0.05	5	147	2.3	0.10	10	297	1.9	0.0	- 7

[1] The check was harvested as one strip and not included in statistical analysis for seed yield.
[2] Average of five fungicide treatments reported in "Effect of early fungicide applications on the seed yield of perennial ryegrass".

Table 3. An economic comparision of the net return above product and application costs from fungicide treatments on two perennial ryegrass seed fields, Willamette Valley, 2005.

		Results									
		North Valley				South Valley					
Treatments Fungicide	Cost	Seed yield	Added seed	Net return	Return per $ invested	Seed yield	Added seed	Net return	Return per $ invested	Two-site average net return	Two site average return per $ invested
	($/a)	(lb/a)	(lb/a)	($/a)	($)	(lb/a)	(lb/a)	($/a)	($)	($/a)	
Untreated Check	0	544	0	$0.00	$0.00	1015	0	$0.00	$0.00	$0.00	
Non-rust model											
Five treatment mean[1]	$84.52	1923	1379	$673.93	$4.63	1213	198	$24.38	$0.29	$349.16	$2.46
Highest yield	$87.70	2043	1499	$736.75	$8.40	1283	268	$59.70	$0.68	$398.23	$4.54
Rust model											
South Valley (1 app)	$26.11					1322	307	$142.74	$5.47	$390.15	$6.32
North Valley (3 app)	$89.00	1865	1321	$637.55	$7.16						

[1] Average of five fungicide treatments reported in "Effect of early fungicide applications on the seed yield of perennial ryegrass".

OCCURRENCE OF A *TILLETIA* SP. IN CHEWINGS FESCUE FIELDS IN OREGON

S.C. Alderman and L.M. Carris

An undescribed species of *Tilletia* with reticulate teliospores was recently found in a shipment of fine fescue seed from the U.S. to China. This fungus was also detected in perennial ryegrass (*Lolium perenne*) seed from Australia. It forms 20-40 uninucleate, nonconjugating basidiospores, while most reticulate species such as *Tilletia bromi, Tilletia controversa* and *Tilletia caries* produce basidiospores that conjugate immediately. In addition, not all seeds in an infected head are bunted, as is the case with *T. bromi, T. controversa* and *T. caries*. Although infected seeds were found in seed shipments, infected plants in the fields had not yet been seen. During 2005, a survey of fine fescue fields was initiated to verify whether this *Tilletia* species was occurring in fine fescue fields in Oregon. During the first week of July 2005, 50 seed heads were collected arbitrarily along each of four transects (200 seed heads total) arranged in a diamond pattern from each of 21 fine fescue fields in Marion County, including 11 fields of *Festuca rubra* var. *commutata* (Chewings fescue) and 10 fields of *F. rubra* var. *rubra* (creeping red fescue). Seed heads from each transect were placed in paper bags (50 seed heads per bag) and stored at room temperature until processed. In addition, 10 fields each of tall fescue (*Lolium arundinaceum*), perennial ryegrass, orchardgrass (*Dactylis glomerata*), and bentgrass (*Agrostis tenuis* or *A. stolonifera*) from Marion, Benton, Linn, or Lane Counties (Willamette Valley) were included in the survey. Seed heads from these grasses were collected within one week of swathing. Each seed head was gently threshed by hand, and the seeds from each individual seed head were examined under a dissecting microscope for presence of partially infected or fully bunted seeds. All samples were examined within 10 weeks of collection. The number of seed heads with bunted seeds and the number of bunted seeds per head were recorded. A seed head with a single fully bunted seed was found in each of two Chewings fescue fields. In a third Chewings fescue field a seed head with 39 fully bunted seeds was found, and 31 seeds on the head appeared healthy. Six additional bunted seeds were found among seed shattered from heads prior to examination. All infected heads included both bunted and healthy seed. Bunted seeds were not detected in the remaining fields. Spores from four bunts were germinated on water agar, and the characteristic nonconjugating basidiospores were observed. This study demonstrates that *Tilletia* sp. is currently present at a low level in fields of Chewings fescue in Oregon. The potential for increase of the pathogen in Chewings fescue or in other hosts such as perennial ryegrass is unknown. Additional surveys over the next few years will be required to assess the extent of occurrence of this pathogen and to determine whether or not it will increase in fields currently infested. It is not known whether the *Tilletia* sp. is a pathogen recently introduced into the U.S. or whether it has been present for some time. Occurrence of a new *Tilletia* species in fine fescue seed in the U.S. is of particular concern since presence of the pathogen in seed could seriously impact the U.S. fine fescue seed trade.

FAST AND ACCURATE METHOD FOR ESTIMATING SLUG DENSITIES

W.E. Gavin, G.M. Banowetz, J.J. Steiner, S.M.Griffith and G.W. Mueller-Warrant

Introduction
Four species of slugs cause serious economic losses to grass seed production enterprises in western Oregon seed fields. From October to June, slug damage causes stand loss, decreased yields, increased production costs from baiting and reseeding, and overall loss of plant vigor. With increasing use of no-till planting, improved field drainage, and full straw chop-back management, growers committed to these practices need dependable relief from slugs and other pests that damage newly planted stands. Although valuable observational and anecdotal information exists, it is sometimes hard to interpret and can be misleading because of differences in the biology of multiple species.

Information is lacking on the types of slugs present in western Oregon grass seed fields, how their life histories interplay with other organisms, population densities in relation to crop yield losses, and causes of variation within and among fields. Reliable approaches and techniques are needed to address some of these questions.

Methods for estimating slug densities
For years researchers, field scouts, and growers have used baited or un-baited refuge cover traps to measure activity levels of slugs when determining the effects of chemical control, bait efficacy, and rate and timing studies (Fisher et al., 1994, 1995, 1996, 1997, 1998). This technique, which involves the use of a board, blanket, or inverted flowerpot, has been the most frequently used tool to detect slugs in crops because it's cheap and relatively fast. However, this approach can sometimes bias the measurement of adult slug activity by not detecting juveniles and under or overestimating populations. Slug activity can be greatly influenced by temperature, precipitation, wind, and predators. A more reliable technique that measures total slug density is the cold water floatation method (South, 1992). This approach has been used for years, but is labor intensive, takes five days for final results, and requires space and patience to produce an accurate measurement of slug density. It involves excavating and transferring a 12″ x 12″ x 4″ deep sod sample back to the lab and into water to force slugs to the surface where they can be collected and counted. Other methods used by researchers studying earthworm populations have employed electrical currents, dryness, heat, and chemical expellants to drive the worms to the surface. Chemical expellants, such as formalin, St. Ives fluid, and others were poured directly onto the soil surface to bring worms to the surface, but were often fatal to slugs, and sometimes unsafe for humans (Lee, 1988; Baker, 1988).

The oil of mustard (allyl-isothiocyanate) was first used by C.H. Högger (1993), as a safe alternative for extracting earthworms, and at low doses, was effective for expelling slugs. Various concentrations of mustard oil and mustard powder were successfully tested on four snail species and three species of slugs. The solution penetrated the soil as deep as 32 in., which corresponds to the winter active zone for most slug species in western Oregon. Slugs, earthworms, and other invertebrates are all expelled from the soil using this method.

We demonstrated that this method is quick, cost effective, and reliable for extracting slug species found in soil and cropping conditions in western Oregon. This method enables an accurate estimate of the numbers of slugs in small or large field-scale bait trials, field variation pattern studies, and in seasonal and species difference trials. The approach can be used effectively to determine seasonal changes in slug age classes, slug numbers in relation to crop yields, to determine how slugs are affected by field drainage, and how slugs affect stand differences caused by different farming practice. Earthworm data obtained at the same time may be useful to determine biological activity levels in the soil.

Comparison of slug detection methods
We established experiments to compare the efficacy of the mustard extraction method with other approaches on western Oregon soil types during wintertime conditions in commercial south Willamette Valley fields. The conditions included no-till establishing and established grass, grass/white clover companion planting, and meadowfoam fields. The test compared refuge traps (activity pit traps), the traditional approach used to measure slug surface activity, with the mustard expellant and cold-water floatation methods that measure surface and subterranean slug densities.

Ten to 12 covered activity refuge pit traps were prepared by removing a plug of soil using a flower bulb planter, baited with organic dry dog food, and spaced diagonally along a transect approximately 300 ft apart across a 60 to 80 acre field. The numbers of slugs in each trap were counted after three days to determine if populations were sufficient to warrant comparison of the mustard expellant treatment and cold-water floatation methods.

Mustard solutions were mixed just prior to testing using one level tablespoon of dried mustard flour per gallon of water. The dried mustard was obtained from a local grocer in bulk quantities. The rocking motion of the ATV used to carry the supply of mustard solution to the testing stations in the field provided sufficient agitation to keep the mustard in suspension. The defined area for the mustard extraction consisted of a plastic bottomless five-gallon bucket. The bucket was driven into the soil to a depth of 4 in., mustard solution was poured to a depth of 1 in., and the bucket then covered with a lid (Figure 1). Total extraction time was 30 minutes and usually required an application of a second dose of mustard solution to keep the soil surface covered with solution. The slugs were collected from the soil surface, identified, and weighed so the age class could be determined. Twelve replicates across a 60 to 80-acre field take approximately one-and-a-half hours to complete.

Figure 1. Adding the mustard solution to a defined area quadrant (4 in. deep) for expelling slugs from the soil.

The cold-water floatation treatment method consisted of cutting out round sod or soil turves, 10½ inches in diameter x 4 in. deep that were removed from the field in buckets with lids and brought back to the laboratory. In the laboratory, 1 in. of water was added daily to slowly raise the level of water to crown height after four days. Slugs driven to the upper surface of grass blades, debris, or the bucket sides or lid were collected, identified, and weighed. Slug activity also was monitored with covered refuge pit traps for three days in the field during the experiment.

Table 1. Efficacy of field methods to quantify populations of the gray field slug.

	Slug density		Slug activity
Sites	Mustard expellant	Cold water extraction	Covered pit trap
	----------- (slugs/m^2) -----------		(Total slugs)
1	34	44	177
2	69	46	61
3	11	9	59
4	8	8	8
5	10	8	10
Average	26	23	63

The mustard extraction method was as good as the cold water floatation treatment method for accurately elucidating slug population densities (Table 1). This approach, albeit more time consuming than activity monitoring with surface traps, is quicker, more time efficient, and less labor intensive than the cold water floatation treatment method. Both the mustard extraction and cold water floatation methods accurately estimated absolute slug density. The surface activity refuge trap method may be less appropriate for accurate density studies. This mustard extraction method should prove to be a valuable adjunct to surface monitoring for farmers, company field representatives, and researchers to improve our understanding of the effects of farming practices on slugs and to develop more effective and economical approaches to control slug populations when treatments are needed.

Other findings

Timing of egg laying. We observed that our covered pit traps frequently became partially filled with residue and castings produced by near-by earthworm activity and were being used as egg-laying chambers for the Gray Field slug (*Deroceras reticulatum*), and to a lesser extent, the Brown-banded Arion (*Arion circumscriptus*)[1]. These observations suggested that this approach could be used as a tool for growers, researchers, and field representatives to monitor the onset of adult egg laying activities (Figure 2).

[1] This is a new report of a species of slug that is damaging to grass seed fields.

Figure 2. Pit trap showing egg masses and adult of the gray field slug. (Arrows indicate live slug and eggs). This technique can be used to monitor egg-laying activity.

Figure 3. Slug and slug eggs can be found, in an undisturbed position, in the soil matrix under close examination. By delineating the dimensions of the pit, data can be quantified and used as a comparative tool.

Egg monitoring traps were constructed by digging a pit 2 in. diameter x 3 in. deep using a bulb planter, partially filling with nearby residue or worm castings, and covering with a board or other suitable cover.

A test was established in a second year orchardgrass field in no-till high residue production with known moderate populations of slugs. The numbers of slugs and slug eggs were counted and collected every three days. Eggs were transported to the lab for further testing. Data were collected on 21 and 27 of February and 3 and 6 of March with 22%, 28%, 38% and 58% of traps containing eggs, respectively.

Differences in egg clutch numbers under residue levels. Sixteen excavated pits 20 in^2 x 4 in. deep were dug under high and low litter layer locations to observe the position and numbers of eggs and egg clutches and their relationship to residue levels (Figure 3).

The Brown-banded Arion slug lays most of its eggs, 13-21 eggs per clutch, in abandoned earthworm holes >5/16 inch in diameter, 0.5cm-5.5cm deep or deeper. Eggs are pearly white, 1.5-2.0mm in diameter, usually in tight clustered clutches. Eggs are stickier than the gray field slug eggs. The gray field slug generally lays loosely constructed clutches or single scattered translucent or cloudy-looking eggs 1.0-1.5mm in diameter. Eggs of this species are most commonly found in the O-layer of soil, the rich interface between litter and mineral soil, deep in older plant crowns, in soil cracks, and rarely in abandoned earthworm holes. Soil temperatures averaged 50.5°F on bare soil and 45.5°F under residue levels at 5.0cm depth. Air temperature on the day of excavation was 53.7°F.

Table 2. Late winter residual straw piles give the brown-banded Arion optimum environments for egg-laying and juvenile survivability.

Residue	Straw biomass	Eggs average depth	Eggs per clutch	Egg density
	(g)	(mm)	(no.)	(m^2)
High	595.8	29	15	357
Low	26.50	2.5	3.5	26.5
Probability	0.001	0.001	0.001	0.001

Conclusions

We have demonstrated the use of a rapid extraction technique to study the densities of slugs and their age class presence. This technique has the advantage over refuge-type traps by sampling both juvenile and adult stages of slugs. Understanding the age structure of slug populations may help us understand the efficacy of baits on juveniles, why slugs seem to re-emerge after bait treating, how we may better stage treatment effects for the future crop, and in constructing a life history table to compare with predator interventions and weather.

Studying the timing and occurrence of egg laying using our pit trap method, will help researchers, commercial field scouts, and growers detect future problem fields or potential 'hot spots' in fields, help researchers easily locate an abundance of eggs for possible predator and parasite occurrence and research testing, and help in the development of a weather-timing model.

Excavating replicated 20 in^2 soil pits will help researchers understand why and where 'hot spots' of slugs emerge, and quantify some of the requirements for egg laying sites such as residue layers or pooling, drainage differences, weed outbreak spots, bait treatment effects, crop age or type, and effects of crop and soil management.

Acknowledgements:

We would like to thank the growers Brian Glaser, Dave Goracke, George Pugh, and Don Wirth for the use of their land, their insights on slugs, and helpful suggestions. Also to Richard Caskey for the photographs, helpful design concepts, and help in the field.

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TWO SEED-FEEDING THRIPS PEST SPECIES DETECTED IN GRASS SEED PRODUCTION FIELDS IN THE WILLAMETTE VALLEY

S. Rao and A.F. McKinnis

Introduction
A new seed-feeding thrips, *Chirothrips manicatus*, was reported developing in florets of bentgrass in seed production fields in the Willamette Valley in 2004 (Rao and Alderman, 2005a, b). Florets infested with a thrips had no trace of a caryopsis, and hence the presence of one thrips represented the loss of one bentgrass seed. In New Zealand, this thrips is a pest in orchard grass (Doull, 1956a; Morrison, 1961), and has been reported to cause over 30% damage to the seeds (Doull, 1956b). It is not known how long this thrips pest has been present in Oregon, whether it attacks orchard grass in the Willamette Valley, and whether other grasses raised for seed production in Oregon are also at risk. Hence we conducted a study to determine the host range of *C. manicatus.*

Material and Methods
Field survey: We surveyed seed production fields of annual and perennial ryegrass, orchardgrass, tall fescue and fine fescue in the Willamette Valley. We also repeated the survey of bentgrass fields conducted the previous year. For each crop three fields were surveyed, and in each field, approximately 50 panicles were collected at random along each of four transects. A random sample of 3000 florets from the 200 panicles per field was selected and each floret was examined under a stereo microscope using dark field illumination with transmitted light.

Thrips identification: The thrips were separated from the florets, recorded, and preserved in ethyl alcohol. A random sample of thrips were mounted on slides. There appeared to be more than one species of thrips. Hence the specimens were sent to thrips specialists at the Systematic Entomology Laboratory, Washington DC, for identification.

Seed Loss: The number of thrips recorded in 3000 seeds per field (1000 seeds from tall fescue fields) was used to estimate percent seed loss as the presence of each thrips resulted in the loss of one seed.

Results
Field survey: Thrips were detected in 15 (83.3%) of the fields that we surveyed. We found thrips in annual and perennial ryegrass, orchardgrass, fine fescue and bentgrass. No thrips were detected in any of the three tall fescue fields surveyed.

In annual and perennial ryegrass, orchardgrass, and fine fescue, we observed the presence of not one but two thrips pest species. The two species were oriented in the same manner with the head towards the base of the florets. Only one species was present in bentgrass.

In each crop studied, the seed-feeding thrips was observed developing on the embryo and the endosperm. It was present enclosed firmly within the lemma and palea and hence detection of this pest in the crop was challenging. The only way the pest could be seen was by examination of each seed under a microscope with light shining from below.

In florets where adult thrips were detected, the seeds were destroyed to varying levels. As the thrips were feeding on the developing embryo, the presence of each thrips resulted in the loss of one seed.

Thrips identification: The two thrips species differed in size and in other characters. They were identified as *C. manicatus* and *Limothrips cerealium* (Figure 1). The latter are larger in size compared to *C. manicatus* and can be easily distinguished based on the shape of the pronotum (segment adjacent to the head) and a set of spines on the terminal body segment.

Figure 1. Seed-feeding thrips in grass seed production fields in the Willamette Valley: *Chirothrips manicatus* (left) and *Limothrips cerealium* (right).

Seed Loss: Seed loss was estimated from the number of thrips observed as the presence of one thrips resulted in the loss of one seed. Over all estimated seed loss in grasses infested with thrips ranged from 0.06 % to 2.9 %. Seed loss varied with grass seed host (Table 1). The actual seed loss is speculated to be higher as we recorded only infested seeds occupied by female thrips. Female thrips remain in the floret while males leave soon after emergence. According to Morrison (1961) the sex ratio is 50:50. Hence the number of seeds destroyed could be double the number of female thrips found in seeds collected at harvesting.

Table 1. Presence of seed-feeding thrips in grass seed fields in the Willamette Valley based on a survey conducted in summer 2005. Three fields were surveyed for each crop, and 3000 seeds from each field were examined under the microscope.

Grass seed crop	Percent fields infested	Thrips species detected	Mean seed loss due to thrips*
	(%)	(#)	(%)
Perennial ryegrass	100	2	1.04
Annual ryegrass	100	2	0.58
Orchardgrass	100	2	0.06
Fine fescue	100	2	0.24
Tall fescue**	0	0	0
Bentgrass	100	1	2.9

* Seed loss could be double as only seeds with female thrips were recorded and the species is speculated to have a 50:50 female:male ratio.

** Only 1000 seeds surveyed.

Discussion

This is the first report of *C. manicatus* in commercial fields of perennial ryegrass and fine fescue anywhere in the world. It has been reported as a pest in orchardgrass in New Zealand where a population density of 20 thrips per inflorescence was reported to cause 30% seed loss (Doull, 1956b). This thrips pest has been reported in bentgrass in New Zealand and Europe (Mound and Walker, 1982; Zur Strassen, 2003), but no information is available on the impact on seed production. In our earlier study, we reported seed loss ranging from 0.8% to 5.1% in Highland bentgrass (Rao and Alderman, 2005).

This is also the first report of *L. cerealium* in perennial ryegrass and fine fescue anywhere in the world. *Limothrips cerealium* is known as the cereal or the grain thrips. It is widespread in temperate regions and causes severe reduction in grain yield in wheat, oats, barley and maize. According to Sharga (1933), it could be responsible for destruction of 38% of spikelets in oats. As cereal plants dry, the mated females leave the crop and move to grasses (Doull, 1956a). However, unlike *C. manicatus*, *L. cerealium* has not been observed breeding in orchardgrass in New Zealand.

In our study, while *C. manicatus* and *L. cerealium* were present in annual and perennial ryegrass, orchard grass and fine fescue, only *C. manicatus* was present in bentgrass. Of the two species, the predominant species was *C. manicatus*. It is possible that the size of bentgrass seed is not large enough to support development of the larger *L. cerealium*.

Infestation levels in all grass seed crops surveyed in our study in the Willamette Valley were low. As mentioned earlier, the levels could be double the numbers listed in Table 1 as seeds infested by male thrips were not counted. It is also possible that we underestimated infestation levels as the early stages of thrips development may have escaped detection under the microscope. In 2005 infestation level in bentgrass was close to half the infestation level observed the previous year when a much larger number of seeds (seeds from 50 panicles per field) were examined. Examination of each seed under the microscope is labor intensive and time consuming, and we extended the study to include 5 additional grasses, hence we limited the study to examination of only 3000 seeds per field. This may also have resulted in the lower seed loss.

Post (1947) reported the presence of both *C. manicatus* and *L. cerealium* in Oregon. However it is not known for how long these seed-feeding thrips pests have been present in grass seed production fields in the Willamette Valley. As there is no external indication of thrips within the seeds, their presence could have remained undetected for a while. The source of seed-feeding thrips pests in grass seed production fields is also unknown. It is possible that infestation levels have built up in recent years as a result of the phase-out of the practice of burning the straw residue in fields after harvest. Many thrips are likely to be taken away from the crop at harvesting but some florets fall off at or prior to harvest, and these could infest the crop the following year. Males mate and die by the end of summer, but females overwinter in the dead florets. Burning could well have resulted in extensive thrips mortality in grass seed fields and reduced populations of thrips overwintering in the crop. Another source of infestation could be grasses present around the seed production fields. Currently, there is no information of the presence of *C. manicatus* and *L. cerealium* in wild grasses adjacent commercial fields in the Willamette Valley.

We plan to continue surveys in grass seed production fields to evaluate the impact of seed feeding thrips on seed yield in grass seed production fields in Oregon, and to determine pest management strategies if population sizes increase in the future.

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MEADOWFOAM MANAGEMENT IN PERENNIAL GRASS SEED PRODUCTION SYSTEMS

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Introduction

There has been a rapid change in the practices used to produce western Oregon perennial grass seed crops because of the phase down in open field burning of straw (Steiner et al., 2006a). Also, a majority of the seed crop being produced is private turf-type cultivars that meet high quality market demands, in contrast to earlier times when public forage cultivars dominated the market (Meyer and Funk, 1989). As a result, the length of time that perennial grass seed fields remain in production has shortened to as few as three or four years, compared to times past when stands could remain in production for 10, 20, or more years. Because grass seed crops readily shatter when reaching maturity, added pressures have been placed on seed growers to meet genetic purity standards when changing cultivars of the same species (Mueller-Warrant et al., 1995; Young and Youngberg, 1996).

Poorly drained soil conditions where grass seed crops are often grown limit the rotation crop options for these systems. Meadowfoam has emerged as an additional crop option that can be added to the present rotation crops that include spring wheat and white clover seed. Meadowfoam produces high quality oil that gives this crop potential for usage in the production of lubricants, cosmetics, rubber additives, and plastics.

Alternative conservation production systems, including no-till seeding combined with maximal residue chopped back onto fields, have been shown to be suitable for producing perennial grass seed without need for conventional tillage establishment and straw removal by baling after seed harvest (Steiner et al., 2006a). However, information is scant that reports how these conservation practices affect meadowfoam seed yield and seed oil content. Work by other researchers has shown meadowfoam does not respond positively to added nitrogen fertilizer (Jolliff et al., 1993). The purpose for this research was to determine how to manage meadowfoam as a rotation crop component in perennial grass seed production systems that use conservation practices suited to western Oregon.

Methods and materials

The study was conducted as a series of experiments in 1996-97, 1997-98 and 2000-01 at three long-term research sites in the Willamette Valley as a part of an experiment maintained from 1992 to 2001 (Steiner et al., 2006c). The long-term study determined the effects of alternative conservation practices to burning straw on temperate perennial grass seed production (Steiner et al., 2006a). The Linn County site was a poorly drained commercial field where perennial ryegrass and annual ryegrass were grown for seed. The Benton County site was a poor to moderately well drained soil on the Hyslop Research Farm in an area where tall fescue seed and other crops adapted to better-drained soil conditions are grown. The Marion County site was a well-drained commercial field with a 2 to 12-percent sloped erodible soil where creeping red fescue seed is grown.

