2007
SEED PRODUCTION RESEARCH
AT OREGON STATE UNIVERSITY
USDA-ARS COOPERATING
Edited by William C. Young III

Page

Exploring Remote Sensing Applications in Perennial Ryegrass Seed Production....1
Response of Seed Yield to Swathing Time in Tall Fescue and Creeping Red Fescue....9
Effects of Bails and Bait Alternatives on Slug Mortality, Egg Production, and Seedling Survival....12
Summer Timing for Control of Gray Field Slug in Non-Irrigated White Clover....18
Choke in Orchardgrass: Research Update and Potential Control....22
Insects, Slugs and Mites Associated with Choke in Orchardgrass in the Willamette Valley....24
Control of Mannagrass in Grasses Grown for Seed....27
Kentucky Bluegrass Tolerance to Primisulfuron....29
Evaluating Vole Monitoring Tools for Grass Seed Production....31
Use of ESN® for Spring Nitrogen Fertilizer Management in Tall Fescue Seed Production....33
Long-Term Annual Ryegrass Field Trial Established at Hyslop Farm....35
Three-Year GIS of Western Oregon Grass Seed Cropping Practices....37
Impact of Seed-Feeding Thrips Pest in Grass Seed Production Fields in the Willamette Valley....41
Sod Webworms in Western Oregon Grass Seed Fields....44
The Effect of Fungicide Applications on Seed Yield in Perennial Ryegrass, and Evaluation of the Rust Model Decision Aid....46
Effect of Water Volume When Applying Systemic Fungicides for Ergot Control in Seedling Perennial Ryegrass var. *Americus* in the Southern Columbia Basin....49
Controlling Ergot with Foliar Applied Fungicides in Seedling Perennial Ryegrass var. *Americus* Grown for Seed in the Southern Columbia Basin....52
Anthropods Commonly Found in Grass Seed Fields in Eastern Oregon....54
Comparison of Red Clover Pollination by Commercial and