Nine total experiments were conducted in the three production seasons using different arrangements of production sites, rotation crops preceding the meadowfoam crops, establishment methods, residue management amounts, and combinations of spring-applied herbicide and nitrogen fertilizer amounts and times of application. Main plots at all three sites were approximately 60 feet wide x 100 feet long with four main plots arranged in a randomized complete block design. The previous crops in the rotation sequences with meadowfoam were white clover grown for seed, oat grown for seed, spring wheat, or tall fescue seed. Plot preparation for planting by conventional tillage was done using a tractor-powered rotor-tiller to simulate plow and disc operations. Plot preparation by both conventional tillage and no-till planting were seeded using commercial double-disc openers. All herbicides used were registered and used per label recommendations and farmer practice. Meadowfoam seeds were harvested using a Carter flail plot-scale forage harvester, collected in burlap bags, and immediately dried in a walk-in, gas-heated drier, and then weighed. Seed yield was determined after the seeds were separated from plant material using a Kurt Pelz Saatmeister seed thresher. Seed oil percentage was determined by near infrared spectrophotometry, and oil yield determined as the product of seed yield and seed oil content percentage. Total plant phytomass was determined by subtracting the weight of the seeds from the initial harvested dry mass. The relationship between seed yields and seed oil contents was plotted for all treatment combinations.

<u>Fertilizer-Herbicide treatment combination experiments</u>. This experiment was conducted two years at the Linn County site with no-till establishment. Seven combinations of spring-applied herbicide (H) and fertilizer treatments (F) were applied. The mixtures of herbicides (spring herbicide regime) were clethodim (Select®), sethoxydim (Poast®), and clopyralid (Stinger®). The fertilizer was 40 pounds per acre of nitrogen in the form of urea. The chemical treatments were either made at the time when producers would normally make applications to their fields (+) (19 and 16 March in 1998 and 2001, respectively), delayed (d) (14 and 24 April in 1998 and 2001, respectively), or not applied (-). Autumn-applied metolachlor was applied to all treatments in 1997 and 2000.

The combinations of fertilizer and herbicide treatments were chosen after an experiment was attempted in 1996-97 in which annual bluegrass was still abundant after using the spring-applied clethodim, sethoxydim, and clopyralid herbicide regime, without autumn-applied metolachlor (Dual®). Annual bluegrass growth was greatly reduced in the no-nitrogen fertilizer plots by the application of spring-applied herbicides, compared to plots that received nitrogen fertilizer. Annual bluegrass plants in the no-nitrogen plots were also greatly infested by powdery mildew. Periods of precipitation during late-winter rainfall may affect when farmers can apply herbicides. In addition, reductions in production costs, such as not using herbicides or fertilizers, would increase net return for a rotation crop grown in sequence with profitable grass seed crops. All of theses perspectives were used to choose the fertilizer and herbicide application treatments.

Conservation practices effects. Results from six experiments conducted at the three sites in 1998 and 2001 were pooled to compare no-till seeding with conventional tillage establishment. In addition, soil compaction measurements were taken at four depths in each block replication of a comparison of no-till seeded and conventional tillage establishment plots at the Linn County site in 1997 using a Dickey-john Soil Compaction Tester. Only the results from the first four depths are reported. Seedling emergence counts were also made for six 3.1 feet lengths of planted rows in each plot. The effects of establishment methods on soil compaction and seedling emergence in 1997 were assumed to be applicable to the results that would have been obtained in 1998 and 2001 conditions.

Grass seed residue amount treatments applied were determined for those plots that had perennial grass seed as either the immediate prior or two crops prior in the rotation sequence. There was one grass straw management amount comparison for each of the three locations.

The Revised Universal Soil Loss Equation (RUSLE) using RUSLE 1.06c software was used to estimate the annual amount of soil erosion in the planting method and residue management comparisons. The crop production calendar for RUSLE was based on a 15 August start date. A partial budget approach was used to compare the estimated costs of the different establishment systems. All other production practices were considered the same, regardless of the establishment system, so are not included in the budget costs.

Relay established tall fescue spring-planted into meadowfoam. Comparisons were made at the Benton County site for no-till planted tall fescue seeded on 9 March 1998 into autumn-planted meadowfoam with meadowfoam grown alone, and then tall fescue planted in autumn on 19 October 1998 after meadowfoam seed harvest in summer. The spring relay seeding of tall fescue was done when the meadowfoam plants were still in the rosette stage of development, before the plants had begun to enlarge and fill in the area between planted rows. The relay-planted tall fescue was seeded in the same direction as the meadowfoam. Meadowfoam was harvested in the summer 1998 as described above, leaving the newly established tall fescue plants. Tall fescue seed yields were determined in 1999, 2000, and 2001 for the relay-planted and autumn-planted treatments using plot-sized harvest equipment as described in Steiner et al. (2006a).

Results and Discussion

Spring-applied Fertilizers and Herbicides. There was a range of meadowfoam responses for seed yield, seed oil content, and oil yield to the seven fertilizer-herbicide treatment combinations (Figure 1). In all cases, the no-fertilizer-or-no-herbicide treatments produced responses for all yield components that equaled or exceeded any other treatment combination. We had hypothesized that annual bluegrass would be more susceptible to the spring-applied herbicides if the nitrogen fertilizer application was delayed until powdery mildew infestations were present. Delaying the nitrogen fertilizer application would also allow the meadowfoam to grow and better compete with the annual bluegrass until the herbicide became effective.

Fertilizer treatment effects. Treatment plots that received no nitrogen produced greater seed and oil yields than those receiving mid-March or delayed-April applications of nitrogen (Figure 1). Seed oil percentage was not affected by the fertilizer treatments. In the only other reports of nitrogen application effects on meadowfoam production, seed yield and seed oil percentage were reduced when 69 or more lbs per acre of nitrogen were applied in late-February, compared to no fertilizer applied (Jolliff et al., 1993). Our results show that even lower rates of nitrogen fertilizer do not increase seed yields and further substantiates meadowfoam grown in this region does not need nitrogen fertilization. These findings suggest that residual amounts of nitrogen remaining after grass seed production may adversely affect meadowfoam grown in a rotation cycle.

Herbicide treatment effects. Regardless of the timing of the spring herbicide regime, seed and oil yields were adversely affected by the herbicides, compared to the no herbicide treatment (Figure 1). Seed and oil yields were more adversely affected by the delayed mid-April application than the earlier application in mid-March. Seed oil percentage was only decreased with the delayed herbicide regime application.

Inclusion of the autumn-applied metolachlor resolved any annual bluegrass problem that may have occurred, as was observed in the 1997 experiment. Any weeds that are not controlled by the pre-plant and pre-emergence herbicide applications can be controlled by a spring-applied herbicide regime. However, we observed minimal weeds remaining in the plots in the spring, following the autumn-applied herbicide applications.

If the spring-applied herbicide regime is used, then it appears that the earlier the herbicides are applied to emerged annual bluegrass seedlings, the better. However, the spring herbicide

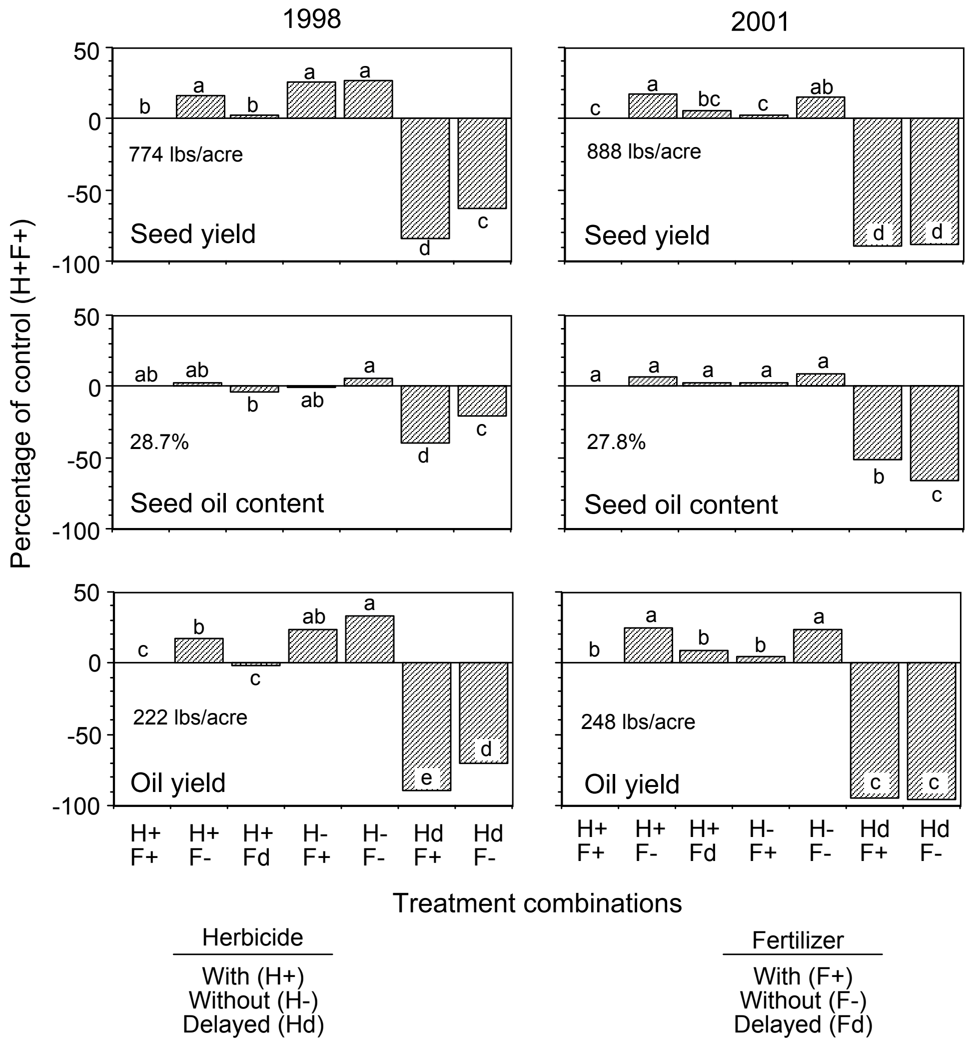

Figure 1. Effects of seven spring-applied fertilizer and herbicide treatments on seed yield, seed oil content, and oil yield of no-till planted meadowfoam grown as a rotation crop for perennial ryegrass seed on a poorly drained soil in western Oregon in 1998 and 2001. Specific herbicide and fertilizer treatment combinations are described in the manuscript. The H+F+ control treatment is the combined application of herbicide and fertilizer at typical spring timing after weed seedlings have begun to emerge. The mean seed yield, seed oil content, and oil yield for each control in both years is shown in each graph. Bars within each graph shown with the same letter are not different at $P \leq 0.05$ according to Duncan's New Multiple Range test.

regime is effective only with emerged weeds, so there is an advantage to delaying application time to get the greatest control efficacy. Under these growing conditions, annual blue grass has a major peak emergence period in late-November and a lesser peak in early-April, so the mid-March application time could miss some delayed emergence weed seedlings. The trade-off with delayed herbicide applications is the adverse effects on oil yield (Figure 1).

The lowest seed yielding treatment combinations also had the lowest seed oil percentages (Figure 2), indicating that not only are the number of florets produced reduced by herbicide applications (G. Hoffman, personal communication, 2005), but also the seed capacity to produce oil. Practically, given the negative impacts of spring-applied herbicides on seed oil yield, farmers should pay particular attention to whether the spring herbicide use is needed based on the anticipated needed efficacy for weed control for subsequent grass seed production. Depending upon the kinds of weeds present in spring, the detrimental effect of the spring herbicide regime should be considered in light of the amount of meadowfoam production that will be lost.

Conservation Practices Impacts

No-till establishment. Meadowfoam average seed and oil yields were greater when using no-till seeding than conventional tillage establishment (Table 1). Seed oil percentage was unaffected by the establishment method. Another benefit from using no-till seeding is the reduced cost of establishment, compared to conventional tillage costs. The cost savings for no-till seeding meadowfoam with non-selective herbicide compared to conventional tillage establishment after tall fescue, red clover, wheat, and white clover were $41.51, 46.46, 51.41, and 31.61 per acre, respectively.

The tilled soil layer of poorly drained Amity silt loam soils at the Linn County site became saturated with water when winter precipitation began. As a result, the soil was less resistant to a penetrometer probe to the depth of the tillage layer, than the untilled soil (Table 1). The soil became more resistant at the depth below the tillage layer, and then was similar to that of the untilled soil. The unstable soil in the conventional tillage plots also resulted in fewer seedlings emerged and less total plant phytomass, compared to the no-till seeded establishment treatment. These unstable soils cannot be driven on by farm equipment without substantial tire traffic marks until the soils drain in the spring.

Spring relay planted tall fescue. The stability of the soil in no-till seeded meadowfoam provides additional crop management options to perennial grass seed growers. Tall fescue can be no-till planted in spring as a relay crop into an already-established autumn-planted meadowfoam stand while the plants are in the small rosette development stage, without adverse effect on seed yield (Table 2). This allows a unit of land to produce income each year without the loss of revenue that otherwise occurs during the establishment year of a conventional tillage established tall fescue seed crop planted in spring. The weed control benefit of the meadowfoam rotation crop is also realized. Alternatively, an autumn-planted tall fescue produces a reduced seed crop the following summer (Table 2), so only a portion of the income lost would be gained, compared to the typical winter-fallow system with spring-planting that yields a full crop, but that requires one year to establish without income. In general, the disadvantage to using tillage to prepare fields for autumn planting or winter fallow is the spring-planted crop cannot be seeded by relay or conventional establishments methods the next spring until soil conditions become stable after the soil drains. This is typically three or four weeks later than in the no-till management system.

Maximal residue management. There were limited experimental combinations to compare the effects of maximal and minimal residue management amount on meadowfoam production. For the three experimental combinations where residue amounts could be compared, the amount of residue left on the plots had no effect on the meadowfoam yield components (average meadowfoam seed yields for maximal and minimal residue management amounts were 692 and 659 lb per acre, respectively). The lack of response to residue amounts are similar to those reported from farmer field trials (Jolliff, 2004). These findings are also similar to the lack of responses when comparing straw management amounts on seed yields of perennial ryegrass, tall fescue, and creeping red fescue (Steiner et al., 2006a).

When producing meadowfoam, there are other advantages for using maximal residue management from the preceding perennial grass seed crop grown in the rotation sequence. Maximal grass seed crop residue management reduces the estimated amount of soil erosion during meadowfoam production, compared to minimal residue management, especially when combined with no-till planting (Figure 3). With these conservation practices combined, only 2.8% of the annual erosion amount occurs, compared to a conventional tillage with minimal residue management system. Meadowfoam seeded in late-November and December provides little ground cover during the winter months, so when meadowfoam is grown using these conservation practices, the effect of poor relative soil cover by meadowfoam on soil erosion should be significantly mitigated. This will be especially evident on steep slopes with erodible soil such as where creeping red fescue seed is grown (Figure 3). The meadowfoam crop provides a break in the rotation creeping red fescue crop sequence to maintain crop genetic purity and allow use of no-till planting (Steiner et al., 2006a). Meadowfoam used as a rotation crop also reduces the short-term activity of gray-tailed voles in no-till perennial grass seed production systems (Steiner et al., 2006b).

Conclusions

This research determined the suitability of meadowfoam as a rotation crop in western Oregon perennial grass seed

Table 1. Analysis of variance results comparing the effects of no-till seeded and conventional tillage established meadowfoam grown at three sites in 1998 and 2001 in western Oregon.

Establishment method	Seed yield	Oil Content	Oil yield	Total phytomass	Emergence†	Penetrometer† depth (inches) 0 to 3	3 to 6	6 to 9	9 to 12
	(lb/acre)	(%)	(lb/acre)	(lb/acre)	(per foot^2)	------------------ (lb/inch^2)-------------------			
No-till seeded	736	28.7	211	2703	38.6	113	110	124	138
Tillage	572	28.9	168	1790	21.4	65	85	150	131
Difference	***	NS	***	*	***	**	*	*	NS

NS, *, **, and *** indicate: not significant and significant at $P \leq 0.05$, 0.01, and 0.001, respectively.
† These data were obtained from the 1997 experiment conducted at the Linn site.

Table 2. Comparison of meadowfoam and tall fescue seed yields grown at the Benton County site from autumn established meadowfoam with tall fescue relay-planted by no-till planting in spring with tall fescue planted by conventional tillage in spring after winter fallow. Tall fescue seed yields were determined for three crop years during the period from 1999 to 2001.

Crop rotation component	Establishment system: Spring relay-planted no-till seeding	Autumn conventional tillage	Establishment system difference
	-----------------------(lb/acre)	---------------------	*(Probability)*
Meadowfoam	653.9	710.1	NS
Tall fescue seed year:			
First	873.2	135.4	**
Second	1619.7	1594.6	NS
Third	1768.1	1521.9	**
Total tall fescue	4261.0	3251.8	**

NS and ** indicate: not significant and significant at $P \leq 0.01$, respectively.

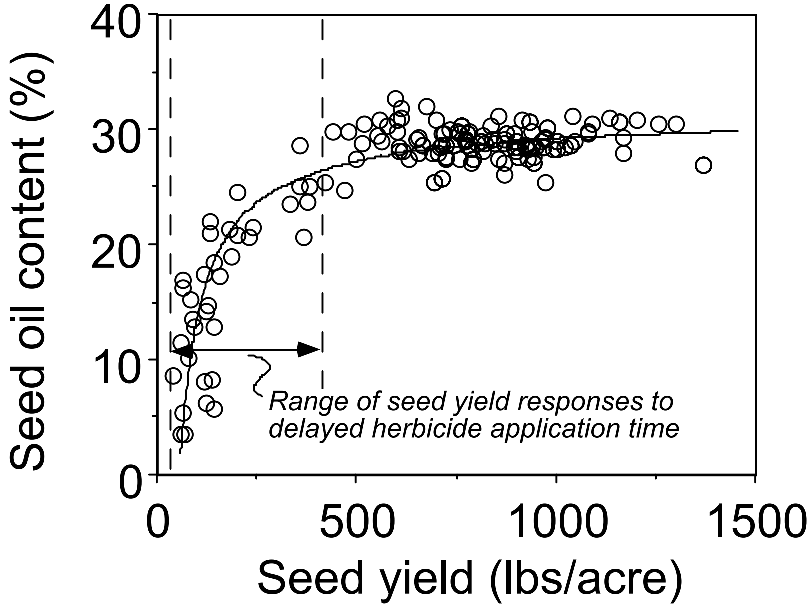

Figure 2. The effect of the resulting seed yields from all treatment combinations on seed oil content percentage in 1998 and 2001 at three research sites in western Oregon. Vertical broken lines show the range of seed yields resulting from delayed herbicide application treatments.

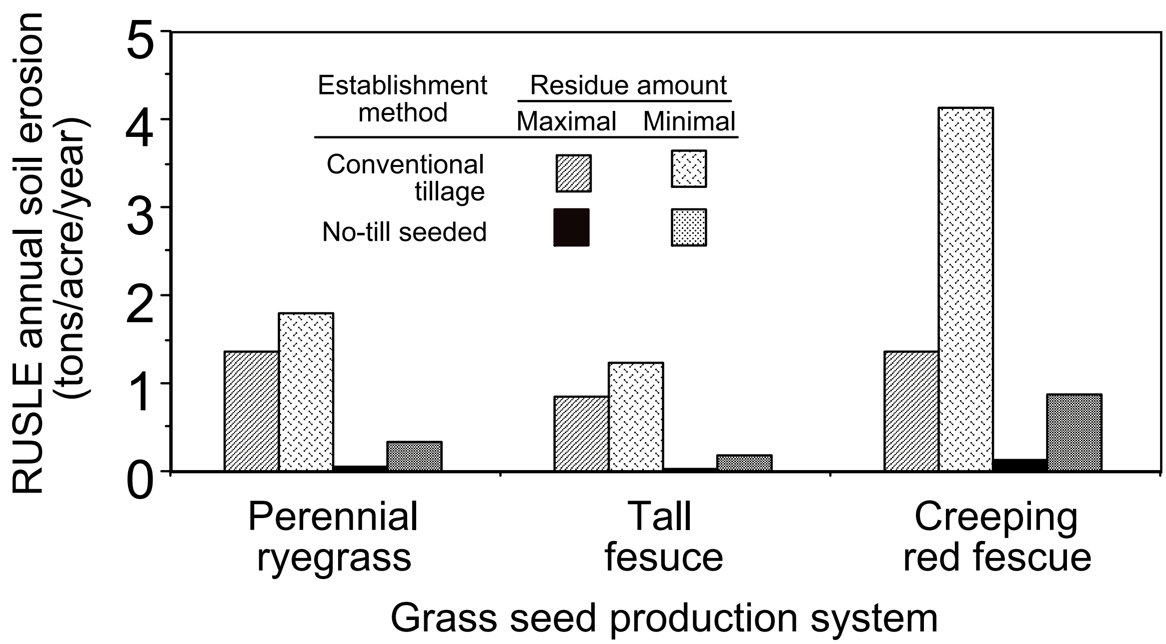

Figure 3. Comparison of conventional tillage and no-till establishment methods and maximal and minimal amounts of post-harvest straw returned to fields prior to autumn-planted meadowfoam in rotation sequence following perennial grass production on estimated annual soil erosion amount. Results are for the meadowfoam rotation crop component used in three perennial grass seed systems typical to western Oregon. Soil erosion is estimated by the Revised Universal Soil Loss Equation (RUSLE 1.06c software).

production systems. Meadowfoam is suited to low input production and is adapted to the use of conservation practices, including no-till seeding and maximal residue management of perennial grass seed crops. Meadowfoam did not require a supplemental application of nitrogen fertilizer in spring to achieve maximal yield. The suite of spring-applied herbicides used to control any grassy or broadleaf weeds that may emerge in spring decreased seed yield and seed oil content, especially if application time was delayed. The lower cost of establishment using no-till seeding provides an additional benefit, compared to conventional tillage establishment. Concurrent with lower establishment costs, use of no-till seeding and maximal residue management should also reduce soil erosion when meadowfoam is inserted into a perennial grass seed crop rotation system.

Acknowledgments:
The authors thank William Gavin, Scott Culver, and Richard Caskey for technical assistance with this project. This research was funded in part by grants from the Oregon Department of Agriculture, Alternatives to Field Burning research program (Grant no. ARF C36-0074-92). We are most grateful to Bruce Jaquet, Dwight Coon, and Mike Coon for their long-term commitment to the use of their farms while we conducted this research.

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BIODIESEL FEEDSTOCK POTENTIAL IN THE WILLAMETTE VALLEY

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Introduction

Biodiesel feedstock crops grown in rotation with grass seed crops in the Willamette Valley can increase the profitability of grass seed production enterprises while reducing weed and disease problems. Rising fuel prices and international instability make the search for alternative fuel sources even more important, and at this point these fuels need to be imported from outside the region. Rather than import these fuels, it is possible for them to be grown and refined locally. Virtually all biodiesel sold in the Pacific Northwest is imported from the Midwestern US, while acceptance of biodiesel as a transport fuel in our region is very high. Local biodiesel processors are currently limited to using waste grease as a feedstock. Availability of inexpensive, locally grown feedstock will help to expand the biodiesel industry in the Pacific Northwest. Annual consumption of diesel in Oregon is 800 million gallons.

Potential Feedstock Crops

Soybean. Soybeans are the major source of oil for biodiesel in the US, but are not well adapted to the environmental conditions prevalent in the Willamette Valley. Under Willamette Valley conditions, oil yields for soybeans will be in the range of 15 to 25 gallons per acre based on OSU's research on the crop whereas the national average is 57 gallons per acre. No breeding and crop development programs are present in the Pacific Northwest, so the prospect of locally adapted soybean cultivars for the region is rather remote. The energy balance for soybeans is 3.2:1, according to the US Department of Energy.

Yellow Mustard. Yellow mustard (*Sinapsis alba*) has some potential as a biodiesel crop in the Willamette Valley, but we have no information on the adaptation of this crop at this time. We are currently conducting trials on yellow mustard. The crop has several attractive features including potential for good oil yields (about 100 gallons per acre at a projected 3000 lbs per acre seed yield). The crop has shown this level of seed yield performance at high rainfall sites in northern Idaho. Another reason to consider yellow mustard is that it is not a member of the genus *Brassica* like canola and so it does not fall under the production restrictions recently imposed by the ODA. The crop has a several drawbacks as well. The oil concentration in the seed is lower than canola (27% vs. 40%) and the meal is high in glucosinolates, making the meal not suitable for consumption by livestock. The meal might be saleable in the natural pest control market. The plant breeding program at the University of Idaho has released one commercial variety and is working on developing new lines. Only spring varieties of yellow mustard are available at this time. The energy balance for yellow mustard is unknown.

Sunflower. Sunflower has limited potential as an economic biodiesel crop in the Willamette Valley. The late maturity of the sunflower means that the crop's seed will mature and develop late in our production season requiring much irrigation water. Grown under irrigation, the oil yields of sunflower are very good, ranging from 90 to 100 gallons of oil per acre. The high cost of irrigation and low availability of water in late summer would likely prevent the economic culture of sunflower for biodiesel in the Willamette Valley. Like soybeans, no breeding program is present in the region for the development of locally-adapted varieties. The energy balance for sunflower is 2.6:1.

Canola. Winter canola is the best candidate for a biodiesel fuel rotation crop in the Willamette Valley. Winter canola can produce more oil per acre (100 to 200 gallons per acre) than any other potential biodiesel crop in the Willamette Valley. The meal remaining after processing is a rich source of protein, which can be fed to livestock and would be an additional source of income. Local feed processors are currently importing oilseed meal into the Pacific Northwest, so a ready market already exists for high quality, locally produced canola meal.

The most recent OSU winter canola cultivar trials for the Willamette Valley were conducted in the late 1980s. Seed yields in OSU's past canola trials in the valley have ranged from 1,533 to 3,726 lbs/acre depending on cultivar and year. OSU extension statistics indicate that grower yields of winter canola averaged 2,300 lbs/acre in the early to mid-1990s when limited commercial production was present in the Willamette Valley. Current regulations allow the production of canola for oil in the Willamette Valley with a special permit that can be obtained from the ODA.

Although the potential for high winter canola yield exists in the Willamette Valley, there has been only limited work done on yield trials and on the development of management practices. We conducted a trial in 2005 that examined spring nitrogen management and winter canola cultivar performance at Oregon State University's Hyslop Farm near Corvallis, Oregon. Seven cultivars and advanced lines of winter canola were examined in this trial, the first of its kind here in 15 years. Cultivars and advanced lines were sown at 6 lbs/acre on September 30, 2004 in 6-inch rows. Sowing depth was ½ inch. The seedbed was prepared in a field previously in fine fescue seed production trials for four years. Lime was applied at a 2 ton/acre rate and starter fertilizer of 48 lbs N/acre (16-20-0) was applied prior to seeding. This application also supplied phosphorus (not a limiting factor in the Willamette Valley) and sulfur. The experimental design was a split-plot with spring N fertilizer main-plots and cultivar subplots arranged randomly within 4 blocks. Each subplot was 8 feet x 50 feet.

Spring nitrogen treatments (0, 50, and 100 lbs N/acre) were made on February 18, 2005. Boron was also applied at 2 lbs/acre. K-Mag (21.5% K, 10.5% Mg, and 21.5% S) was applied at 100 lbs/acre after tissue analysis indicated critically low plant Mg. The crop was swathed with a specially-modified John Deere plot swather and combined with a Hege Model 180 plot combine with pickup attachment.

A spring nitrogen x cultivar interaction was evident in canola seed yield responses in 2005 (Table 1). All winter cultivars responded to a topdressing of 50 lbs N/acre with increased seed yield, but some cultivars benefited more by an additional 50 lbs N (100 lbs total spring N) than did others. Yields of Athena, UIC 02.2, UIC 3.1 were highest with 100 lbs spring N/acre while yields of Baldur, Ceres, Kronos, and UIR 3.5 were equal at 50 and 100 lbs spring N/acre. Maximum yield of all cultivars exceeded 4,000 lbs/acre, but it is unclear whether yields might have been different has timing of N application had been earlier or later or had N been applied in greater amounts.

Winter canola yields in our trial were very good considering that grass seed and winter wheat yields were reduced by 40% or more by high rainfall between March and May, and by abnormally high meadow vole populations.

Table 1. Spring N and cultivars effects on seed yield of winter canola.

Cultivar	Spring N (lb N/acre) 0	50	100
	-------------------- (lb/a)	---------------------	
Athena	2994	3387	4491
Baldur	3636	4428	4650
Ceres	3012	4017	3872
Kronos	3486	4287	4331
UIC 02.2	3367	3789	4819
UIC 03.1	2966	4021	4525
UIR 03.5	2819	3820	4185
Spring N mean	2821 a	3457 b	3854 c

Rotation with canola may improve grass seed growers' ability to control grass weeds since several herbicides are registered in Oregon for controlling grasses in canola. The presence of grass weeds in wheat was reduced when canola was included in the rotation. Canola has a strong taproot, which can penetrate soils that fibrous-rooted grasses cannot. Long-term traffic in grass seed fields produces high bulk density soil layers (pans) that reduce rooting of grasses.

Weed control consisted of an application of Select 2EC at 5 oz/acre and was made on November 10, 2004. The grass seed field was infested with annual bluegrass, and several other grass weeds as well as substantial quantities of fine fescue seed in the seed bank. The single application of Select 2EC provided near 100% control of these weeds. While Select provided excellent weed control, it was apparent that the crop growth and development was retarded for an extended period by this treatment. The crop remained stunted in the rosette stage and leaves were small and red-purple colored until late February. Some herbicide damage symptoms were apparent but were not completely consistent with this chemical. Other biotic or environmental factors likely played a role in the manifestation of these symptoms. Winter precipitation was abnormally low for the region. Once the canopy expanded in spring, especially in April, the soil surface was completely shaded and produced an environment not conducive to weed development. Our current trials with Treflan also showed excellent weed control in winter canola.

One limitation to the planting of winter canola in the Pacific Northwest is the potential for occasional poor stand establishment under dry fall conditions. Furthermore, late seedings made to coincide with late arriving fall rains have much lower seed yields than earlier seedings. However, where available, irrigation would likely increase the probability of a good fall stand of canola.

Work in wheat has shown that canola can be successfully direct-seeded (no-till planted) into wheat stubble in the Pacific Northwest in areas outside of the Willamette Valley, but it is not known whether it is possible to direct-seed winter canola into grass seed crop stubble.

Winter canola has another advantage over other potential biodiesel crops in that there is a nearby genetic improvement and breeding program at the University of Idaho. One component of this program's effort focuses on evaluating cultivars for seed and oil yield at many Pacific Northwest locations, including two in Oregon (Pendleton and Hermiston). The energy balance of canola has been calculated by the University of Idaho to be 4.2:1.

Cultivar and irrigation management trials in winter canola are underway in the 2005-06 season.

Potential Acreages of Biodiesel Feedstock Crops

The number of total acres harvested in the Willamette Valley is 909,866 according to the USDA's latest agricultural census data. The valley's grass seed acreage was 469,120 in 2004 and more than 500,000 acres have been in culture here for several years in the last decade. To be a successful rotation management tool in the Willamette Valley, biodiesel crops need to occupy about 100,000 acres. This reduction in acreage and rotation would not only alleviate the cause of many weed and disease problems of grass seed crops but would also eliminate the true cause of overproduction, too many acres grown. Historical acreages of grass seed crops when other cropping options have been available range from 250,000 to 375,000 acres.

USING ADVANCES IN PLANT GENOMICS TO DEVELOP A DNA-BASED TEST TO BENEFIT THE RYEGRASS SEED INDUSTRY

L.D. Cooper, R.E. Barker, S.E. Warnke and R.N. Brown

The problem

The majority of the worldwide supply of perennial (*Lolium perenne* L.) and annual (or Italian) (*L. multiflorum*) ryegrass seed is produced in Oregon's Willamette Valley. Perennial ryegrass is grown mainly for turf production, while the annual cultivars are primarily used for forage. Since the legislative-mandated reduction in field burning, weed problems in the perennial ryegrass fields have increased. Annual ryegrass, which is also a seed crop in Oregon, is a problematic weed for perennial ryegrass production. Both of these grasses have many useful agronomic properties, but the close genetic similarity of the two is of concern because contamination of high quality turf-type perennial ryegrass by forage-type annual ryegrass is objectionable.

Identifying annual ryegrass contamination in perennial ryegrass seed lots has been a major interest in the seed industry for many years. The reasons that annual ryegrass is such a problem are several-fold. Without adequate control, annual ryegrass seed stays in the soil seed bank for years and readily volunteers in perennial ryegrass seed production fields. These two species are able to pollinate one another when their flowering dates overlap. Genetic (pollen from adjacent fields) or physical (seed mixing) contamination can occur during seed production and handling. Since the seeds are indistinguishable visually, other means are needed to determine the amount of contamination in the higher quality perennial seed intended for turf use. More accurate detection of seed lot contamination would benefit seed growers by reducing incorrect price reductions, and would benefit turf growers by reducing off-type plants in the turf. Grass seed growers, seed testers and end users would all benefit from the ability to provide a higher quality, more genetically pure product within a shorter testing time than has previously been possible.

The "Fluorescence Test" as described by the Federal Seed Act (Sec. 201.58a Indistinguishable Seeds) was developed to solve the challenge of separating the two growth types in grass seed-testing laboratories. Unfortunately, the seedling root fluorescence (SRF) test has become increasingly ineffective as a species discriminator as genes from these two species have intermingled over the years in seed production areas and in new variety development. The SRF test over estimates the amount of annual contamination in perennial ryegrass seed lots and grower profits are often discounted because of false SRF tests (Barker *et al*., 2000). Through cooperative research between Oregon State University and the USDA-ARS, a maturity Grow-Out Test (GOT) was developed and beginning with the 2002 crop year, the seedling root fluorescence test has augmented by the SRF test. All of the fluorescent seedlings from a SRF test are transplanted to pots, along with 25 non-fluorescent seedlings from the test and 25 annual ryegrass control seedlings (OSU Seed Lab, 2001). These plants are then grown for six weeks in a controlled environment under conditions optimized to induce heading in annual ryegrass. Seedlings that head or have wide, light-colored leaves are counted to determine the contamination level of the perennial ryegrass seed lot. Until the GOT test was implemented to supplement the SRF test by seed testing and regulatory agencies in 2002, the industry estimated that as much as $5 to $7 million was lost to growers each year because of payment discounts (Personal communication, Oregon Ryegrass Seed Testing Committee, 2001). The addition of the GOT results in a lower estimate of contamination levels, which benefits growers, but the GOT is expensive and time-consuming to conduct. Further, the GOT *per se* does not fully estimate growth-type, but overly predicts perennial-type plants and under estimates those that are actually annual and the results can be altered by even minor changes in the conditions under which the plants are grown.

The objective of our work over the past few years has been to identify the genetic basis of the differences in growth habit between the annual and perennial ryegrasses. Most temperate grasses, including perennial ryegrass grown for turf in the U.S, require a prolonged period of low temperatures, called vernalization, followed by an increase in the length of daylight to induce flowering. This dual requirement ensures that flowering occurs during the favorable environmental conditions of spring and summer. In contrast, the annual ryegrasses have an annual to weakly perennial growth habit, in most cases, with no vernalization requirement, and lack the requirement for long days to induce flowering. The grass seed industry has supported our research to find the genes that control whether a ryegrass plant behaves as an annual or a perennial. This seems like a simple question, but it is complicated by the fact that the ryegrasses actually form an interbreeding continuum of plant types, they are obligate out-crossers and there is a paucity of molecular tools at our disposal. That said, one of the main advantages to working on a grass species is that we can utilize the advances that have been made by other researchers studying the related crops wheat, barley and rice. Many of the recent advances that have been made in those species are transferable to *Lolium* and we can utilize the information and tools that have already been developed.

What we have accomplished

In previous work conducted in the Barker lab at NFSPRC, a genetic linkage map was developed by crossing Manhattan, a perennial and Floregon, an annual ryegrass. This hybrid population called "MF" is an important tool for studying the differences between annual and perennial types of ryegrasses. Genetic linkage is the tendency for two characteristics to be inherited together in the progeny of the cross. The linkage map can be considered a "road map" of the plant genome and can help us determine the location of important genes that control traits we are interested in. While the whole genome approach takes much longer, results are more positive for real-world application than those obtained from "shotgun" or "association" studies. Through much work, the progeny of the MF cross were characterized using a variety of molecular tools to produce "markers" or genetic "addresses" for specific traits or, in some cases, specific genes. After this analysis, a computer program was used to calculate the relationships between the various markers, based upon their inheritance patterns in the population. The resulting framework or map allows us to determine which regions of the *Lolium* genome are responsible for the traits we are interested in such as the requirements for vernalization and long days to induce flowering. Once we have those regions identified, we can better identify the underlying genes that control those traits.

A second, very important use for the MF map is to compare the framework of the *Lolium* genome with the genome structure of other related species that have similar maps. The ryegrasses of the genus *Lolium* are taxonomically related to many important cereal crop and grasses in the plant family including rice, wheat, barley, maize, oat and sorghum. A recent study published in a scientific journal (Sim *et al*., 2005) using the MF mapping population found there was considerable similarity of genome structure between the ryegrasses and other closely related crops oat, rice, wheat and barley. This similarity allows the ryegrass genetic maps to be aligned with, and to benefit from genetic maps and genomics tools available in species where more advanced studies have been undertaken. Although the tools for genomics research are limited for *Lolium sp*., in the closely related cereal crops there are extensive, publicly available databases of expressed genes that have been sequenced, whole genome libraries, and in the case of rice, the entire genome has been sequenced and much of it has been annotated.

A major difference between annual and perennial ryegrass is the control of flowering in these two species. Ryegrass flowering control is similar to the mechanisms that separate spring and winter wheat classes. The differences in the requirements for daylength and vernalization between these two species makes the genomic regions influencing these traits good targets for the development of DNA-based species separation tests. As in the ryegrasses, in winter wheat and barley cultivars, variation in flowering time is mainly due to variation in genes regulated by long exposures to low temperatures (vernalization) and by daylength changes. These genes include a primary vernalization response gene (*Vrn-1*), as well as several heading date genes, and genes controlling the shift from vegetative to reproductive growth (Laurie *et al*., 1995).

Recently, a second vernalization responsive gene (*Vrn-2*) has been identified in winter wheat and barley that plays an important role in the vernalization response required for flowering (Yan *et al.*, 2004; Dubcovsky *et al.*, 2005; Karsai *et al.*, 2005). The second vernalization gene, *Vrn-2*, interacts with *Vrn-1* preventing flowering until the vernalization requirement has been met. In wheat and barley spring cultivars, it has been shown that the *Vrn-2* gene is completely missing, allowing the development of a simple, accurate DNA-based test for use as a genetic marker and as a tool in breeding programs (Dubcovsky *et al.*, 2005). In a similar approach, we are working towards identifying critical DNA sequence differences in the vernalization response genes that may explain the differences between annual and perennial ryegrass cultivars. Since the ryegrasses are so closely related to wheat and barley, we have utilized the publicly available information about the vernalization genes to develop tools for use in *Lolium sp.* We have identified a candidate for the primary vernalization response gene (*LpVrn-1*) and are currently working on isolating and genetically mapping candidates for the second vernalization gene, *LpVrn-2*.

We have developed a DNA test for the first vernalization gene (*LpVrn-1*) based on a DNA sequence difference between the annual cultivar 'Gulf' and the perennial cultivar 'Manhattan'. We have also performed vernalization trials under carefully controlled conditions to further understand how temperature and daylength influence flowering in both the perennial and the annual ryegrasses grown in Oregon. These studies help us to understand the changes occurring in the plants during the transition from vegetative growth to flowering. We have also made considerable progress towards identifying the *Lolium* candidate of the second vernalization gene *Vrn-2*, which represses flowering until the cold period is met. We utilized the publicly available sequence of a gene (*LpCO*) closely related to *Vrn-2*, which had been cloned and sequenced from *Lolium perenne* by a group in Denmark (Martin *et al.*, 2004). The *LpCO* gene codes for a protein that has a similar structure as the *Vrn-2* gene from wheat and barley.

Based on the DNA sequence of *LpCO*, we identified small difference (a single nucleotide polymorphism or "SNP") in the DNA sequence of the parents of the MF mapping population. Using this information, in cooperation with Dr. Scott Warnke, we were able to genetically map *LpCO* in the MF population and determined that it is located on *Lolium* linkage group 7, near a region of the genome involved in the response to vernalization (Figure 1).

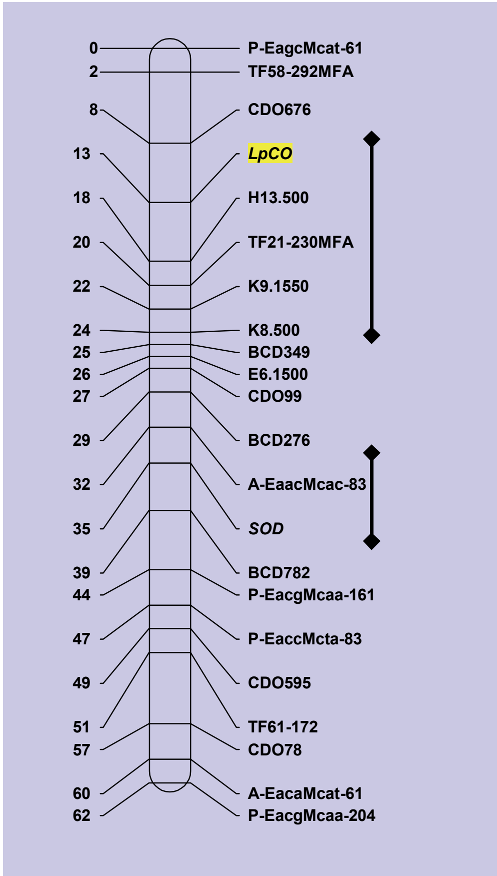

Figure 1. *Lolium* Linkage Group 7 (simplified), showing the position of *LpCO* relative to the vernalization-response regions (indicated by black bars).

As part of the objective to develop a DNA-based test to differentiate between the annual and perennial growth types, we assayed the *LpCO* SNP in at least ten individuals from each of a number of annual and perennial cultivars. The *LpCO* SNP was universally absent in the perennial cultivars tested and was present in approximately 50% of the annual types. Variation for the SNP among and within a limited number of cultivars showed it is a good marker for perennial growth types, but is inconsistent within annual-type cultivars (Table 1).

Table 1. Comparison of the occurrence of the *LpCO* SNP in individuals of various annual and perennial ryegrass cultivars.

Lolium multiflorum	% *LpCO* SNP	*Lolium perenne*	% *LpCO* SNP
Floregon	40	4500	0
Gulf	10	Integra	0
Tachiwase	70	Manhattan*	0
Waseyutaka	80	Brightstar II	0
Marshall	33	Caddieshack	0
Aubade	100	Americus	0
Passerel	25	Buccaneer	0
Jackson	50	Barlenium	0
		Delaware Dwarf	0
Total ARG %	**52%**		
		Total PRG %	**0%**

Ryegrass growth types also differ for some molecular compounds that we used in previous studies. These compounds include two enzymes called superoxide dismutase (SOD) and phosphoglucose isomerase (PGI). We have shown that specific combinations of SOD and PGI together can predict ryegrass plant type (Warnke *et al*., 2002). The tests needed to determine the enzyme sizes in individual plants are too slow and expensive for use in the seed lab. However, we are in the process of determining the DNA sequences for the genes that control these enzymes. If we can identify sequence differences that cause the size differences, we can develop DNA tests to look for the enzyme sizes associated with annual ryegrass in perennial ryegrass seed lots. We are currently studying the SOD and PGI genes from both annual ryegrass and perennial ryegrass with the aim of identifying the DNA sequence differences responsible for the differently sized proteins.

Conclusion and future prospects

DNA-based tests would enable the seed testing laboratories to screen perennial ryegrass seed lots more quickly and with greater accuracy. Developing such tests requires knowledge of the genetic differences between annual and perennial ryegrass. We are utilizing the tools developed in the large, well-funded-plant genomics projects of wheat and barley, as well as those of other research groups working on *Lolium*, to develop DNA-based protocols to discriminate between annual and perennial ryegrasses. We have made considerable progress and have begun developing possible test protocols in our lab. The protocols include multi-locations in the genome to “triangulate” on more accurate detection of ryegrass growth types. These procedures will be examined and implemented through our connections with organizations such as the Oregon Seed Certification Service, the Oregon Seed Testing Lab, Commercial Seed Testing Labs, the Turfgrass Breeders Association and the OSU Extension Service, each of which is interested in aspects of marker-assisted selection and marker-based testing.

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A SENSITIVE PCR-BASED ASSAY TO DETECT *NEOTYPHODIUM* FUNGI IN SEED AND PLANT TISSUE OF TALL FESCUE AND RYEGRASS SPP.

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Introduction

Cool season grasses such as tall fescue (*Festuca arundinacea Schreb.*), Italian (*Lolium multiflorum Lam.*) and perennial (*Lolium perenne L.*) ryegrasses can be infected with endophytic fungi of the genus *Neotyphodium*. All of the *Neotyphodium spp.* infections are symptom-less in their host. The fungus is found primarily in the crowns and leaf sheath tissues of vegetative plants. Transmission of these fungi is through hyphal infection of the seed embryo and aleurone layer during seed development. Infected plants may display increased vigor and enhanced tolerance to a variety of biotic and abiotic stresses, characteristics that can increase the survival and persistence of the plant in a diverse range of environments (Bacon and Hinton, 1998; Malinowski and Belesky, 2000). These beneficial effects of endophyte infection are desirable for turf applications, but the plant/fungus symbiosis also results in the production of alkaloids that are toxic to livestock. The livestock toxicosis resulting from the consumption of these alkaloids is one of the leading causes of reproductive and performance loss among cattle in the U.S. and abroad. The potential for livestock toxicosis can limit the utility of these grasses in forage and pasture applications and the value of grass straw as an export commodity for use in Pacific Rim livestock feed markets.

Due to concerns regarding forage quality and livestock toxicity, a variety of methods have been developed to test plant tissues and seed for the presence of these endophytes. These approaches include histological staining of seed and plant tissue, serological methods such as ELISA, tissue printing or immunoblot, and polymerase chain reaction (PCR) protocols. The previously developed PCR assays were limited to detection of the *Neotyphodium* endophyte in tissues from tall fescue plants. The purpose of this research was to develop and evaluate a general PCR method for detecting *Neotyphodium* endophytes in seed and plant tissue from tall fescue, Italian and perennial ryegrasses. Our PCR approach amplified endophyte DNA products from infected seed lots of tall fescue, Italian ryegrass and perennial ryegrass. Based on DNA mixture tests and bulk seed analysis, the assay was sensitive enough to detect as little as one infected seed per 50 seeds tested. In addition, the primer set detected the *Neotyphodium spp*. endophyte in all plant tissues tested except roots. Comparison of the PCR based assay to microscopic examination and immunoblot detection of endophytes in seed lots showed that all three methods detected endophyte-infections with similar frequency. None of the three methods distinguished between viable and non-viable endophyte in seed. This PCR method provides an accurate, sensitive approach for detecting the presence of the endophyte in these grasses.

Materials and Methods

Plant Materials: Plants of *N. coenophialum* infected (E+) or non-infected (E-) tall fescue cv. Kentucky 31 (*Festuca arundinacea*), and *N. lolii* perennial ryegrass (*Lolium perenne*) E+ (cv. Express) and E- (cv. Blazer II) were grown in a greenhouse at ambient temperatures (18-23°C) with a 14-16 hr photoperiods. The plants were grown in 1-3 gallon pots or in flats containing a standard soil based potting mix, and were fertilized to maintain vigorous growth throughout the experiments. The tall fescue ranged from 2 months to 2 years of age, while the perennial ryegrass was 2-6 months of age. In addition, surface sterilized seed of perennial ryegrass was sown onto PDA agar and germinated at 25°C /15°C with an 8 hr photoperiod in a germinator. Seeds from cultivars of Italian ryegrass were evaluated for the presence of its fungal endophyte (*N. occultans* - proposed by Moon et al., 2000) by microscopic examination prior to use in this study.

Fungal Materials: *N. lolii* hyphae were obtained from E+ seed of perennial ryegrass cv. Express and *N. coenophialum* hyphae from E+ seed of tall fescue cv. Kentucky 31. Seeds were scarified, surfaced sterilized and aseptically transferred to potato dextrose agar (PDA) slants (Azevedo and Welty, 1995). At 3 weeks post germination the fungal hyphae grew onto the agar surface and were isolated and cultured. *Claviceps purpurea* (ergot) DNA was generated from single sclerotial isolates of infected Kentucky bluegrass seed from eastern Oregon and cultured on PDA. Fungal seed surface contaminants were cultured on corn meal agar plates.

Microscopic Analysis: Seed and plant tissue were stained and examined for the presence of the fungal endophytes using light microscopy as described by Saha et al., (1988), with the modification that seed treatments were performed using 5% NaOH to soften the seeds.

Immunoblot Assay: Detection of endophyte presence in seeds and tillers was performed according to manufacturer's (Agrinostic Ltd. Co., Watkinsville, GA) protocols as described in the following kits, Phytoscreen Seed Endophyte Detection Kit (Cat. #ENDO797-1) and Phytoscreen Field Tiller Endophyte Detection Kit (Cat #ENDO797-3).

PCR Protocol: Polymerase chain reaction (PCR) is a molecular technique that specifically amplifies a minute amount of DNA into quantities that can easily be detected in gel electrophoresis. The DNA is visualized as discrete bands using ultraviolet light. Specific bands signify the presence of a particular organism or pathogen. A PCR method was developed to amplify a conserved region of the *Neotyphodium spp.* tubulin 2 gene which is present in *N. coenophialum* (endophyte of tall fescue)*, N. lolii* (endophyte of perennial ryegrass)*, and N. occultans* (endophyte of Italian ryegrass). The exact details of this procedure are presented in a manuscript that will be published in Crop Science (Dombrowski et al., 2006).

Results and Discussion

The objective of this study was to develop and evaluate a PCR approach to detect the presence of *Neotyphodium* DNA in seed and plant tissue from tall fescue*,* Italian and perennial ryegrasses. Our PCR amplified a specific gene (tubulin 2) that served as an accurate marker of *Neotyphodium spp.* infection in these grasses and detected endophyte in all plant tissues tested except for roots. The method was sensitive enough to detect *Neotyphodium spp* in low level infections (sparse hyphae). The amount of fungal DNA isolated from plant tissue or seed varies significantly from sample to sample, due to different amounts of fungal hyphae present in the seed or tissue. These variances alter the level of detection for a specific sample. Our results indicated that using 1 nanogram of isolated total DNA template was sufficient for successful use of this PCR approach to detect *Neotyphodium spp* in E+ plant tissue/seed samples.

This PCR assay yielded the expected amplification products in E+ seed lots from tall fescue, perennial ryegrass and Italian ryegrass, but did not amplify products from non-infected (E-) seed or ergot. The PCR confirmed results previously obtained through microscopic examination for the presence of endophyte in 15 cultivars of tall fescue, 15 cultivars of perennial ryegrass and 7 cultivars of Italian ryegrass (data not shown). In addition to ergot, DNA extracted from potential contaminating fungi and spores residing on the surface of seeds, such as *Alternarium and Cladosporium* and other unidentified fungal species, did not yield amplified products, indicating that they were unrelated to *Neotyphodium spp.* and that our PCR was specific to endophyte DNA.

To determine the sensitivity of the PCR detection protocol, we combined DNA extracts in different proportions from E+ (seed known to be 90% positive) and E- seed lots. These results showed that the PCR assay detected as little as 2% E+ seed DNA added to the E- seed DNA. Furthermore, DNA was isolated from mixtures of 50 seeds containing E+ seed added to the E- seed in different proportions. Results obtained were consistent with the DNA mixing analysis shown in, where the PCR assay detected 1-2 E+ seeds per 50 seed sample tested. This PCR has sufficient sensitivity to detect one E+ seed in 50 in a bulk seed extraction.

We compared the effectiveness of the PCR to microscopic examination and immunological detection, utilizing selected seed lots of tall fescue and perennial ryegrass. Table 1 shows the results of this comparative analysis to detect endophyte in single seeds. In general, all three detection methods measured similar levels of infection for each seed lot tested. However, the immunoblot assay generally indicated higher levels of infection than the PCR or microscopic examination methods. This apparent higher percentage of infection may be due to the inherent subjectivity in interpreting a positive response on the immunoblots. The determination for each individual seed in the immunoblot assay is based on the comparison of the seed's staining intensity observed on a nitrocellulose membrane relative to that of positive and negative control seeds included in the kit. Due to variation in staining of the seeds, it can be difficult to determine if a seed is weakly positive or negative. In addition, the immunoblot assay can cross-react with protein extracts from ergot, although the sodium hydroxide pre-treatment prescribed in the kit is an effective means to diminish false positives associated with this fungal contaminant. In contrast, microscopic examination occasionally detected lower levels of infection in a seed lot. This may be due to difficulties in detecting the fungi in plant tissue or seed with sparse hyphae or in lots with low levels of infection. The lower PCR detection values observed in Table 1 may be attributed to inhibitors of the PCR reaction present in some single seed DNA extracts or inadequate quantities of DNA extracted from the seed.

To determine whether any of the methods discriminated between viable and non-viable endophyte, tall fescue seed from three different lots were propagated in a greenhouse (Table 1). Plants ranging in age from 3-12 months were initially tested for the presence of endophyte. All three detection methods indicated the tall fescue seed lot B was >76% infected with endophyte (Table 1). As expected a high percentage (86%) of plants produced from seed lot B tested positive for endophyte. In contrast only 6% of the plants produced from the tall fescue seed lot C contained endophyte, even though all three methods determined that the seed lot was greater than 74% infected. These results indicated that none of the methods distinguished between viable and non-viable endophyte in seed, consistent with observations made by Hill et al., 2002. Apparently, even though the endophyte is no longer viable, its DNA, hyphal structure and proteins remain intact in the non-germinated seed.

It should be noted that while this PCR assay detected extremely minute amounts of DNA, we found that one consequence of this sensitivity was a potential to develop false positives from airborne contaminants. False positives were eliminated through the use of UV treated bio-containment hood and aseptic techniques. It is important to monitor potential background and contamination in the air by including blank controls during seed preps and water (no template) reactions.

Compared to immunoblot and histological methods, the adaptation of the PCR methodologies does not significantly reduce the time or cost associated with the detection of endophytes in seed and plant tissues. PCR does provide a very sensitive and flexible means to assay different tissues throughout plant development. However, we do not recommend that PCR supplant established assays (microscopic or immunoblot) for endophyte detection in single seed currently used in seed testing laboratories. The method of choice for endophyte detection will depend on an individual's background and training, the availability of equipment, the type of tissue to be tested, the amount material available, and the number of samples.

In order to survey endophyte infections in seeds and plants efficiently it is critical to have a simple, fast and reliable method of detection. Microscopic examination is a reliable method of detection, but requires specific expertise and training to identify fungal infections in tissue and seed. Histological staining of fungal hyphae is a non-specific process that can result in false positives. Microscopic examination may not be as sensitive as PCR or serological methods, and can miss E+ plant and seed samples with sparse hyphae. Serological methods provide a quick, sensitive means of detection, but can produce false positives caused by cross-reaction with proteins from the plant or closely related fungi. The immunoblot assay produced false positives as high as 20% in some Italian ryegrass seed lots tested. In contrast, PCR and microscopic analysis did not detect endophyte in these same lots (data not shown). Despite these findings, we found that the immunoblot assay an effective means to detect endophyte in perennial ryegrass and tall fescue. The immunoblot assay is relatively easy to use, sensitive and possesses a high throughput capability when there is need to examine large numbers of single seeds (Hiatt et al., 1999; Hill et al., 2002).

PCR is a reliable, sensitive and rapid approach to fungal detection in plant tissues. Unlike microscopic examination it requires less training and experience to achieve effective and repeatable results. Our PCR provided an appropriate level of specificity and did not amplify DNA from other potential fungal contaminants. One strength of this approach is the tolerance of a wide variety of source material, such that most parts of the plant could be assayed. This general PCR method provides a valuable tool for researchers to assess the presence of *Neotyphodium* endophytes in diverse tissue types and grass species.

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Acknowledgments:

Special thanks is extended to Vicky Hollenbeck USDA-ARS for her technical assistance. Dr. Bob Doss USDA-ARS for providing PCR primers and lab space, Dr. Hiro Nonogaki Oregon State University for providing lab space, Dr. Sabry Elias of the Oregon State University Seed Laboratory for providing ryegrass seed samples, and Steve Johnson of DLF-International Seeds for providing seed lots of endophyte infected and non-infected tall fescue cultivar Kentucky 31. Experimental methods performed in this research complied with current laws and regulations of the U.S.A. The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the United States Department of Agriculture or the Agricultural Research Service of any product or service to the exclusion of others that may be suitable.

Table 1. Detection of endophyte in tall fescue and perennial ryegrass by different methods.

PLANT TYPE	Seed Analysis*			Plant Material			
	Microscope	Immunoblot	PCR	Germination	Plants Tested	E+ Plants	% E+ Plants
Tall Fescue cv Kentucky 31 (A)	6%	10%	12%	88%	45	1	2%
Tall Fescue cv Kentucky 31 (B)	82%	92%	76%	89%	57	49	86%
Tall Fescue cv Kentucky 31 (C)	80%	88%	74%	85%	48	3	6%
Tall Fescue cv Fawn	0%	0%	0%	ND	ND	ND	ND
Perennial Ryegrass cv Express	64%	68%	62%	ND	ND	ND	ND
Perennial Ryegrass cv Blazer II	0%	0%	0%	ND	ND	ND	ND

ND -not determined * - Percentages are derived from the # positive seeds / 50 seeds tested

SANTIAM CANAL: WATER QUALITY THROUGH URBAN AND RURAL LANDSCAPES

S.M. Griffith

Introduction

The source of drinking water for the City of Albany, OR in 2004 and 2005 was the Santiam Canal, which derives its water from the Santiam River east of the City of Lebanon, OR. The canal passes through the City of Lebanon, across an agricultural landscape primarily in grass seed production, and then through the City of Albany before arriving at the Albany City Water Treatment Plant and continuing to the Willamette River.

As part of the Treatment plant's routine water purification process, chlorine is added to reduce levels of certain undesirable contaminates and to help maintain high water quality. On several occasions during the spring of 2003, the Albany Water Treatment Plant had to add higher than normal amounts of chlorine to maintain their drinking water standards. During a February 2004 public meeting with local residents and farmers, a representative from the Oregon Department of Agriculture and the Albany Water Treatment Plant suggested that the abnormal additions of chlorine were required in order to remove urea nitrogen (N) fertilizer that resulted from off-site movement from agricultural fields into the Santiam Canal. There were no data to support this notion nor was there baseline water quality data for the canal. As a consequence, meeting attendees proposed that canal water quality data be collected before further discussion occurred. A report of the first year study can be found in Griffith (2005). These findings demonstrated high water quality for the months of March and April 2004. The study was repeated the following spring (2005) and the reports are reported here.

The objective of the study was to measure the concentrations of nitrate-N, ammonium-N, total nitrogen, and organic-N (total N - total inorganic-N) in water collected from the Santiam Canal during March and April 2005. Levels of turbidity, pH, conductivity, suspended solids (sediment), total organic carbon, and ortho-phosphate were also measured to broaden the scope of understanding of the canal's water quality.

Water Sampling and Analysis Procedures

<u>Sampling Locations</u>

- **Site #1:** Albany Water Treatment Plant, 300 Vine St. SW, Albany, OR
- **Site #2:** Fry Rd. just south of Grand Prairie Rd. (east of Albany, OR)
- **Site #3:** O.F. Cemetery (north of the Lebanon Hospital, Lebanon, OR)

<u>Sampling Frequency and Duration</u>

Water samples were collected at these sites every other day from March 1 to April 28, 2005.

<u>Chemical Analyses</u>

All water analyses were performed at the USDA-ARS National Forage Seed Production Research Center, Corvallis, OR. The following water quality parameters were measured: nitrate-N, ammonium-N, and total nitrogen (organic-N + inorganic-N), turbidity, pH, conductivity, suspended solids, total organic carbon, and ortho-phosphate. Organic-N (urea nitrogen is a component of organic-N) was determined by the following calculation: Total N – Total inorganic-N (nitrate-N and ammonium-N). Total N and total organic carbon were analyzed using a Shimadzu TOC/TN analyzer. The measurement principal is by thermal decomposition / NO detection (chemiluminescence method). This method yields the determination of total organic-N plus inorganic-N. Specific methodologies and a copy of the QC-QA Plan are available from Griffith, USDA-ARS, Corvallis, OR,

Results and Discussion

Analyses of Santiam Canal water quality during March and April of 2005 showed that quantities of these common nutrients were at, or below published acceptable levels of water quality (Mueller and Helsel, 1996) at all sites during the entire sampling period (Table 1 and Figures 2-9).

March and April of 2005 were unusually wet months compared to the 30-year average (Figure 1). The high precipitation events that occurred during this period might be expected to flush nutrients from the surrounding landscape into adjacent waterways, including the Santiam Canal if soil N retention and crop N efficiencies were low. As a consequence, if fertilizer N was transported from agricultural fields between Sites #3 and #2, then elevated nutrient levels would be expected during, and immediately following these precipitation events at a time when fertilizer was traditionally applied to grass seed fields. The data reported here do not indicate that this occurred in this portion of the landscape although there are suggestions that transport did occur from the Albany residential portion between Fry Rd. and the Albany Water Treatment plant. The maximum concentration of each chemical constituent analyzed was always highest at Site #1, the Albany Treatment Plant, suggesting that elevated levels of nutrients entered the canal from the primarily residential portion of the landscape between Fry Rd. (Site #2) and the Albany Water Treatment Plant (Site #1).

Nitrate-N did not exceed 0.46 ppm (Table 1 and Figure 6). Ten ppm N is the maximum for the drinking water standard of well water. Urea was not directly measured but estimated by subtracting the amount of inorganic N from the total N value, yielding the total organic N (TON) value. The concentration of total organic N, the N fraction that contains urea if it is present, was 5-times higher at the Albany Water Treatment Plant (Max

= 5.36 ppm N), then that measured in the portion representing the agricultural landscape (Max = 0.85 ppm N) and the portion representing the City of Lebanon (Max = 0.59 ppm N). Urea was the greatest concern voiced at the meeting in reference to the above normal chlorine additions during the water purification process.

In summary, these data confirm those collected in 2004 which demonstrated that the Santiam Canal water exceeded minimal water quality standards for TON, nitrate, ammonium, pH, turbidity, ortho-P, and total P concentrations during the months of March and April when the majority of fertilizer N is traditionally applied to grass seed fields,. Maximum concentrations of these nutrients were always highest down stream after flowing through the residential portion of the landscape that bordered the canal.

These data are consistent with previously published reports that quantified surface and ground water quality in grass seed production landscapes of western Oregon, particularly in poorly drained landscapes when best management practices are used. No-till or conservation tillage, cover crops, use of spray buffers and unmanaged filter strips have been demonstrated as effective for maintaining a sustainable agricultural and high water quality.

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Table 1. Quantification of chemical and physical indicators of water quality at three sites along the Santiam Canal during the spring of 2005; Site #1: Albany Water Treatment Plant, 300 Vine St. SW, Albany, OR, Site #2: Fry Rd. just south of Grand Prairie Rd. (east of Albany, OR), and Site #3: O.F. Cemetery (north of the Lebanon Hospital, Lebanon, OR). Computations were made using the combined data for each location for all sample dates. The units mg/L equals parts per million (ppm).

Location sample was Taken	Turbidity	pH	Conductivity (uS)	Sediment (mg/L)	TOC (mg C/L)	TN (mg N/L)	TON (mg N/L)	NH_4-N + NH_3-N (mg N/L)	NH_4-N (mg N N/L)	NO_3-N (mg N/L)
Lebanon O.F. Cem.[1]										
Mean	5.8	7.3	41.4	15.7	4.37	0.31	0.16	0.14	0.04	0.10
Median	5.3	7.3	42.0	14.6	4.29	0.28	0.17	0.14	0.03	0.08
Max	11.0	7.5	47.5	30.4	5.22	0.81	0.59	0.33	0.18	0.24
Min	2.5	6.9	31.5	7.5	3.84	0.16	0.03	0.05	0.01	0.04
Fry Rd.[2]										
Mean	6.8	7.3	45.7	19.7	4.72	0.46	0.24	0.23	0.06	0.17
Median	6.4	7.4	45.8	19.2	4.51	0.38	0.19	0.20	0.04	0.14
Max	16.5	7.7	57.5	41.5	6.76	1.57	0.85	0.72	0.35	0.38
Min	2.1	6.8	30.0	6.3	3.90	0.20	0.06	0.07	0.00	0.04
Albany WT Plant[3]										
Mean	9.6	7.2	48.8	22.1	4.92	0.73	0.42	0.32	0.14	0.18
Median	7.5	7.2	46.5	21.1	4.60	0.37	0.19	0.20	0.03	0.16
Max	33.0	7.7	78.5	57.8	8.48	7.24	5.36	1.88	1.54	0.46
Min	3.8	6.9	37.0	5.2	3.84	0.21	0.04	0.07	0.00	0.06

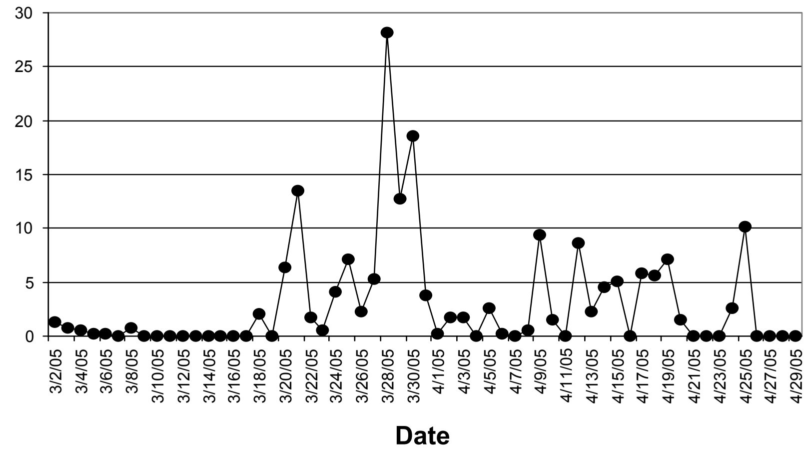

Figure 1. Daily precipitation recorded at Oregon State University Hyslop Farm by the Oregon Climatic Service Experiment Station, Corvallis, OR.

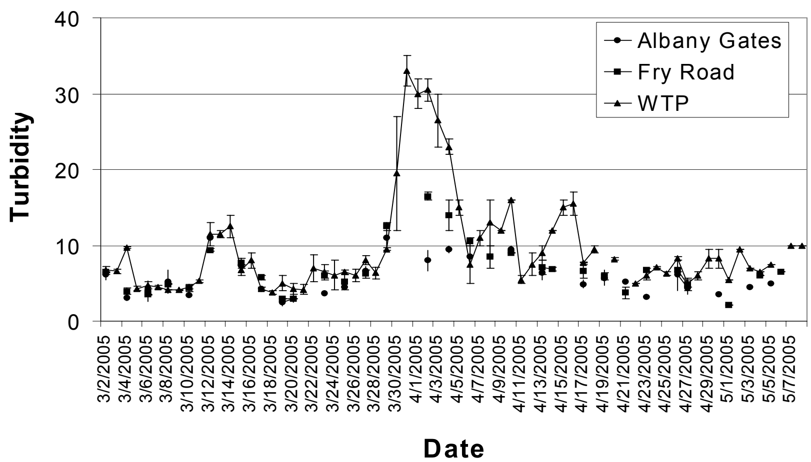

Figure 2. Temporal changes in turbidity of the Santiam Canal water at three locations from March 1 to April 28, 2005.

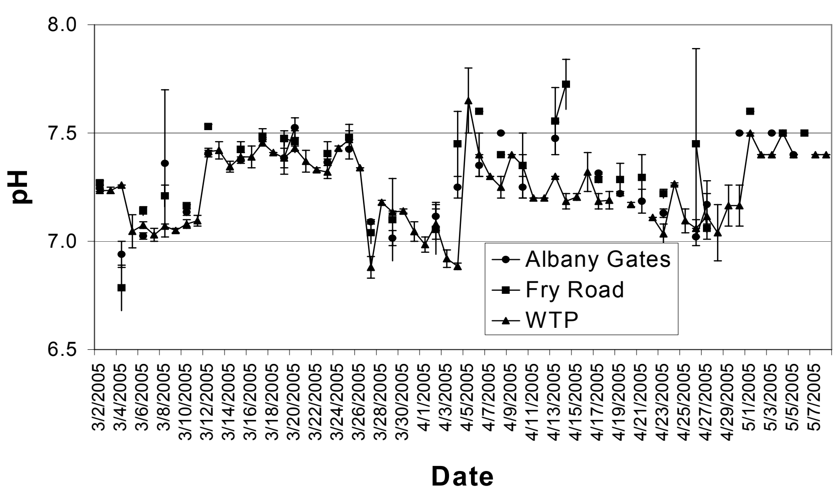

Figure 3. Temporal changes in pH of the Santiam Canal water at three locations from March 1 to April 28, 2005.

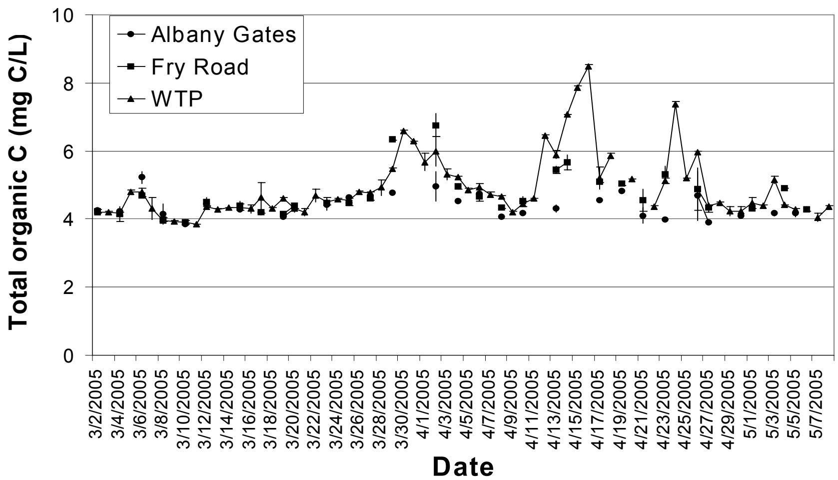

Figure 4. Temporal changes in total organic carbon of the Santiam Canal water at three locations from March 1 to April 28, 2005.

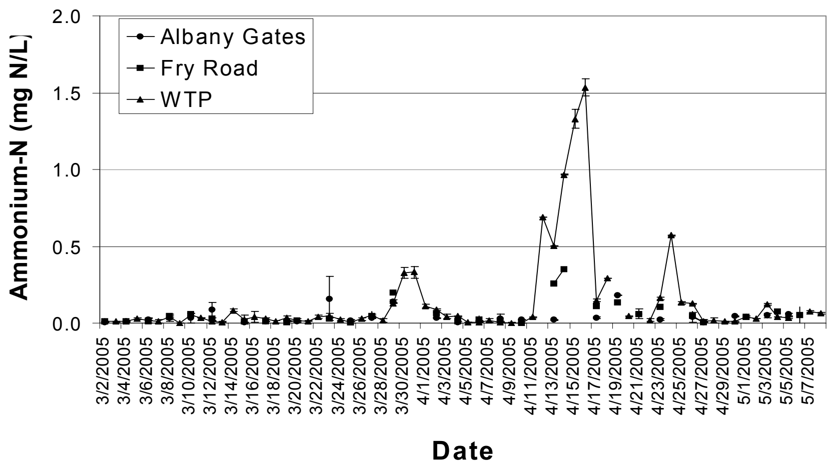

Figure 5. Temporal changes in ammonium-N of the Santiam Canal water at three locations from March 1 to April 28, 2005.

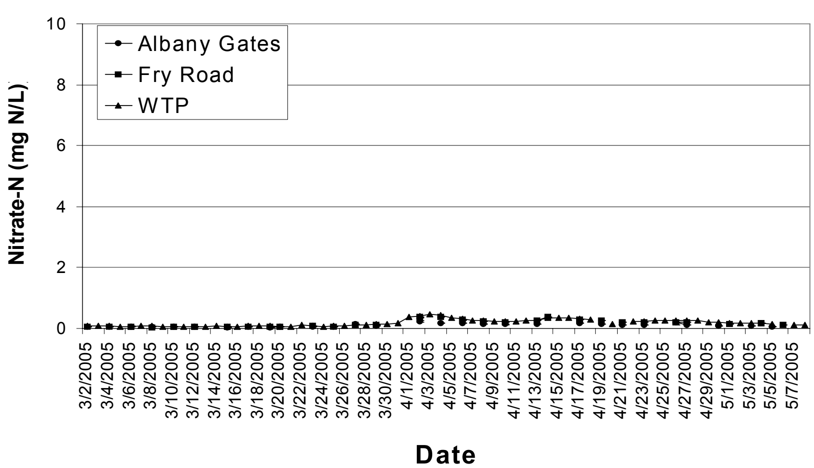

Figure 6. Temporal changes in nitrate-N of the Santiam Canal water at three locations from March 1 to April 28, 2005.

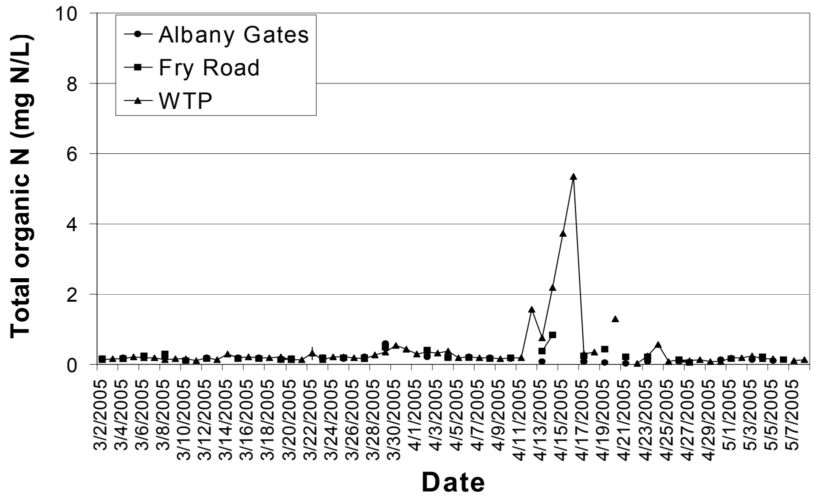

Figure 7. Temporal changes in total organic nitrogen of the Santiam Canal water at three locations from March 1 to April 28, 2005.

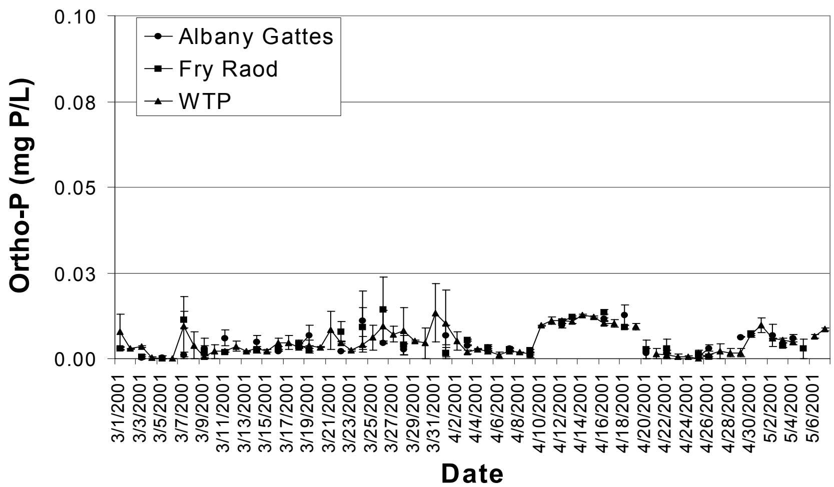

Figure 8. Temporal changes in ortho-phosphate of the Santiam Canal water at three locations from March 1 to April 28, 2005.

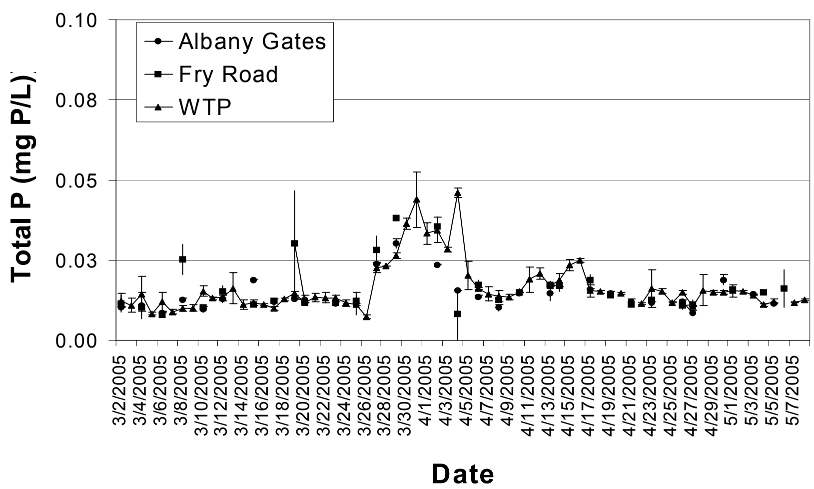

Figure 9. Temporal changes in total phosphorus of the Santiam Canal water at three locations from March 1 to April 28, 2005.

FISH AND AMPHIBIAN USE OF INTERMITTENT AGRICULTURAL WATERWAYS IN THE SOUTH WILLAMETTE VALLEY

G.R. Giannico, J.L. Li, K.L. Boyer, R.W. Colvin, W.J. Gerth, M.E. Mellbye, S.M. Griffith and J.J. Steiner

Background
In the Pacific Northwest, seasonal streams and wetlands in lowland areas provide habitat for fish and amphibians during the wet-period of the year (fall through spring). In the south Willamette Valley, agriculture is a predominant land-use and most of such lowland seasonal waterways flow through grass seed producing fields. Concerns about water quality and native aquatic species in the Valley encourage agricultural practices and other conservation efforts that contribute to the protection of these seasonal habitats. At the beginning of this study, little was known about water quality and habitat conditions in drainages across the agricultural landscape where grass seed crops predominate. Furthermore, there was no information to help identify conservation practices that could have positive effects on water and aquatic organisms while offering growers access to programs that could offer an additional income in payment for such efforts.

More than 20 growers in the Benton, Lane and Linn counties have allowed us to sample on their farms along ditches and natural channels within the Calapooia, Luckiamute, Mary's, Amazon, Muddy, Flat and Long Tom watersheds. These are waterways that are completely dry from late spring to early fall. We sampled 21 seasonal stream sites during the 2002-03 wet-season, and more intensively studied 12 sites in 4 seasonal drainages in the 2003-04 wet-season. Fish and amphibians were collected from November to May using minnow traps, hoop traps and backpack electrofishing. We also collected invertebrates from the benthos (channel bottom) and the drift (those suspended in the water column) at the same 21 sites where fish and amphibians were sampled.

During the 2003-04 field season, fish species, their distributions and the diets of four indicator species were examined in more detail in four different drainages: (1) Butte Creek, (2) Tributary to Butte, (3) Ridge Road Creek and (4) Tributary to Luckiamute River. Sites were selected so the first two of these systems had incised channels with little or no flooding of the riparian zones and adjacent floodplain areas during seasonal high flows. Whereas, channels in 3 and 4 were unconstrained and their high waters could easily access the adjacent floodplains. This was important because fish access to off-channel pond-like areas could potentially give them access to terrestrial invertebrates rather than just aquatic ones, and therefore expanding their food supply. We also examined seasonal differences in the contribution terrestrial and aquatic invertebrates made to fish diets.

We also collected water samples to determine its quality at the fish and amphibian sampling sites. In addition, invertebrates found in the water and in stomachs of the fish were sampled to assess the availability and possible sources of food in these seasonal waterways.

Findings
<u>Aquatic Vertebrates</u>
Fifteen species of fish and 5 species of amphibians were collected over the study period (Table 1), including three salmonid species (chinook salmon, rainbow/steelhead trout, and cutthroat trout). Most fish (11 species) and amphibians (4 species) were native to the Willamette Basin. The rest were exotic (introduced) species, which not only were relatively scarce in these seasonal waterways, but seem to enter these habitats as conditions got warmer in the spring. In contract, exotic species are very abundant in the Valley's permanent streams and wetlands (Colvin, 2005).

In the 2002-03 survey, sites dominated by amphibians were distinguished by slower water velocities than sites dominated by fish. In sites dominated by fish, more fish were caught in drainages to the west of the Willamette River than in systems on its eastern side. Additionally, western sites were distinguished from eastern sites by having higher abundances of sculpins and fewer sticklebacks. Regional differences in the proportion of the watershed that was covered by forests and in the gradient (steepness) of the channels may account for some of the observed west-east side differences in fish abundance and aquatic community composition (Colvin, 2005).

Our results of the 2003-04 survey showed that the number of fish species found at our sampling sites decreased as distance to downstream perennial streams increased, independently of channel connectivity to the floodplain. For the diet component of this study we studied only four species: redside shiner, reticulate sculpin, speckled dace, and threespine stickleback. They were used because they were: (a) broadly distributed throughout our sampling sites, and (b) easy to sample for diet by washing out the content of their stomachs with a small jet of water. Out of the 230 individual stomach samples that we obtained, approximately 62% had invertebrates in them. In turn, of these invertebrates the vast majority (over 90%) were aquatic, which indicates that at least for these species and at the times we sampled the contribution of terrestrial invertebrates to their diets is extremely small (Colvin 2005). That does not mean that terrestrial invertebrates are not relevant to the food base of these aquatic habitats. They may benefit fish in an indirect way by being the prey of some aquatic invertebrates that in turn are eaten by fish. Differences in the diet composition between seasons and between drainage types were observed, but they were very small.

Table 1. Fish and amphibian species captured in intermittent streams during 2002/03 and 2003/04, ordered by decreasing relative abundance (from Colvin 2005).

Fish		**Amphibians**	
Threespine stickleback	*Gasterosteus aculeatus*	Roughskin newt	*Taricha granulose*
Redside shiner	*Richardsonius balteatus*	Long-toed salamander	*Ambystoma macrodactylum*
Reticulate sculpin	*Cottus perplexus*	Pacific treefrog	*Hyla regilla*
Speckled dace	*Rhinichthys osculus*	Redlegged frog	*Rana aurora*
Largescale sucker	*Catostomus macrocheilus*	Bullfrog*	*Rana catesbeiana*
Northern pikeminnow	*Ptychocheilus oregonensis*		
Chinook salmon (juv)	*Oncorhynchus tshawytscha*		
Rainbow trout	*Oncorhynchus mykiss*		
Cutthroat trout	*Oncorhynchus clarki*		
Riffle sculpin	*Cottus gulosus*		
Oregon chub	*Oregonichthys crameri*		
Mosquitofish*	*Gambusia affinis*		
Goldfish*	*Carassius auratus*		
Bluegill*	*Lepomis macrochirus*		
Yellow Bullhead*	*Ameiurus natalis*		

*denotes Exotic species

Evidence provided by tagged individuals from several different species, combined with changes in the size distribution of threespine sticklebacks showed that fish could grow in these seasonal habitats despite relatively low temperatures. Furthermore, the sudden appearance in spring of very small sticklebacks (approximately 10 mm in length) indicates that at least this species spawns and finds suitable nursery habitats in these seasonal waterways.

Although fish were able to travel relatively long distances (over 9 miles) to colonize these seasonal habitats, results from our fish tagging work did not allow us to determine movement patterns and/or differences in movement among species. Only 13 individuals were recaptured out of 496 fish that were tagged. Those 13 individuals were recaptured at the sites where they had been tagged. However, such a small recapture rate does not allow us to determine whether fish are highly mobile or they experience high mortality rates. This work is being repeated for the 2005-06 winter-spring season.

Aquatic Invertebrates

Aquatic invertebrates are important because they process organic matter derived from within the channel and near stream environment, provide food for aquatic vertebrates, and can indicate stream habitat and water quality conditions. Terrestrial invertebrates from riparian (river bank) zones or nearby farm fields could also be swept into seasonal waterways, and although they did not seem to be important components of the diet of the four species we selected, they may still play an important role in "feeding" the aquatic community.

At all sites, non-insects and chironomids made up more than 75% of benthic abundance. Non-insects collected at most sites included nematodes, flatworms, oligochaetes, lymnaeid snails, ostracods, isopods, amphipods and harpactacoid copepods. Although not abundant, species of caddisfly, were also collected at many sites. Greater invertebrate abundances were found at sites with slower water velocities and higher amounts of vegetation growing on the streambed. As with the vertebrates, the types of invertebrates differed between sites in drainages west and east of the Willamette River. Western sites had higher relative abundances of several aquatic insects (e.g., baetid mayflies, blackflies and midges), while eastern sites had more non-insects (e.g., ostracods, amphipods and flatworms). In contrast to benthic samples, drift samples contained organisms that were of both aquatic and terrestrial origin. Common invertebrates in drift samples included mites, collembola, midges and several types of microcrustaceans. Drift density was highest in sites with smaller watershed area, shallower waters and higher channel slopes. Again sites east and west of the Willamette River were distinctive. Drift from western sites contained more aquatic organisms including midges and microcrustaceans; eastern site drift contained more terrestrial organisms including collembola, spiders, barklice and thrips.

Water Quality

During the 2004-05 water year, the average nitrate-N concentration was 0.98 ppm at approximately 90 sample sites along the entire length of the Calapooia River watershed (from the headwaters to the Willamette River); 98% of all samples contained less than 10 ppm nitrate-N. Unlike previous years (2001 to 2004), the greatest nitrate-N concentrations during the 2004-05 season were observed as two distinct peaks over time instead of just one; one was detected in December and the other in April and were associated with high winter and spring precipitation periods respectively. Relatively dry conditions predominated between the two peak periods. The average ammonium-N was 0.09 ppm, with 98% of all samples being less than 0.5 ppm and 99% less than 1.0 ppm. The pH of the water measured in these systems was 7.2. The average ortho-P concentration was 0.035 ppm and total P at 0.097 ppm. Average suspended sediment concentrations were 12.6 ppm, with no sample points greater than 522 ppm. The highest concentrations of soluble chemical constituents were found in the lower portion of the Calapooia River watershed between Brownville and the Willamette River (Table 2).

The concentrations of water quality constituents found in winter-seasonal agricultural drainages were generally low relative to concentrations believed to affect aquatic vertebrates. Nitrate- and ammonium-N and suspended sediment concentrations were generally below what are referred to as the lowest observed adverse concentrations (LOAC) when aquatic wildlife is present. A LOAC is typically far less than an acute concentration such as the LD_{50} (lethal dose at which 50% of the test sample dies). Published reports indicate Pacific Tree Frog embryos exposed for 10 days were affected by ammonium-nitrogen at 6.9 ppm, and tadpoles by 24.6 ppm (Schuytema and Nebeker, 1999; 2000). Previous research demonstrated that not all nitrogen forms found in drainages were derived from fertilizer applications. Naturally occurring nitrate-N moves with precipitation run-off from soils to streams and typically peaks in early winter when significant precipitation follows the dry summer season (Griffith et al., 1997; Wigington et al., 2003). The southern Willamette Valley soils are generally characterized as poorly drained and typically cause denitrification reactions to occur during the winter when soils are saturated. These and previous reported findings indicate that the quality of water in winter-seasonal agricultural drainages is generally good utilizing established recommendations for constituent concentrations that adversely affect aquatic wildlife. More detailed analyses will be conducted to determine the duration of exposure at the higher constituent concentration levels when wildlife are present.

Table 2. Water quality data of the Calapooia River watershed main-stem and associated tributaries from September 2004 through August 2005. The water quality constituents measured were pH, nitrate (NO_3-N), ammonium (NH_4-N), total phosphorous (TP), dissolved organic carbon (DOC), and suspended sediment.

Location	pH	NO_3-N	NH_4-N	TP	DOC	Sediment
	(ppm)					
Agriculture (lower portion)						
Average	7.3	2.73	0.22	0.252	13.7	21.0
Median	7.3	1.02	0.03	0.061	11.4	13.3
Maximum	8.6	19.70	29.70	23.800	68.8	522.2
Minimum	6.6	<0.01	<0.01	<0.005	1.7	0.8
Mixed Forested-Ag (middle portion)						
Average	7.3	0.45	0.04	0.046	8.31	12.15
Median	7.3	0.17	0.02	0.021	6.13	8.78
Maximum	8.5	5.77	3.32	1.510	49.33	86.43
Minimum	6.3	<0.01	<0.01	<0.005	2.35	0.67
Forested portion (upper portion)						
Average	7.2	0.08	0.02	0.023	3.87	7.44
Median	6.3	0.6	0.01	0.015	3.82	6.67
Maximum	8.8	0.77	0.40	0.802	7.49	33.33
Minimum	7.0	<0.01	<0.01	<0.005	1.68	0.00

Conclusions

This research demonstrates that seasonal waterways (ditches as well as natural channels) that flow through grass seed producing fields in the Willamette Valley provide winter and spring habitats to many different species of native fish and amphibians. During the periods and at the locations where we sampled, water quality -in terms of nutrient concentrations- does not present a problem to aquatic vertebrates. These seasonal competition and/or predation shelters from exotic species may prove critical to the long-term presence of some of the native species that occur in the Valley.

Providing a species inventory and documenting the food resources in these seasonal waterways were the first steps towards describing the current situation for species that rely on habitats that are only a trace of what they used to be (see Hulse et al., 2002). The evaluation of the effects of agricultural conservation practices on these seasonal habitats and the aquatic vertebrate species that use them has not been completed yet. In fact, based on data from our first three years of work, we decided to examine the influence of vegetated (or grassed) ditch bottoms vs. bare clay on fish species composition, fish abundance, and their period of residence at a site. Additional conservation practices will be evaluated in future years.

This information can be used by farmers to determine the types of practices they can employ to protect water quality and wildlife habitats in the channels that drain their lands. Collaborators from the USDA-ARS are analyzing the economic tradeoffs between income forgone by not farming poorly drained portions grass seed fields, and Farm Program payments for establishing conservation practices in those areas. These programs have not been widely available to western Oregon grass seed farmers until the relatively recent inclusion of the Conservation Title in the 2002 USDA Farm Bill (Steiner et al., 2005).

Funding

This research was supported by the Oregon Seed Council, Oregon Department of Agriculture, USDA-CSREES Grass Seed Cropping Systems for Sustainable Agriculture Special Grants Program, Hyslop Endowed Extension Chair, OSU Department of Fisheries and Wildlife, Forest Engineering, OSU Extension Services, and USDA-ARS National Forage Seed Production Research Center. Work currently underway is funded by the USDA-NRCS Wildlife Habitat Management Institute, and USDA-ARS National Forage Seed Production Research Center.

Acknowledgments:

In addition to the south Willamette seed growers who kindly allow us access to the waterways and riparian corridors in their properties, many other people have contributed significantly to this project. These include: G.W. Whittaker, G.W. Mueller-Warrant, G.M. Banowetz, Jim Wigington, Richard Caskey, William Gavin, Machelle Nelson, Don Streeter, and William Floyd.

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CEREAL LEAF BEETLE ATTRACTION TO OAT PLANTING OF DIFFERENT AGES

G.D. Hoffman, S. Rao and D.T. Ehrensing

Introduction
The cereal leaf beetle (CLB) is a key cereal pest in the Pacific Northwest that currently limits production efficiency. Adults and larvae feed on the foliage and the corresponding reduction in photosynthesis results in considerable yield loss. In Oregon, insecticides are applied to cereal crops when adults, larvae or damaged leaves are first sighted. Since CLB adults are reported to respond to odors from oat seedlings (Cossé et al., 2002) and odors produced by plants differ with plant age (Buttery and Ling, 1984), we conducted a study to assess CLB adult attraction, and egg laying, to plants of different ages to determine whether preferences (if any) can be exploited to better manage populations of this damaging insect as they move from over-wintering sites to fields of cereal crops.

Procedures
The experiment was conducted in an oat planting (variety Cayuse) at the Hyslop Field Station. There were four oat planting date entries (Figure 1), planted approximately 3 weeks apart. The fourth planting was delayed until June 2 due to the high rainfall in May. The experiment was set up as a randomized block experiment with 4 replicates. Each plot consisted of 45 oat rows in plots 22.5' wide and approximately 140' long. There were two border plots at either end of the experimental plots.

We monitored CLB adult, larvae and egg populations throughout the insects' spring and early summer activity period. This included CLB adults that over-wintered in protected/sheltered areas outside of farm fields, those in the adjacent CLB insectary used to establish parasites, and four releases of adult CLB made by ODA / APHIS in the adjoining insectary of volunteer oats (Figure 1). We speculated that the released adults would mirror the behavior of long distance migrating adults moving into the experimental area. The even distribution of adults across the different blocks suggests this assumption was valid. The number of adults released was relatively small compared to the total number of adults in the experimental plots, ranging from 32% (first release) to 8% (third release).

Sampling commenced soon after the first adults were seen in the plots and continued on a weekly interval until egg laying adults were no longer present in the plots. The number of CLB adults, larvae, and eggs were counted in 10 randomly selected 1-foot sections of a row. The data were averaged for comparisons between plots from the various planting dates. The first adults arrived when only the first two plantings were established. The sampling regime ended before the emergence of new adults (from current year's larvae).

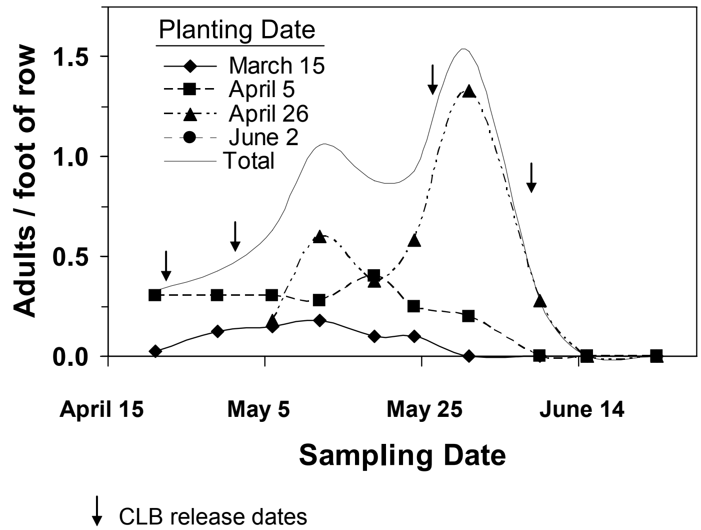

Figure 1. Density of cereal leaf beetle adults on oats of different age. The data show a preference by CLB adults for oats of younger age. Four releases of CLB adults occurred in the adjacent CLB insectary during this period, but most adults came from more distant locations. No adults were recorded during two surveys of the June 2nd planted entry, however a few adults were seen outside the rows sampled.

Plant height was recorded to assess plant "age" differences for the different planting dates.

A CLB egg takes about 2 weeks to hatch at springtime temperatures in the Willamette Valley. Because of this, the "same" eggs could by counted at two or three weekly sampling periods, particularly when the temperatures are cooler in early spring. Expressing the data on a physiological degree-day time scale eliminates the effect of variable temperatures, whether early season versus late season, or week to week. To change the data from a calendar day scale to a physiological degree-day scale we used temperature data from the Hyslop weather station, the CLB development thresholds (Guppy and Harcourt, 1978), and set April 16th as the start of the degree day accumulation. To determine how many actual eggs were laid we divided the total number of egg degree-days by the number of degree-days it takes for an egg to hatch (Southwood, 1978).

Results
During each sampling date, CLB adults had a choice of oats of two or more ages. In every instance they preferred the younger oats (Figure 1). We observed some level of movement of adults from the third planting back into the older

oats during the third week in May, during a period when there was an overall decline of adults in the experimental plots. This was a week of intense rainstorms and we speculate that the adults may have been seeking refuge in areas of greater biomass. At the time the plant height of the 2nd planting was 31.4 cm versus 12.0 cm for the 3rd planting.

The pattern in egg density among the four planting dates matched that of the adult populations to a limited extent. There are two notable exceptions. The egg density in the second planting (April 5th) was only slightly greater than that in the first planting (Figure 2), even though the adult population was twice as great in the second planting (Figure 1). Similarly, even though the population of adults on the third planting (April 26th) was greater than that on the second planting, the number of eggs laid was approximately the same.

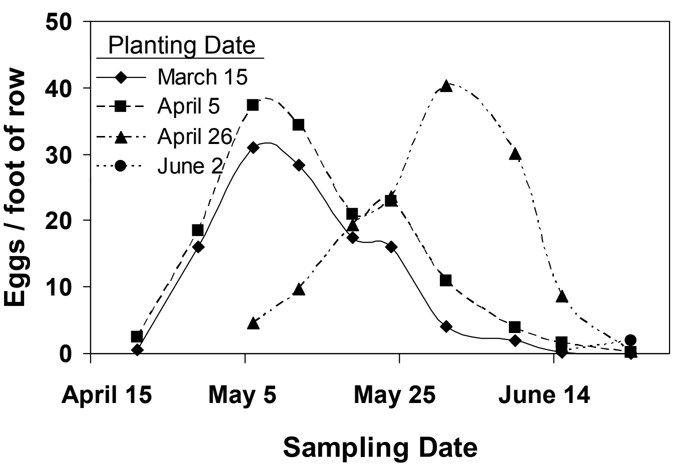

Figure 2. Density of CLB eggs counted on each sampling date on oats of different age. Egg density integrates the density of adults over time and incorporates the egg laying rate per adult. While no adults were recorded when sampling the last planted entry (June 2nd), eggs where found in small numbers.

Expressing egg density on a degree-day scale did not greatly change the pattern of egg counts in the different ages of oat (Figure 3). Surprisingly, the actual number of eggs laid is about the same for the first three planting date (Figure 3). Because there were fewer adults counted in the earlier planting date entries, this suggests that the adults on the older oats were laying more eggs.

Several factors could have influenced the relationship between the number of adults counted and the number of eggs laid. It is conceivable that the female:male sex ratio was not the same in each of the planting date treatments. Differences in oat nutritional quality related to plant age could have affected food consumption rates and therefore egg laying rate. Finally, daily movement of adults between oats of different age, due to potentially competing preferences for the most favorable feeding, egg laying, or shelter/protection host, may have obscured the true eggs per female relationship. If females that had not yet started laying eggs had different preferences for oat plant age compared to egg laying females, this would further complicate the relationship.

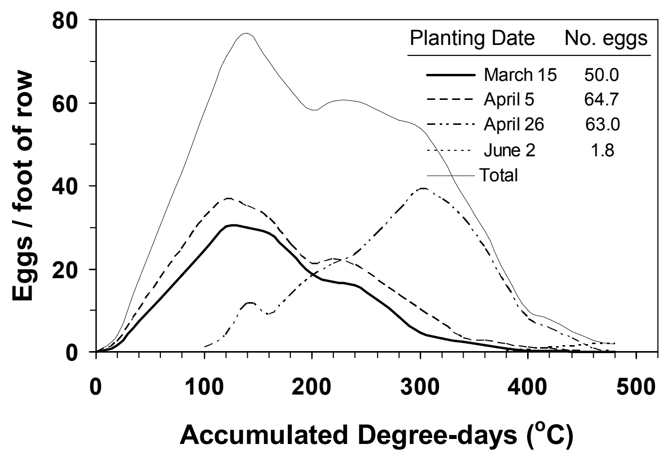

Figure 3. Density of CLB eggs counted in relation to the number of centigrade degree-days accumulated from April 16th. This allows comparison of early versus late season egg production using a physiological time scale. The pattern in the total number of eggs counted matches the fecundity of CLB females over their life span. The number of eggs (No. eggs) is the total number of actual eggs per foot of row in that entry. This value is determined by adjusting the weekly egg counts by the probability of "recounting" the same egg more than once.

Based on this, estimation of adults does not reflect the number of eggs laid on plants of a certain age. Hence for more accurate estimations, eggs need to be sampled. However adults contribute to feeding too, and they are easier to sample due to their bright coloration. Hence, further research is needed to determine how well adult sampling can be correlated with potential damage. Answers to these questions are needed before the role of cereal leaf beetle attraction to younger plants can be assessed for its potential role in managing CLB populations. During the 2006 growing season we will repeat this study, and via a series of more controlled experiments, try to elucidate some of the trends and questions that arose from the results 2005 planting date host preference study.

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CONTROL OF ROUNDUP READY CREEPING BENTGRASS AND ROUGHSTALK BLUEGRASS IN KENTUCKY BLUEGRASS SEED PRODUCTION IN CENTRAL OREGON, 2004-2005

M.D. Butler, J.L. Carroll and C.K. Campbell

The Oregon Department of Agriculture established a control area for the production of Roundup Ready creeping bentgrass seed north of Madras, Oregon. This area east of the Cascade mountain range was chosen because of its isolation from the Willamette Valley. The 60,000 acres of irrigated agricultural land in this arid, high desert region surrounded by sagebrush and juniper includes seed production of Kentucky bluegrass (*Poa pratensis*) and rough bluegrass (*Poa trivialis*). Four hundred acres of commercial plantings of Roundup Ready creeping bentgrass (*Agrostis stolonifera*) were made within the control area in 2002, harvested in 2003 and removed in the spring of 2004 prior to heading.

During 2004-2005 herbicides were evaluated for both control of potential creeping bentgrass escapes and roughstalk bluegrass contamination in Kentucky bluegrass seed fields. Plots 10 ft x 25 ft were replicated four times in commercial fields of Roundup Ready creeping bentgrass, roughstalk bluegrass and Kentucky bluegrass. Treatments were applied October 7 and November 19, 2004 using a CO_2 pressurized, hand-held boom sprayer at 40 psi and 20 gal/acre water. Plots were irrigated following the October 7 applications.

Plots were evaluated April 5, 2005 for percent reduction in biomass for Roundup Ready creeping bentgrass and roughstalk bluegrass, and crop injury in Kentucky bluegrass. The Roundup Ready creeping bentgrass and roughstalk bluegrass fields were taken out of production following the spring evaluation. Kentucky bluegrass plots were evaluated for reduction in seed set on June 14, 2005.

Calisto and a combination of diuron plus Sinbar provided the greatest control of Roundup Ready creeping bentgrass across the two application dates (Table 1). For roughstalk bluegrass the combination of durion plus Sinbar and the three-way combination of diuron plus Sinbar plus Beacon provided the greatest control.

There doesn't appear to be a significant trend when comparing the October 7 and November 19 application dates for Roundup Ready creeping bentgrass. For roughstalk bluegrass the October 7 application generally performed better than the November 19 application. However, there is significant variability that doesn't appear to be related to specific herbicides. There was no consistent crop injury or reduction in seed set observed in the Kentucky bluegrass plots.

Table 1 Evaluation April 5, 2005 of herbicides applied October 7, 2004 and November 19, 2004 on the percent reduction of biomass on Roundup Ready bentgrass and Roughstalk bluegrass, near Madras, OR.

		Percent biomass reduction			
		Applied October 7, 2004		Applied November 19, 2004	
Treatments	Rate/acre	Roundup ready bentgrass	Roughstalk bluegrass	Roundup Ready bentgrass	Roughstalk bluegrass
Calisto	8 oz	97 a	19 b	98 a	0 d
Diuron +	2 lb				
Sinbar	.33 lb	89 a	68 ab	96 a	89 a
Goal +	12 oz				
Diuron +	2 lb				
Sencor 4L	4 oz	68 b	64 ab	50 bcd	84 ab
Sinbar	.5 lb	63 bc	44 ab	61 b	39 c
Beacon +	38 oz				
Diuron	2 lb	54 bc	91 a	55 bc	70 b
Goal +	16 oz				
Diuron	2 lb	38 cd	74 ab	43 bcd	68 b
Banvel +	16 oz				
Diuron	2 lb	34 cde	26 ab	34 cd	66 b
Beacon +	.38 oz				
Sinbar	.33 lb	23 de	55 ab	10 e	30 c
Diuron	2 lb	9 de	54 ab	30 d	76 ab
Goal +	12 oz				
Diuron +	2 lb				
Sinbar	.25 lb	5 e	73 ab	79 a	83 ab
Goal +	16 oz				
Sencor 4L	8 oz	0 e	29 b	3 e	9 d
Beacon	.75 oz	0 e	53 ab	0 e	14 d
Goal	16 oz	0 e	25 ab	0 e	0 d
Sencor 4L	8 oz	0 e	14 ab	0 e	10 d
Beacon	.38 oz	0 e	20 b	0 e	3 d
Untreated	----	0 e	5 b	0 e	0 d

[1]Mean separation with Least Significant Difference (LSD) at P ≤ 0.05.

EVALUATING THE CORRELATION OF STRIPE RUST LEVELS IN THE FALL WITH LEVELS THE FOLLOWING SPRING IN KENTUCKY BLUEGRASS IN CENTRAL OREGON, 2004-2005

M.D. Butler, C.K. Campbell and J.L. Carroll

Stripe rust (*Puccinia striiformis*) is a major disease concern of Kentucky bluegrass seed growers in central Oregon. Occurrence of the disease is weather dependent and usually occurs between May and June. The objective of this project was to determine if there is a correlation between the incidence of rust in Kentucky bluegrass fields in the fall and the level of rust in the fields the following spring.

Plots were placed in three Kentucky bluegrass fields with known rust infections November 15, 2004. Four plots were flagged in areas of each field where there was low to no incidence of rust and four plots were flagged in areas where there was medium to high incidence of rust. Levels of rust were rated the following spring on June 9, 2005 using a rating scale of 0 (no rust present) to 5 (total leaf coverage). Ten random ratings were made per plot.

There does not appear to be a correlation between the level of rust in the fall and occurrence of rust the following spring (Table 1). Levels of rust varied between fields the following spring from 0 to 1.6, but did not correlate to the overall level of rust in the fields the previous fall or with the difference in level of rust within the plots the previous fall.

Table 1. Level of stripe rust (*Puccinia striiformis*) in Kentucky bluegrass plots evaluated June 9, 2005 to compare plots with no to low incidence of rust and plots with medium to high incidence of rust on November 15 the previous fall

	Level of rust on June 9, 2005					
Level of rust on Nov. 15, 2004	Location 1		Location 2		Location 3	
Absent to low level	0[1]	a[2]	0.35	a	1.6	a
Moderate to high level	0	a	0.35	a	1.5	a

[1] Rating scale was 0 (no rust) to 5 (total leaf coverage).
[2] Mean separation with Least Significant Difference (LSD) $P \leq 0.05$.

SURVEY OF INSECT PESTS IN KENTUCKY BLUEGRASS SEED PRODUCTION IN CENTRAL OREGON, 2005

C.K. Campbell, M.D. Butler and L.L. Samsel

A two year survey of insect pests in Kentucky bluegrass fields was conducted in central Oregon and the Grande Ronde Valley during 2003-2005. Results indicated the presence of sod webworm (*Chrysoteuchia topiaria*) and cutworms (*Protagrotis obscura)* in central Oregon. No billbugs (*Sphenophorus venatus confluens*) were collected in 2003-2004, while 22 were collected during 2004-2005. No differences were observed in two fields with multi-acre non-burned and open field burned plots. Sod webworms are an emerging pest that can have a financial impact on Kentucky bluegrass fields. As a result, this year's study focused on sod webworm populations and distribution. However, the presence of cutworms and bill bugs were also noted. The strategy for 2005 was to use pheromone traps that emit a scent to attract males to track the flights of the sod webworm moth. It is hoped that pheromone traps can be used as an early indicator of which fields will have treatable levels of larvae in the fall. This was followed by sod-sampling to determine the correlation between moth and larval populations.

Three pheromone traps were placed in each of twenty-three commercial bluegrass seed production fields on June 28, 2005. Fields with potential for insect problems in the Madras and Culver areas were chosen for the survey. The contents of each trap were collected weekly from July 4 to August 21. The number of sod webworm moths and cutworm moths were noted for each trap. Traps were removed to the side of the field for swathing, threshing and baling activities.

Nine fields were chosen for follow-up sod sampling. With three fields representing the highest total number of moths collected (287 to 610), the intermediate range (164-277) and lowest number of total moths (77-133) were chosen. Twelve sod samples one-foot in diameter by two inches deep were collected from each field during September 14-16, October 3-5, and October 26-28. Four sod samples were collected from the area where each of the three pheromone traps were located earlier in the season. This sampling procedure was used to minimize field variability in an effort to focus on the correlation between pheromone trapping of adults and larval numbers in sod samples. Sod samples were processed for 24 hours using Berlese funnels. Insects were collected into jars and identified daily. Sod samples were kept refrigerated while waiting processing.

The number of sod webworm moths in the pheromone traps was considered low for all fields compared to fine fescue seed fields in the Willamette Valley (Table 1). The overall peak in population was from the last week of June thru mid July. Sod webworm moths ranged from 77 to 610 between fields. The highest number of sod webworm moths collected in one week was 212 during July 11-17, while the lowest number was zero during August 15-21. The average number of sod webworm moths collected weekly per field ranged from 89 during July 4-10 down to 15 during August 15-21. Based on the average number of sod webworm moths collected per field it would appear that the peak flight begins during or before the first week of July, and declines steadily from that point.

A total of 1641 cutworm moths were collected in the pheromone traps (Table 2). It is assumed that cutworm moths were not specifically attracted to the pheromone traps, but were inadvertently caught. Eighty-two percent of the cutworm moths were collected from July 4- 24. The average number of cutworm moths per field remained level (24, 25, 23) in weekly collections during July 4-24, then sharply declined (9, 5, 3,1) through mid August.

Traps were moved to the edge of the field during swathing and threshing activities, and placed back in the field as soon after as possible. Pheromone trapping continued until the field was ready to burn, at which time the traps were permanently removed from the field.

No sod webworm larvae were collected in sod samples at any locations during any collection date (Table 3). Although six of the fields were treated with an insecticide, no larvae were found before these insecticide applications. The reason for this lack of larvae is unclear; however, the widespread nature of this phenomenon would seem to point to something other than specific grower management practices. Fine fescue fields in the Willamette Valley also experienced a remarkable lack of sod webworm larvae.

Cutworm larvae collected from sod samples varied from field to field. Field 1 and 7 had the highest number of larvae (108 and 119 respectively). The numbers were spread more or less evenly across sampling dates. A total of six bill bugs were found in three fields.

Table 1. Sod webworm moths collected per field in Kentucky bluegrass seed during the summer of 2005.

Field	Collection dates							Total
	July 4-10	July 11-17	July 18-24	July 25-31	Aug 1-7	Aug 8-14	Aug 15-21	
	(Number of moths/field)							(no.)
1	43	33	12	----	5	4	0	97
2	77	212	146	117	----	45	13	610
3	6	8	46	----	152	56	9	277
4	----[1]	92	34	2	97	42	----	267
5	117	38	----	4	4	1	----	164
6	154	65	----	44	17	6	1	287
7	----	56	39	34	3	1	----	133
8	20	19	----	----	25	13	----	77
9	39	90	100	177	20	----	33	459
10	96	131	11	19	31	----	----	288
11	159	47	13	38	----	----	----	257
12	147	130	111	164	16	26	----	594
13	90	171	----	----	50	----	----	311
14	125	2	2	7	----	4	----	140
15	74	47	16	10	----	14	----	161
16	----	87	19	7	72	----	----	185
17	57	43	8	----	----	----	----	108
18	64	23	----	23	2	----	1	113
19	71	18	----	8	6	----	4	107
20	----	60	38	63	34	----	----	195
21	65	28	----	105	7	3	0	208
22	146	155	----	72	102	----	61	536
23	140	145	----	60	54	----	31	430
Total	1690	1700	595	954	697	215	153	6004
Field average	89	74	43	50	39	18	15	----

[1]Traps not collected.

Table 2. Cutworm moths collected per field in Kentucky bluegrass seed during the summer of 2005.

Field	Collection dates							Total
	July 4-10	July 11-17	July 18-24	July 25-31	Aug 1-7	Aug 8-14	Aug 15-21	
	(Number of moths/field)							(no.)
1	19	36	35	----	0	2	1	93
2	40	30	5	2	----	2	0	79
3	47	65	40	----	3	2	1	158
4	----[1]	10	32	0	5	4	----	51
5	10	29	----	4	0	0	----	43
6	8	18	----	8	0	5	0	39
7	----	17	21	3	0	0	----	41
8	60	61	----	----	7	0	----	128
9	39	34	37	27	7	----	0	144
10	21	11	20	1	2	----	----	55
11	24	30	23	4	----	----	----	81
12	10	17	25	9	5	9	----	75
13	14	6	----	----	13	----	----	33
14	28	27	4	5	----	4	----	68
15	24	15	29	4	----	1	----	73
16	----	6	24	6	5	----	----	41
17	23	16	2	----	----	----	----	41
18	22	13	----	4	3	----	0	42
19	14	22	----	12	5	----	4	57
20	----	31	28	13	3	----	----	75
21	22	44	----	12	12	1	2	93
22	16	10	----	23	4	----	6	59
23	13	19	----	32	8	----	0	72
Total	454	567	325	169	82	30	14	1641
Field average	24	25	23	9	5	3	1	----

[1]Traps not collected.

Table 3. Cutworm (CW) and bill bugs (BB) found in sod samples, 2005.

Field	Insecticide Application	Sampling dates: Sept 1-16		Oct 3-5		Oct 26-28		Total	
		(Number of insects/field)						(no.)	
		CW	BB	CW	BB	CW	BB	CW	BB
1	None	44	0	21	0	43	0	108	0
2	October 10	4	0	13	3	0	1	17	4
3	October 1	3	0	1	0	0	0	4	0
4	September 20	2	0	2	0	0	0	4	0
5	October 1	0	0	0	0	0	0	0	0
6	November 14	4	0	9	0	14	0	27	0
7	September 25	46	0	32	1	41	0	119	1
8	None	0	1	1	0	0	0	1	1
9	None	7	0	8	0	18	0	33	0

COMPARISON OF NITROGEN FERTILIZERS: EFFECTS ON KENTUCKY BLUEGRASS (*POA PRATENSIS* L.) GROWN FOR SEED

S.M. Griffith and G.A. Murray

Introduction

Grass seed growers are not using ammonium nitrate fertilizer as much as in the past. This is in part due to proactive steps taken by fertilizer companies to self regulate ammonium nitrate distribution due to U.S. national security concerns. Ammonium nitrate is the least expensive and most widely available ingredient used in commercial explosives. Ammonium nitrate is available in two basic forms: one intended for use as a blasting agent ingredient, and one intended for use as fertilizer. In many agricultural areas, this change in ammonium nitrate availability leaves seed producers with fewer N source options and raises concerns about the effectiveness of alternative N source. Also in question is whether N fertilizer application should occur in the fall, spring, or in split application. Ammonium sulfate and urea are two fertilizer alternatives to ammonium nitrate.

The primary objective of this research was to measure the effects of different forms of N fertilizer on dry mass production and seed yield components of different cultivars of Kentucky bluegrass grown for seed at multiple locations in the Pacific Northwest. A preliminary study also examined fall versus spring applied N on the same growth parameters. This report is a brief summary of those findings and an expansion of the findings reported by Murray and Griffith (1994; 1995).

Materials and Methods

Two fertilizer N sources: Effects on genotypes at different locations. This experiment compared the growth response and seed yield components of Kentucky bluegrass cultivar that received enhanced ammonia nutrition, ammonium sulfate, or ammonium nitrate fertilizers. Field sites were established at five locations within the major Pacific Northwest Kentucky bluegrass production areas including the Rathdrum Prairie, near Coeur d'Alene, Idaho, the Plant Science Research Farm at Moscow, Idaho, production fields near Rockford, WA/Worley, ID, and a site near Madras, OR. Results from another site at La Grande, OR were also included in the study. This study was conducted on the same crop from the first to the fourth seed-year and included the following five Kentucky bluegrass cultivars: 'Adelphi', 'Glade', 'Liberty', 'South Dakota', and 'Suffolk'. These cultivars were chosen for their contrasting genotypic and phenotypic variation in vernalization length, flowering time, tillering characteristics, turf and forage quality, and well as, morphological factors (e.g., stem length). The Moscow and Madras sites were irrigated, while the other three sites were dryland. The experimental design was a randomized block with four replications. Either ammonium sulfate or ammonium nitrate was applied to the plots in the fall each year at a rate of 140 kg N/ha.

Five N fertilizer sources: Effects on growth and seed yield. This study was conducted at La Grande, OR under dryland conditions to determine the effect of a wide spectrum of N fertilizers in the growth and seed yield of a second-year stand of Kentucky bluegrass 'Coventry'. Five different N fertilizer treatments were applied in the fall at a rate of 140 kg N ha^{-1}. The N fertilizers were: calcium nitrate, ammonium nitrate, ammonium sulfate, and Urea-DCD (urea-dicyandiamide). The study was designed as a randomized block with four replications.

Ammonium vs. nitrate - hydroponic experiment. Twenty-eight contrasting cultivars of Kentucky bluegrass were grown under hydroponic conditions as described by Griffith and Streeter (1994). Cultivars consisted of: 'Wabash', 'Merit'. Chateau', 'Victa', 'Liberty', 'Cheri', 'South Dakota', 'Huntsville', 'Bistol', 'Hyss', 'Eclipse', 'Newport', 'Julia', 'Leikra', Suffolk', 'Baron', 'Adelphi', 'Abbey', 'Hattfielldal', '03-6-53-2', '03-6-48-3', '9009', 03-6-49-1', 'Lavang', '8702', 'Coventry', 'Ikone', and 'Glade'. Solution N concentration was maintained at 10 mM nitrate-N or ammonium-N. Half of the plants received all nitrate and half received all ammonium as an N source. The hydroponic solution pH was continually monitored and automatically maintained at pH 6.

Results and Discussion

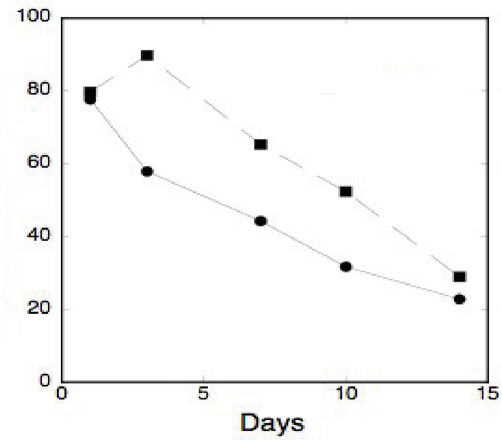
N fertilizer source on growth and seed yield components. The results of a one year study at La Grande, Oregon determining the effect of five different N fertilizers on Kentucky bluegrass 'Coventry' growth and seed yield components are reported in Table 1. Calcium nitrate and ammonium nitrate treated plants produced higher seed yield, tillers per unit area, and total shoot dry mass per unit area than ammonium sulfate and urea-DCD treated plants. Seed yield of plants treated with calcium nitrate or ammonium nitrate were not significantly different (P = 0.05). Seed yield harvested from the grower's adjacent 'Coventry' seed crop fertilized with ammonium nitrate was 1467 kg/ha (estimated from a m^2 sampling) and not significantly different from the our treated ammonium nitrate and calcium nitrate treated plots. Urea-DCD and ammonium sulfate and fertilization significantly reduced seed yield by 10% and 23%, respectively, and final total shoot mass by 27% and 11%, respectively, compared to both nitrate-N treated plots. Changes in shoot mass and seed yield reflected changes in harvest index for each treatment. Urea-DCD fertilization increased harvest index by 24% over nitrate containing fertilizer treatments treated plots, whereas ammonium sulfate reduced harvest index by 13%. Urea-DCD increased total cleaned seed mass per tiller.

Table 1. Effect of four nitrogen fertilizers on components of seed yield in Kentucky bluegrass 'Coventry'. Fertilizer was applied in the fall to plots of an existing two-year crop located at La Grande, OR. Each plots measured 12 m^2. Means followed by the same letter are not significantly different by Newmans-Keuls test ($P < 0.1$).

N-source	Panicle number	Shoot biomass	Seed yield	Harvest index
	(no./m^{-2})	(kg/ha)	(kg/ha)	(%)
Calcium nitrate	5728 a	22,978 a	1566 a	6.8 a
Ammonium nitrate	5492 a	22,032 a	1507 a	6.8 a
Ammonium sulfate	9311 b	20,152 b	1188 b	5.9 b
Urea-DCD	4439 b	16,771 b	1375 b	8.4 c

These data support controlled growth chamber hydroponic findings where 28 cultivars of Kentucky bluegrass screened had 0 to 50% more shoot dry mass accumulation when fertilized with nitrate compared to ammonium (data not shown). This might be attributed to higher nitrate-N uptake rates compared to ammonium-N uptake (Figure 1). These data also support the notion that Kentucky bluegrass is a facultative nitrate user and potentially a good scavenger of soil nitrate, reducing nitrate leaching potential. This would have important implications with regard to water quality in agricultural landscapes. These data also suggested the potential use of N management to alter the harvest index in favor of reducing post-harvest straw residue while maintaining high seed yields. Ammonium based fertilizers might provide more efficient N utilization resulting in greater N conservation and lower fertilizer cost relative to nitrate fertilizers.

Figure 1. Disappearance of NO_3-N (•) and NH_4-N (▪) from a hydroponic solution containing growing Kentucky bluegrass. Y-axis represents the 'Relative Total N Concentration' of the hydroponic solution. The hydroponic system was pH controlled to maintain a constant pH. Plant development was at the 3- to 4-leaf stage.



<u>N-form effects on five genotypes at four Pacific Northwest locations.</u> Contrary to the one-year study at La Grande with 'Coventry', a five year study with five Kentucky bluegrass cultivars, 'Liberty', 'Adelphi', 'Glade', 'Suffolk', 'Classic', 'Merit', and 'South Dakota', at five locations utilizing two different N fertilizers (ammonium sulfate vs. ammonium nitrate) did not significantly ($P = 0.05$) affect final seed yield and panicle number (Tables 2-7; data not shown for Madras and La Grande). These two N forms did not affect above and below ground biomass accumulation, vegetative tiller, or seed harvest index (data not shown). Variability due to position in the field (replications) was generally greater than variability attributed to cultivar or form of N.

Table 2. The influence of nitrogen form on seed yield of five Kentucky bluegrass cultivars, established at Worley, Idaho, and harvested in July of 1993, 1994, 1995, and 1996. Values are means of four crop years and three or four replications.

Cultivar	N-source NH$_4$	N-source NO$_3$+NH$_4$	Cultivar mean
	----------- (kg/ha) ---------		
Adelphi	613 *	625	620 abc
Glade	524	502	513 c
Liberty	643	677	660 ab
S. Dakota	565	587	576 bc
Suffolk	694	777	735 a
Treatment mean	609 a	633 a	

* The interaction of form of nitrogen with cultivar was not significant at $P = 0.05$.

Table 3. The influence of nitrogen form on panicle density of five Kentucky bluegrass cultivars, established at Worley, Idaho, and harvested in July of 1993, 1994, 1995, and 1996. Values are means of four crop years and three or four replications.

Cultivar	N-source NH$_4$	N-source NO$_3$+NH$_4$	Cultivar mean
	--------(panicles/m^2)------		
Adelphi	2669 *	2766	2713 bc
Glade	1981	2454	2217 cd
Liberty	2982	3208	3100 b
S. Dakota	2185	1690	1938 d
Suffolk	3767	4133	3950 a
Treatment mean	2723 a	2852 a	--

* The interaction of form of nitrogen with cultivar was not significant at $P = 0.05$.

Table 4. The influence of nitrogen form on seed yield of five Kentucky bluegrass cultivars, established at Moscow, Idaho, and harvested in July of 1994, 1995, and 1996. Values are means of three crop years and four replications.

Cultivar	N-source NH$_4$	N-source NO$_3$+NH$_4$	Cultivar mean
	---------- (kg/ha) ---------		
Adelphi	711 *	905	808 b
Glade	693	638	666 b
Liberty	1116	1112	1114 a
S. Dakota	898	758	829 b
Suffolk	1018	1036	1027 a
Treatment mean	887 a	889 a	--

* The interaction of form of nitrogen with cultivar was not significant at $P = 0.05$.

Table 5. The influence of nitrogen form on panicle density of five Kentucky bluegrass cultivars, established at Moscow, Idaho, and harvested in July of 1994, 1995, and 1996. Values are means of three crop years and four replications.

Cultivar	N-source NH$_4$	N-source NO$_3$+NH$_4$	Cultivar mean
	-------(panicles/m^2) -----		
Adelphi	3003 *	3444	3229 bc
Glade	2207	2605	2400 c
Liberty	3380	3789	3584 ab
S. Dakota	2422	3122	2777 bc
Suffolk	4166	4306	3154 a
Treatment mean	3035 b	3455 a	--

* The interaction of form of nitrogen with cultivar was not significant at $P = 0.05$.

Table 6. The influence of nitrogen form on seed yield of five Kentucky bluegrass cultivars, established at Rathdrum, Idaho, and harvested in July of 1993, 1994, and 1995. Values are means of three crop years and four replications.

Cultivar	N-source NH_4	N-source NO_3+NH_4	Cultivar mean
	----------- (kg/ha) ---------		
Adelphi	134 *	164	149 c
Glade	100	127	113 d
Liberty	193	185	190 b
S. Dakota	140	176	158 c
Suffolk	274	220	247 a
Treatment mean	168 a	174 a	--

* The interaction of form of nitrogen with cultivar was not significant at P = O.05.

Table 7. The influence of nitrogen form on panicle density of five Kentucky bluegrass cultivars established at Rathdrum, Idaho, and harvested in July of 1993, 1994, and 1995. Values are means of three crop years and four replications.

Cultivar	N-source NH_4	N-source NO_3+NH_4	Cultivar mean
	--------(panicles/m^2)------		
Adelphi	134 *	164	149 c
Glade	100	127	113 d
Liberty	193	185	190 b
S. Dakota	140	176	158 c
Suffolk	274	220	247 a
Treatment mean	168 a	174 a	--

* For separation of form of nitrogen by cultivar interaction means, LSD 0.05 = 43.

There was no significant effect (P=0.1) on the number of tillers per unit area and shoot dry mass between the N-form treated plots. However, root/rhizome fresh and dry weights were significantly different (P=0.08) among N treatments. Tillering and shoot weight varied with location and cultivar. The cultivars ‘Glade’ and ‘Suffolk’ were particularly responsive to location differences. In these analyses, CV's averaged about 35%.

We observed that fall tiller number was enhanced with enriched ammonium nutrition (data not shown). Tiller and panicle production was estimated on plant samples taken at the end of winter (March 10) by transplanting plant cores into the greenhouse to accelerate development. Vegetative tiller number was 64 and 69 per 10 cm core for urea and ammonium nitrate treatments, respectively. Panicle number was equal in both treatments. Plants fertilized with urea (enhanced ammonium nutrition) showed earlier panicle development than those that received ammonium nitrate. Form of N fertilizer did not affect early (fall), mid (winter), and late (July) aboveground biomass production (data not shown).

<u>Soil N</u>. Soil pH was in the acid range at all locations (data not shown) except Madras where it ranged from 7.8 to 8.2. Soil pH increased with increasing depth at all locations. At Madras and Rathdrum the soil pH was lower in plots treated with ammonium sulfate and higher in plots treated with ammonium nitrate. This pH change was not observed at Worley or Moscow.

Total soil N level, just prior to seed harvest (Moscow and Nezperce), averaged 51 kg N/ha in the top 60 cm soil. A total soil loss of 60.8 kg N ha^{-1} was measured at Moscow during the cropping season. Generally, fall (September and November) and early spring (March) soils had high ammonium to nitrate ratios whereas in the late spring (May) the inverse was true. This may have occurred because soil nitrate loss to the crop (plant uptake) was greater at a time when N demand was greatest during the peak growth periods. Alternatively, ammonium production from mineralization was greater than nitrate production from nitrification.

<u>Fall vs. spring applied N</u>. Often there is uncertainty about the benefit of fall applied N when considering the leaching potential during fall, winter, and spring precipitation periods, and the reduced ability to time spring N application to match crop N demand during the early growing season. For plots established in Corvallis, OR, the timing of fall vs. spring applied N did not significantly (P = 0.01) affect seed yield or final aboveground crop biomass accumulation in the Kentucky bluegrass cultivars, ‘Abbey’, ‘Ryss’, ‘Coventry’, and ‘LaVang’. However, fall applied N more than doubled the panicles per unit area in ‘Abbey’ and ‘Coventry’ (Table 8).

Table 8. Effects of fall versus spring applied N on yield components of four cultivars of Kentucky bluegrass grown for seed.

Cultivar	N timing	Number Panicles		Shoot dry mass		Seed yield	
		(no./m^2)		(g/m^2)		(g/m^2)	
Abbey	Fall	1221	**	1521	NS	84	NS
	Spring	577		999		85	
Ryss	Fall	1010	NS	955	NS	36	NS
	Spring	755		932		28	
Coventry	Fall	1654	**	1521	NS	44	NS
	Spring	511		1254		47	
LaVang	Fall	255	NS	710	NS		
	Spring	500		722			

NS = not statistically significant at 0.05
** Significant at $P = 0.05$

Conclusions

These studies strongly indicate that enhanced ammonia nutrition can be used without adversely affecting Kentucky bluegrass seed yield in western Idaho, eastern Washington, and central and eastern Oregon. An added value in using ammonium-based fertilizer is that ammonium binds longer to the soil and reduces potential N losses to ground and surface water. A cost saving may also be realized if ammonium based fertilizers are used. Prolonged use of ammonium fertilizers may lower soil pH, so the soil pH should be monitored prior to the next growing season. In more basic soils (pH > 7.0), this may not be as critical as in acid soils. Data reported here suggest that fall fertilization, a common practice east of the Cascade Range, may not enhance seed yield if N can be applied in the spring and soil infiltration is aided by spring precipitation. The general rule is that whenever possible, N fertilizer application should coincide with crop growth. This practice will be easier to implement in irrigated systems or in areas west of the Cascade Range where high amounts of rainfall during the spring are more probable.

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EFFECT OF P AND K FERTILIZATION STRATEGIES ON KENTUCKY BLUEGRASS SEED PRODUCTION

G.L. Kiemnec, D.L. Walenta and C.R. McNeal

Introduction

Agricultural Water Quality Management Area Rules for the Upper Grande Ronde River Sub-basin (OAR Chap. 630, Division 95) state that "By January 1, 2003 nutrient application rates and timing shall not exceed specific crop requirements." Nutrient levels on soils used for grass seed production in the Grande Ronde Valley often test high or very high for phosphorus (P) and potassium (K). If P and/or K fertilizer applications were reduced or temporarily halted, knowledge of how these reductions will be manifested in changing soil test levels and seed yield is critical. With the switch to non-thermal residue management, the rate of reduction in soil test K levels increases. Oregon Department of Environmental Quality has established a loading capacity target of 10 μg P/L for portions of the Grande Ronde River and Catherine Creek. Since movement of P to surface waters is predominantly through surface runoff, the use of a spoke wheel applicator to reduce surface soil P concentrations was investigated.

Methods and Materials

In a commercial, irrigated Kentucky bluegrass field (1st year) five, fall fertilizer treatments were applied: 1) P_oK_o (Check), 2) P_oK_+, 3) P_+K_o, 4) P_+K_+, 5) P_+K_+ (spoke wheel). All P and K fertilizers were applied broadcast except treatment (5) where P was applied via spoke wheel; P_+ = 30 lb P_2O_5/acre and K_+ = 30 lb K_2O/acre. Plot size was 9 ft by 60 ft with 4 replications. A plot combine was used to harvest grass seed. Whole plant samples were taken from 6 lineal feet (2, 3 feet samples) and analyzed for P and K concentrations to determine P and K uptake. Soil samples were taken at 0-2, 2-4, and 4-6 inches before fertilizer treatments in fall, 2003 and after 2004 harvest and analyzed for available P and K. The soil was an Alicel fine sandy loam, a member of the fine-loamy, mixed, superactive, mesic Pachic Haploxerolls.

Results

Fertilizer applications had no effect on seed yields in 2004 or 2005 (Table 1). In each year soil test levels for P and K were above levels at which fertilizer is recommended. Growers could reduce fertilizer costs (P and K) for two years at these soil test levels. Soil P was only affected by years; soil K only by depth (Table 2). The increase in K levels in 2004 and 2005 at 0-2 inches was likely due to the amount of residue left after baling and propaning in 2004 and field burning in 2005. The increase in the soil K levels at 0-2 inches, a decrease in K levels at lower depths, and no change in K uptake, indicate that bluegrass is drawing on soil K from below 2 inches and perhaps below 6 inches. This may be due to the fact that this soil is sandy and dries out fast enough to prevent uptake by shallow roots. Spoke wheel application of P did not result in a statistical decrease in the 0-2 inch soil P levels compared to surface P applications in 2004 or 2005. However, in 2005 soil P concentration (0-2 in) averaged 63 ppm with broadcast P applications while soil with the spoke wheel application had a P concentration of 54 ppm.

Table 1. Kentucky bluegrass clean seed yields, and phosphorus and potassium uptake for 2004 and 2005.

Treatment[1]	2004 Seed yield	2004 P_2O_5 uptake	2004 K_2O uptake	2005 Seed yield	2005 P_2O_5 uptake	2005 K_2O uptake
	(lb/a)			(lb/a)		
P_oK_o	1080	47	212	1000	40	206
P_oK_+	1070	46	208	1160	42	208
P_+K_o	1010	44	204	1080	44	212
P_+K_+	1010	48	203	1150	41	202
P_+K_+(spoke)	1120	46	214	1010	48	233
LSD 0.05	NS[2]	NS	NS	NS	NS	NS

[1]P_+= 30 lb P_2O_5/a; K_+= 30 lb K_2O/a
[2]NS = not significant

Table 2. Soil potassium and phosphorus levels 2003 - 2005.

Nutrient/depth	2003	2004	2005
		(ppm)	
K			
0-2 in	350	405	472
2-4 in	341	327	312
4-6 in	360	358	317
LSD 0.05 = 44 (between any year or depth)			
		(ppm)	
P			
0-6 in	59	61	54
LSD 0.05 = 2			

INSECTICIDE/MITICIDE EFFICACY FOR BANKS GRASS MITE CONTROL IN ESTABLISHED KENTUCKY BLUEGRASS GROWN FOR SEED IN THE GRANDE RONDE VALLEY OF NORTHEASTERN OREGON

D.L. Walenta

Introduction

The Banks grass mite (*Oligonychus pratensis*) is a problematic pest for grass seed producers in the Grande Ronde Valley of northeastern Oregon. Heavy infestations of the Banks grass mite (BGM) have been reported to substantially reduce bluegrass seed yields in this area. Currently, there are no insecticides or miticides registered for BGM control in any grass species grown for seed in Oregon. Insecticides registered for effective control of the winter grain mite in grasses grown for seed, however, do not provide effective control of the BGM. A study was conducted in the spring of 2005 in an established stand of Kentucky bluegrass (KBG var. Abbey) grown for seed production near Island City, OR to evaluate the efficacy of selected insecticides/miticides for Banks grass mite control.

Procedure

Banks grass mite populations were determined on March 19, 2005 prior to insecticide/miticide application by counting the number of BGM motiles per leaf from 12 leaf sub-samples per plot with the aide of a 10X hand lens. All treatments (Table 1) were applied on March 21, 2005 to 15 ft by 18 ft plots arranged in a randomized complete block design and replicated four times. Applications were made with a hand-held CO_2 sprayer using 8002 flat fan nozzle tips delivering 20 gpa at 30 psi. Non-ionic surfactant was added to all treatments at 0.5% v/v. Kentucky bluegrass re-growth was 4 to 6 inches in height at the time of application.

Post-treatment application BGM population counts were initiated 17 days after treatment on April 7 and were subsequently collected on 7-day intervals through May 7, 2005. The same BGM population count procedure was followed for determination of post-treatment application BGM populations. KBG foliage damage due to BGM feeding was evident but was not uniform across the study site at the time of application. Seed yield measurements were not collected from this study.

Results and Discussion

In March, prior to insecticide/miticide application, BGM population levels ranged from 11 to 18 motiles per infested leaf within the study area. Although there are no established threshold levels for BGM, this infestation was considered to be moderate as crop damage was already evident on 1% to 5% of the KBG foliage.

Insecticide/miticide efficacy on BGM populations was evident 17 days after treatment on April 7 (Figure 1). Bifenazate, propargite, and dimethoate did suppress BGM populations when compared to the untreated check. Bifenthrin appeared to provide the greatest level of suppression of all treatments, however, differences in suppression/control were not statistically significant at the $P<0.05$ level and may be attributed to variable BGM population levels between replications.

Weather conditions were unseasonably warm (data not shown) in early March which enabled BGM populations to increase in number and begin causing crop damage early. Cool, wet weather followed in mid- to late-April, thus, leading to a reduction in BGM population activity approximately 4 weeks after insecticide application (Figure 1). BGM populations remained static from April 14 through May 7. Visual evaluations of crop injury caused by BGM were not collected due to the lack of treatment differences after April 7. Crop phytotoxicity was not observed during any of the post-treatment BGM population sampling events.

Although there were no statistically significant differences between treatments, results from this particular study suggest that a single application of bifenthrin did provide quick and effective BGM control when applied early season to a light/moderate BGM infestation and followed by cool and wet weather conditions. Bifenthrin, bifenazate, and propargite are not registered for use in grass seed production and are being evaluated on an experimental basis only. Mention of products used in this trial should not be considered as a recommendation for commercial use.

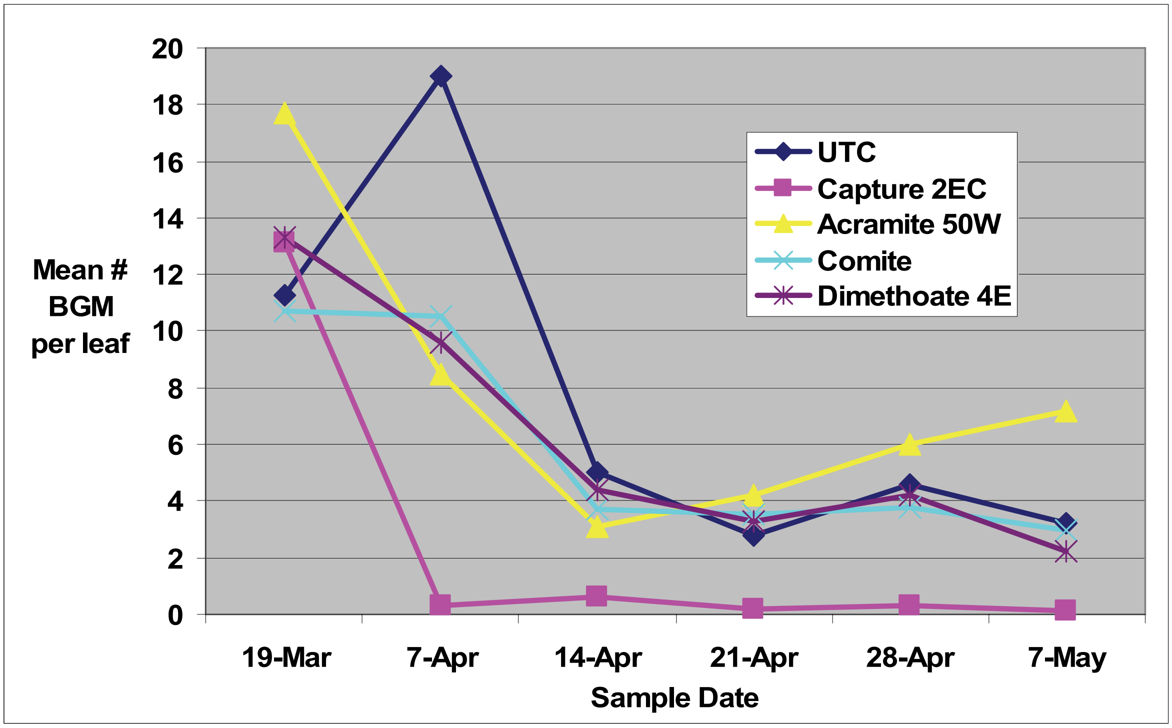
Acknowledgements

Appreciation is extended to FMC, Corp., Bryon Quebbeman, Craig McNeal, and the grower for their support, technical assistance, and cooperation which facilitated completion this research project.

Table 1. Insecticide/miticide treatment list, Spring 2005.

Treatment	Active ingredient	Application rate
		(product/acre)
Untreated check (UTC)	na	na
Capture 2EC	bifenthrin	6.4 fl. oz.
Acramite 50WS	bifenazate	1 lb
Comite	propargite	2.5 pt
Dimethoate 4E	dimethoate	11 fl. oz.

Figure 1. Banks grass mite insecticide/miticide efficacy trial in established Kentucky bluegrass in Oregon's Grande Ronde Valley, Spring 2005.



APPLICATION TIMING EFFECT OF SELECTED INSECTICIDES FOR BILLBUG CONTROL IN KENTUCKY BLUEGRASS SEED PRODUCTION IN THE GRANDE RONDE VALLEY OF NORTHEASTERN OREGON

D.L. Walenta and C.R. McNeal

Introduction
Kentucky bluegrass (KBG) seed producers in the Grande Ronde Valley (GRV) of northeastern Oregon are currently challenged with management of a new complex billbug community that consists of three species, including the bluegrass billbug (*Spenophorus parvulus*), Denver billbug (*Spenophorus cicatristriatus*), and a third species (*Spenophorus sayi*) which lacks a common name. During the last several years, billbug infestations have increased in frequency within commercial KBG and fine fescue production fields and have been associated with increased damage to KBG. Annual pest monitoring efforts conducted from 2000 through 2005 indicate that approximately 40% (total 346 fields sampled) of Kentucky bluegrass and 22% (total 76 fields sampled) of fine fescue seed production fields are infested with billbug at variable population levels.

At this time, only one insecticide is registered for use in grass seed crops for control of billbug species, however, this insecticide only provides suppression of the pest at marginal levels. A study was conducted in a commercial field of established KBG (var. Kelly) grown for seed production near Imbler, OR in Union County to evaluate application timing effect of selected insecticides for control of billbug species found in the GRV.

Procedure
The study site was situated in a KBG field with a known infestation of billbug pests (bluegrass and Denver spp.) as determined by sod-soil samples collected from throughout the field prior to study establishment. Post-harvest residue management consisted of bale + propane flaming in August 2003. Pre-study sod-soil samples (0.6 ft diameter by 4 inch soil depth per sample) were collected randomly across the field on August 22, 2003 (10 samples) and September 19, 2003 (5 samples). Once the study was established, additional sod-soil samples were collected randomly across the field on November 19, 2004 (5 samples), August 4, 2004 (10 samples), and September 9, 2004 (20 samples).

Insecticide treatments were applied in fall 2003 (October 19), early spring 2004 (April 30), and late spring 2004 (June 2) with a hand-held CO_2 sprayer delivering 20 gpa at 28 psi. Following spring treatment applications, a cage (14 inch height by 11 inch diameter) with a fine mesh cover was placed to a depth of 1 inch in each plot to prevent migration of billbug adults between treatments. Irrigation (0.25 inch) was supplied with an overhead sprinkler irrigation system within 12 hours after insecticide application to move insecticide into plant canopy. Weather conditions and crop growth stage are summarized in Table 1. Plots were 8 ft by 20 ft arranged in a randomized complete block design with 3 replications. Soil type was a deep, well drained Imbler fine sandy loam with neutral pH (6.6 to 7.3).

Billbug insect pest (pupa, larvae, and adult life stages) populations within the study site were sampled by collecting one sod-soil sample per replicated treatment both pre- and post-insecticide treatment application. At each sampling date, sod-soil samples were collected from each treatment with a golf course green cup cutter (4.25 inch diameter by 4 inch depth). Pre-insecticide application samples were collected at random from within each plot immediately prior to treatment application. Post-insecticide application samples were collected approximately 14-21 days following treatment application from within the caged-area in each plot. Berlese funnels were used to extract adult billbugs from the sod and sieves were used to collect adult, larvae, and pupae from the soil for field and study site sod-soil samples. Three pit fall traps were placed approximately 25 ft away from the perimeter of the study to monitor adult billbug activity from late April to mid-June 2004. Visual observations of crop injury from insecticide application were made at each post-insecticide application sod-soil sampling event. Seed yield measurements were not collected.

Results and Discussion
Billbug population levels were not significantly reduced by any insecticide treatment applications made in the fall 2003 based on visual counts of dead/dying billbug adults on the soil surface 2 days after treatment (Table 2) and the number of live billbug larvae and adults collected from pre- and post-treatment sod-soil samples (Table 3). Billbugs (neither larvae, pupae, nor adults) were not detected in pre- and post-treatment sod-soil samples collected in early spring or late spring 2004 (data not shown). The total number of billbug adults captured in the spring 2004 pit fall traps were 0, 6, 4, 6 and 8 billbug adults on April 30, May 14, May 24, June 2 and June 11, respectively. Crop phytoxicity was not observed during any of the post-treatment sod-soil sampling events.

Field-level sod-soil samples indicate a substantial billbug (larvae and adult) population was present in the field before, during, and after completion of the study (Table 4). Billbug adults were most numerous from mid-September through mid-November 2003 which provides evidence that early fall insecticide treatments were made during a period of time when billbug adults were at peak levels. It is suspected that surviving billbug adults migrated out of the study site in the spring, thus, the reason no billbug adults were detected in the early spring or late spring sod-soil samples collected within the study.

Additionally, it is not known why larvae or pupae were not detected in those same samples. Billbug population sampling techniques utilized in this study need further modification to more effectively determine infestation levels and insecticide efficacy. Bifenthrin, permethrin, and zeta-cypermethrin are not registered for use in Oregon grass seed production and are being evaluated on an experimental basis only. Mention of products used in this trial should not be considered as a recommendation for commercial use.

Acknowledgements:
Appreciation is extended to FMC, Corp., Blue Mt. Seeds, Inc., and to the grower for their support and cooperation which facilitated completion of this research project.

Table 1. Insecticide application conditions on established Kentucky bluegrass.

	October 19, 2003	April 30, 2004	June 2, 2004
Kentucky bluegrass	4 to 6 leaf 2”-3” height	jointing 6”–10” height	early anthesis 12”-16” height
Timing	Fall	Early spring	Late spring
Air temperature (F)	63	56	63
Relative humidity (%)	48	54	64
Wind velocity (mph)	2	3	3
Soil temperature at depth 2 inch (F)	56	50	58

Table 2. Number of billbug adults on soil surface exhibiting symptoms of control 2 days after insecticide application, Fall 2003.

Treatment	Active ingredient	Rate	Adult billbugs controlled
		(product/acre)	(no. per ft^2)
Capture 2EC	bifenthrin	5 oz	0.3
Pounce 3.2	permethrin	8 oz	0.4
Mustang Max	zeta-cypermethrin	4 oz	0.4
Lorsban 4E	chlorpyrifos	32 oz	0.7
Untreated Check			0.5

Table 3. Number of live billbug larvae and adults found in sod-soil samples collected from within the study site 9 days after insecticide treatment, Fall 2003.

Treatment	Rate	Pre-treatment billbug population	Post-treatment billbug population
	product/acre	----------------------(no. per ft^2)	-------------------
		October 18	October 28
Capture 2EC	5 oz	5	10
Pounce 3.2	8 oz	7	10
Mustang Max	4 oz	7	7
Lorsban 4E	32 oz	7	5
Untreated Check		12	5

Table 4. Field-level billbug population prior to study establishment and after completion of the insecticide efficacy study. Fall 2003 and Fall 2004.

Sod-soil sample date	Samples	Larvae	Adults	Total
	(no.)	----------------------------	(no. per ft^2)	----------------------------
<u>Early Fall 2003</u>				
August 22	10	2.5	0.3	2.8
September 19	5	2.0	10.7	12.7
November 19	5	0	10.7	10.7
<u>Early Fall 2004</u>				
August 4	10	3.8	1.7	5.5
September 9	20	1.3	3.7	5.0

MINERAL CONTENT OF GRASSES WITH POTENTIAL USE AS BIOFUEL FEEDSTOCK

H. El-Nashaar, S.M. Griffith, J.J. Steiner and G.M. Banowetz

Summary

National and state bio-based energy initiatives in the Pacific Northwest have focused interest in conversion of agricultural residues into energy products. One plentiful residue in the region is straw from seed-producing and cereal grain cropping systems. Previous efforts to convert straw to energy were plagued by high transportation costs of this low density feedstock material and by anti-quality mineral constituents that impact the long-term success of thermochemical conversion approaches. We conducted mineral analyses on straw from a selection of grasses collected from multiple locations to determine if there were genotypic differences in the accumulation of minerals that would negatively impact thermochemical gasification conversion. We also quantified the content of minerals that represent potential soil nutrients that would be removed from crop fields by straw harvest. Significant ($P = 0.01$) variability in mineral composition was measured, particularly in critical anti-quality minerals that impact the suitability of straw for thermochemical conversion to synthesis gas by gasification. The accumulation of silicon (Si), potassium (K), sulfur (S) and chloride (Cl) varied between species and locations. Analyses of soils from eight locations suggested that plant mineral composition may be due to soil nutrient content, although more analyses are required to quantify the relationship between soil mineral content and plant accumulation. The differences between species collected at the same location suggest genotypic differences exist. There were also differences among locations for the same species. Soil and plant mineral composition needs to be taken into account when determining the quality of bio-feedstocks or attempts to genetically improve grasses for gasification feedstock quality.

Introduction

Much of the world's supply of temperate grass seed is produced in the Pacific Northwest. Although most of the seed is planted for turf and forage use, new markets are emerging for use in buffer strips, riparian zones, and as cover crops to facilitate nutrient acquisition and soil erosion prevention. The harvested grass seed crop represents a small portion of the total crop biomass. Historically, much of the remaining biomass was burned due to a lack of local need for the straw. Regional legislation has curtailed the use of field burning due to citizen concerns about air quality and safety. One alternative to burning would be the conversion of these residues to energy products. Population growth in the region has placed greater demands on electricity generation capacity and increased transportation fuel costs have created a market for non-petroleum-based energy sources. At current straw biomass yields, over 7-million tons of grass and cereal straw in excess of that required for conservation purposes are available in the region. This is sufficient feedstock to produce over 420-million gallons of mixed alcohol transportation fuel annually. Conversion of straw to energy products can be achieved by fermentation and thermochemical technologies (McKendry, 2002). Of the two approaches, the thermochemical route has great potential for on-site or local-scale energy production to reduce the prohibitive feedstock transportation costs that would limit profit directly to producers. One factor that has limited the utilization of straw in thermochemical conversion is the presence in plant tissues of anti-quality minerals that causes slagging and corrosion within gasification reactors (Miles et al., 1996; Thompson et al., 2003). Gasification of feedstock for energy production requires burning straw at temperatures in excess of 750°C to produce synthesis gases (syngas is a mixture of carbon monoxide and hydrogen gases) suitable for conversion to liquid fuels or for the production of electricity by powering internal combustion engines that turn generators. Syngas quality and yield depends greatly on the temperature at which the gasifier is operated. At higher operational temperatures where carbon conversion efficiency is high, feedstock rich in Si, K and other alkalis vaporize and react with other mineral components in straw to form a sticky glass-like substance referred to as slag. Slag formation and corrosive alkalis reduce the lifespan and utility of the gasifier hardware that further diminishes the economic feasibility of converting straw to energy. Little is known about genotypic differences in the suitability of grass straw as gasification feedstock.

The purpose of this research was to conduct initial characterization of the mineral composition of straw from diverse grass species collected at multiple western U.S. locations to evaluate whether genotypic differences existed in Cl, K, phosphorus (P), sulfur (S), copper (Cu), zinc (Zn), molybdenum (Mo), and Si composition. We also characterized mineral composition of soils collected from each location to relate to plant mineral concentrations.

Materials and methods

Aboveground plant biomass from twelve temperate grass species was harvested from the eight locations; Aberdeen, ID; Rockford and Pullman, WA; Corvallis, Shedd, and Silverton, OR; Winters and Lockeford, CA. The grass species included nine U.S. native species, *Bromus marginatus* Nees ex Steud. (mountain brome), *Elymus glaucus* Buckl. (blue wildrye), *Poa secunda* J. Presl (Sandberg bluegrass), *Pseudoroegneria spicata* (Pursh) A. Love (bluebunch wheatgrass), *Elymus lanceolatus* (Scribn. & J.G. Sm.) Gould (streambank wheatgrass), *Festuca rubra* L. cv. Bridgeport (red fescue), *Elymus trachycaulus* (Link) Gould ex Shinners (slender wheatgrass), *Leymus cinereus* (Scribn. & Merr.) A. Löve (basin wildrye), *Leymus triticoides* (buckl.) Pilger (beardless wildrye), and *Pseudoroegneria spicata* (Pursh) A. Löve ssp. *inermis* (Scribn. & J.G. Sm.) A. Löve (beardless wheatgrass) and three cultivated species *Lolium perenne* L. cv. Prana (perennial ryegrass), *Poa* *pratensis* L. cv. Parkland (Kentucky bluegrass), and *Schedonorus phoenix* (Scop.) Holub cv. Hounddog (tall fescue).

Aboveground plant biomass was cut 3 to 5 cm above the soil surface from four replicated 30 by 30 cm quadrats. Biomass was collected at three developmental stages: vegetative (just prior to stem elongation), anthesis (mid-anthesis), and maturity. Plant material was dried at 80°C for 24 hours and ground. In the late spring, three one-inch diameter soil cores were sampled to a depth of 30 cm from each of the four replicated plots.

Plant and soil analysis for K, P, S, Cu, Zn, Mo, and Si were performed using a hydrogen fluoride microwave digestion and inductively coupled plasma (ICP) spectrophotometry. Soil analyses were conducted on dried soil utilizing the same digestion and ICP protocols. Chorine (Cl) was determined using Lachat Instruments QuikChem Method 10-117-07-1-C. Soil pH was determined with a pH meter and electrode. Soil organic matter was determined by combustion.

Mean differences between species and stage of development were determined by analysis of variance (ANOVA) using a split-plot design, with species at a particular location as the main plot and developmental stage as the subplot. Mean differences between locations for a given species were also determined. All differences reported are significant at $P \leq 0.05$, unless otherwise stated. The Tukey test was used for the multiple comparisons for observed means.

Results and discussion

General Soil Characteristics. The soil pH at the various locations where plant material was harvested ranged from 5.33 at Corvallis, OR to 7.96 in Aberdeen, ID. Soil percent organic matter ranged from 1.9 to 4.41 among locations.

Soil and Plant Mineral Analyses. All soil and plant mineral concentrations were within the ranges published in the literature for these materials (Marschner, 1986). Among the locations we sampled, Si comprised about 20.5% of the total soil mass, K 10.2%, S 0.031%, and Cl 0.0011% (Table 1). Soil concentrations of Cl, K, Si, S, Cu, P, and Mo were different ($P \leq 0.05$) among locations (Table 1). Aberdeen, Corvallis, Silverton, and Winters had the highest soil Cl levels and Lockeford, Pullman, and Rockford the least. Soil K concentrations were different at every location. Even though soil Si was very abundant at each location, soil concentrations significantly differed among locations with the lowest level at Lockeford and highest at Shedd.

Plant tissue mineral concentrations ranged from 0.34 to 3.12% for Si, 10.2 to 38.8% for K, 0.14 to 1.3% for S, and 0.057 to 0.49% for Cl (Tables 2 and 3). These four minerals are considered to be the greatest contributors to slagging and corrosion within gasification reactors during the straw thermochemical conversion process. The range of Si concentrations in plant tissue was approximately ten-fold, suggesting considerable genotypic variability in accumulation of this mineral. In this study, perennial ryegrass (*L. perenne*) tissue contained the greatest amount of Si among the 12 grasses studied (Table 3), and *E. glaucus* the least (Table 2). There is considerable variability in Si composition among other reported plant species, including concentrations of 2139 mg kg^{-1} in corn stalks, 623 mg kg^{-1} in peach leaves, and of 14,328 mg kg^{-1} in Kentucky bluegrass lawn clippings (Taber et al., 2002). We report 50% less Si concentration in Kentucky bluegrass (*P. pratensis*) than found by Taber et al. (2002). Silicon accumulation in plant biomass varies among plant species and can range from 1% to 10% by weight (Datnoff, 2005). Wheat, oat, rye, barley, sorghum, corn, and turfgrass contain about 1% Si in their biomass, while aquatic grasses have Si content up to 5% (Epstein, 1994; 1999). Nable et al. (1990) found differences in silica accumulation among barley genotypes. The range of variability in plant Cl accumulation was similar to that observed for Si. In contrast, K content varied within the range of 2- to 3-fold (Table 2).

Our study cannot be used to accurately calculate correlations between soil and plant mineral concentrations, but suggests that higher soil Cl and S concentrations resulted in higher tissue concentrations for those minerals (Table 2). Plant tissue concentrations of Si and K did not appear to have direct correlations with soil concentrations. Tissue Si concentrations of *E. glaucas* grown at Lockeford, CA ranged from 0.71 to 1.59%, from boot through maturity. In contrast, the Si content of *E. glaucas* tissues harvested at the same developmental stages at Corvallis ranged from 0.17 to 0.42%. This relationship was of particular interest because the soil Si content at Lockeford was lower than that measured in Corvallis soil. This was not apparent for the other species studied.

The plant tissue concentrations of Cl, S, Si, K Zn, Mo, Cu, and P were significantly affected by the stage of plant development (Tables 4 and 5), except for K, Zn, Mo, Cu content of plants collected at Corvallis and Cu content measured in Aberdeen plants. In most cases, there were differences in plant mineral concentration among the different species at particular locations (Table 4 and 5), and for some minerals between locations for the same species (Table 6). For most species, there was no location effect for K, Cu, Mo, and Zn, and for two species there was no location effect for P and Si (Table 6).

The content of P within plant tissues is not known to impact slagging during thermochemical conversion, but along with K, is important for estimating the fertilizer cost impact involved in removing straw from fields. Soil P concentrations at the various locations were at nutritionally adequate levels (Table 1; Western Fertilizer Handbook, 2001).

Our demonstration of genotypic differences in mineral composition, especially Si, suggests the potential for genetic modification of mineral uptake to improve the suitability of grasses for use as biofuel feedstock. Much of our effort focused on comparisons of Si accumulation because of the abundance of Si in most soils. Any attempt to alter Si content would require evaluation of potential unintended characteristics to the grass because Si has some demonstrated beneficial effects for increased plant resistance to lodging and drought (Epstein, 1999). Fertilization with Si was effective in suppressing diseases in number of warm and cool season turfgrasses (Datnoff, 2005). Other studies showed that Si improved disease resistance (Hamel and Jeckman, 1999; Brecht et al., 2004), insect and nematode resistance (Swain and Prasad, 1988), soil nutrient availability, nutrient balance within the plant (e.g., N, P, Zn and Mn), photosynthesis, improved reproductive fertility and reduced transpiration (Datnoff et al., 2001).

In contrast, Si content can have negative impacts on the forage quality of grasses. Some pathological conditions such as increased tooth wear and reduced digestibility or palatability have been attributed to silica in the diets of herbivores (Brizuela et al., 1986). Shewmaker et al. (1988) demonstrated considerable genotypic differences in silica content of a variety of western range grasses, and showed that silica reduced digestibility but apparently had no significant effect on grazing preferences of sheep.

Previous research showed that silica and sulfur in combination with alkali and earth metals and facilitated by the presence of chlorine are responsible for many undesirable reactions in combustion furnaces and power boilers (Miles et al., 1996; Jenkins et al., 1998). Alteration of the technology or the feedstock is critical to the successful development of a straw to energy industry in the Pacific Northwest. Proof of concept of new gasification technology scalable to on-farm production has been demonstrated recently (Boateng et al., 2006).

Here we report significant genotypic differences in mineral accumulation within a diverse set of native and cultivated grasses that may impact their suitability as biofuel feedstock. Silicon accumulation in the perennial ryegrass we analyzed was significantly higher than that measured in the other cultivated grasses. Further studies are in progress to determine whether cultivar differences in Si accumulation occur. Although Si plays a major role in plant health and productivity, the genotypic variability suggests that there is a potential for improving biomass quality via plant breeding or genetic manipulation approaches if this were shown to benefit conversion of straw biomass to syngas by gasification. The genetically altered genotypes may improve the quality of biofuels produced and enhance the durability of furnaces and power boilers. However, any efforts to genetically alter mineral accumulation will require careful assessment to ensure that improvements in straw quality do not impact the end-use quality of seeds produced for turf and forage.

Conclusions

Significant variability in the composition of minerals that impact the suitability of grasses for thermochemical conversion to liquid fuels exists. While more analyses are required to quantify the relationship between soil mineral content and plant accumulation, differences between species collected at the same location suggest that genotypic differences exist. There were also apparent differences between locations for the same species. All these factors need to be taken into account when determining quality of bio-feedstocks or in trying to genetically manipulate species for improved gasification feedstock quality with respect to slagging and other gasification issues.

Acknowledgments:

The authors thank Machelle Nelson and Don Streeter for technical assistance. We are most grateful to Ralph Fisher, Larry and David Gady, Don Wirth, George Pugh, and Rominger Brothers Farm for their cooperation and assistance with on-farm research. We are also grateful to personnel at the USDA Natural Resources Conservation Service Plant Materials Centers in Aberdeen, ID, Corvallis, OR, Lockeford, CA, and Pullman, WA for their cooperative spirit and time in the collection of soil and plant materials from their locations.

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Table 1. Mean soil mineral concentration at seven locations in the western U.S. Data are expressed as mg kg $^{-1}$ dry soil. Soil was sampled from the top 0 to 30 cm depth. The Tukey mean comparison test was used (P = 0.05).

Location	Cl	K	P	S	Si	Mo	Cu
Aberdeen, ID	14.5 d	262 d	520 c	344 de	200933 b	2.61 bc	18.5 a
Corvallis, OR	15.0 d	276 e	157 a	284 bc	221000 bc	3.04 c	53.3 e
Lockeford, CA	8.8 b	102 a	306 b	231 a	174367 a	1.80 a	47.1 d
Pullman, WA	4.9 a	388 h	521 c	301 cd	205600 b	2.19 ab	31.7 c
Rockford, WA	5.1 a	176 b	301 b	242 ab	212900 bc	2.59 bc	21.7 ab
Shedd, OR	12.3 c	328 g	1195 d	353 e	232433 c	2.55 bc	24.1 b
Silverton, OR	15.0 d	232 c	274 b	367 e	215333 bc	3.13 c	25.5 b
Winters, CA	19.3 e	306 f	227 b	265 abc	211067 b	2.67 bc	47.7 d

Table 2. Mean chorine (Cl), sulfur (S), silicon (Si), and potassium (K) concentrations in soil and mature aboveground biomass of native grass species grown at multiple locations; Pullman, WA, Lockeford, CA, and Aberdeen, ID. Data are expressed in mg kg^{-1} dry soil or plant tissue. Soil was sampled from 0 to 30 cm depth.

		Soil		Plant		Soil		Plant		Soil		Plant		Soil		Plant	
Species	Location	Cl	*se*	Cl	*se*	S	*se*	S	*se*	Si	*se*	Si	*se*	K	*se*	K	*se*
Bromus marginatus	Pullman	4.9	*0.31*	785	*39*	301	*21*	5,221	*1276*	205,600	*2471*	12,215	*564*	388	*0.5*	14.0	*0.6*
	Aberdeen	14.5	*0.65*	3,906	*23*	344	*9*	8,591	*311*	200,933	*9750*	14,233	*601*	262	*0.7*	15.0	*0.6*
Elymus glaucus	Pullman	4.9	*0.31*	1,013	*33*	301	*21*	5,983	*280*	205,600	*2471*	12,668	*750*	388	*0.5*	15.3	*0.8*
	Lockeford	8.8	*0.14*	2,312	*93*	231	*14*	10,069	*11*	174,367	*4361*	10,931	*329*	102	*0.4*	14.9	*0.6*
	Corvallis	15.0	*0.41*	1,351	*20*	284	*11*	6,138	*1731*	221,000	*9750*	3,347	*114*	276	*0.3*	13.2	*0.3*
Elymus lanceolatus	Pullman	4.9	*0.31*	854	*52*	301	*21*	6,276	*107*	205,600	*2471*	12,685	*928*	388	*0.5*	15.7	*1.3*
	Aberdeen	14.5	*0.65*	2,869	*178*	344	*9*	7,744	*383*	200,933	*9750*	17,600	*1102*	262	*0.7*	12.8	*0.8*
Elymus trachycaulus	Pullman	4.9	*0.31*	569	*78*	301	*21*	3,585	*311*	205,600	*2471*	10,416	*546*	388	*0.5*	9.6	*0.5*
	Aberdeen	14.5	*0.65*	3,220	*29*	344	*9*	7,709	*511*	200,933	*9750*	16,127	*1567*	262	*0.7*	12.3	*0.4*
Leymus cinereus	Pullman	4.9	*0.31*	744	*32*	301	*21*	7,026	*863*	205,600	*2471*	9,526	*973*	388	*0.5*	18.3	*0.7*
	Aberdeen	14.5	*0.65*	3,814	*59*	344	*9*	10,495	*269*	200,933	*9750*	12,970	*335*	262	*0.7*	18.0	*0.9*
Leymus triticoides	Lockeford	8.8	*0.14*	2,830	*93*	231	*14*	10,718	*177*	174,367	*4361*	10,613	*266*	102	*0.4*	15.3	*0.8*
	Winters	19.3	*0.04*	4,936	*173*	265	*2*	1,637	*108*	211,067	*3977*	11,333	*164*	306	*0.8*	15.7	*0.6*
Poa secunda	Pullman	4.9	*0.31*	849	*18*	301	*21*	4,803	*373*	205,600	*2471*	23,583	*868*	388	*0.5*	15.9	*0.7*
	Aberdeen	14.5	*0.65*	3,310	*433*	344	*9*	12,953	*479*	200,933	*9750*	13,807	*808*	262	*0.7*	12.5	*1.1*
Pseudoroegneria spicata	Pullman	4.9	*0.31*	778	*58*	301	*21*	3,780	*1436*	205,600	*2471*	21,385	*1025*	388	*0.5*	10.3	*0.6*
	Aberdeen	14.5	*0.65*	2,786	*154*	344	*9*	10,505	*355*	200,933	*9750*	23,910	*910*	262	*0.7*	13.0	*1.1*
Pseudoroegneria spicata ssp inerme	*Pullman*	*4.9*	*.031*	841	*49*	301	*21*	3108	*1023*	205600	*2471*	28620	*380*	388	*0.5*	11.0	*1.0*
	Aberdeen	*14.5*	*.65*	2349	*246*	344	*9*	9368	*782*	200933	*9750*	20285	*3275*	262	*0.7*	11.0	*.04*

Table 3. Mean chorine (Cl), sulfur (S), silicon (Si), and potassium (K) concentrations in soil and mature aboveground biomass of grass species grown at a single location. Locations include: Pullman, WA, Rockford, WA, Corvallis, OR, Shedd, OR, and Silverton, OR. Data are expressed in mg kg^{-1} dry soil or plant tissue. Soil was sampled from 0 to 30 cm depth.

		Soil		Plant		Soil		Plant		Soil		Plant		Soil		Plant	
Species	Location	Cl	*se*	Cl	*se*	S	*se*	S	*se*	Si	*se*	Si	*se*	K	*se*	K	*se*
Schedonorus phoenix cv. Hound dog	Corvallis, OR	15.0	0.41	1,434	83	284	11	2,742	223	221,000	3854	7,020	160	276	0.3	24.7	1.9
Festuca rubra cv. Bridgeport	Silverton, OR	15.0	0.41	1,473	110	367	3	1,370	89	215,333	5562	7,075	500	232	0.5	17.9	0.4
Lolium perenne cv. Prana	Shedd, OR	12.3	0.25	2,363	236	353	16	2,286	52	232,433	2617	31,194	699	328	0.6	14.2	0.7
Poa pratensis cv.Parkland	Rockford, WA	5.1	0.06	700	63	242	13	2,908	169	212,900	7016	7,464	131	176	0.5	19.3	3.0

Table 4. Statistical summary of U.S. native temperate grass species or plant developmental stage (vegetative, flowering/seed fill, maturity) at each specific location on plant aboveground biomass mineral concentration of chlorine, sulfur, silicon, and potassium. Species at each location included the following: Aberdeen, ID: *Bromus marginatus, Elymus lanceolatus ssp lanceolatus, Elymus trachycaulus, Leymus cinereus, Leymus triticoides, Poa secunda, Pseudoroegneria spicata*; Corvallis, OR: *Elymus glaucus*; Lockeford, CA*: Elymus glaucus, Leymus triticoides; Pullman, WA: Bromus marginatus, Elymus glaucus, Elymus lanceolatus ssp lanceolatus, Elymus trachycaulus, Leymus cinereus, Poa secunda, Pseudoroegneria spicata, Pseudoroegneria spicata ssp inerme).*

	Chlorine		Sulfur		Silicon		Potassium	
Location	Species	Development	Species	Development	Species	Development	Species	Development
Aberdeen	***	***	***	***	***	***	***	***
Corvallis	ND	***	ND	***	ND	***	ND	ns
Lockeford	*	**	***	***	***	***	***	***
Pullman	***	***	***	***	***	***	***	***

ND = no data
ns P > 0.10
* $P \leq 0.10$
** $P \leq 0.05$
*** $P \leq 0.01$

Table 5. Statistical summary of U.S. native temperate grass species or plant developmental stage (vegetative, flowering/seed fill, maturity) at each specific location on plant aboveground biomass mineral concentration of chlorine, sulfur, silicon, and potassium. Species at each location included the following: Aberdeen, ID: *Bromus marginatus, Elymus lanceolatus ssp lanceolatus, Elymus trachycaulus, Leymus cinereus, Leymus triticoides, Poa secunda, Pseudoroegneria spicata*; Corvallis, OR: *Elymus glaucus*; Lockeford, CA*: Elymus glaucus, Leymus triticoides; Pullman, WA: Bromus marginatus, Elymus glaucus, Elymus lanceolatus ssp lanceolatus, Elymus trachycaulus, Leymus cinereus, Poa secunda, Pseudoroegneria spicata, Pseudoroegneria spicata ssp inerme).*

	Zinc		Molybdenum		Copper		Phosphorus	
Location	Species	Development	Species	Development	Species	Development	Species	Development
Aberdeen	***	***	***	ns	***	ns	***	***
Corvallis	ND	ns	ND	ns	ND	ns	ND	***
Lockeford	***	***	ns	***	**	**	***	***
Pullman	ns	ns	**	ns	***	***	***	***

ND = no data, only one species present
ns P > 0.10
* $P \leq 0.10$
** $P \leq 0.05$
*** $P \leq 0.01$

Table 6. Statistical summary of U.S. native temperate grass species grown at two or more western U.S. locations on the above-ground plant biomass mineral concentration of zinc, molybdenum, copper, and phosphorus of mature plants. Species at each location were as follows: *Bromus marginatus* (Aberdeen, ID, Pullman, WA); *Elymus glaucus* (Corvallis, OR, Aberdeen, ID, Pullman, WA); *Elymus lanceolatus ssp lanceolatus* (Aberdeen, ID, Pullman, WA); *Elymus trachycaulus* (Aberdeen, ID, Pullman, WA), *Leymus cinereus* (Aberdeen, ID, Pullman, WA); *Leymus triticoides* (Lockeford and Winters, CA); *Poa secunda* (Aberdeen, ID, Pullman, WA), *Pseudoroegneria spicata* (Aberdeen, ID, Pullman, WA); *Pseudoroegneria spicata ssp inerme* Aberdeen, ID, Pullman, WA).

Species	Cl	S	Si	P	Zn	Mo	Cu	K
Bromus marginatus	***	**	**	***	**	**	ns	ns
Elymus glaucus	***	***	***	***	ns	ns	**	ns
Elymus lanceolatus ssp lanceolatus	***	***	**	***	***	ns	ns	ns
Elymus trachycaulus	***	**	***	***	ns	ns	ns	ns
Leymus cinereus	***	***	***	***	***	ns	ns	ns
Leymus triticoides	*	***	***	ns	**	**	***	***
Poa secunda	***	**	ns	ns	*	*	ns	ns
Pseudoroegneria spicata	***	**	ns	*	ns	***	***	*
Pseudoroegneria spicata ssp inerme	***	***	***	***	ns	ns	ns	ns

ND = no data
ns $P > 0.10$
* $P \leq 0.10$
** $P \leq 0.05$
*** $P \leq 0.01$

This report has been published with a grant from the Oregon Seed Council

Appreciation is expressed to the Officers of the 2005-2006 Oregon Seed Council:

Chris McDowell, President
Mike Hayes, FirstVice President
Mike Thomas, Second Vice President
Jerry Marguth, Treasurer
David S. Nelson, Executive Secretary

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Sincere appreciation is also extended to the growers who have allowed trials to be conducted on their farms. Data presented in many of the research reports would not be available without their cooperation.

Lastly, appreciation is also expressed to Mrs. Barbara Reed for her conscientious attention to detail in formatting this manuscript for publication.

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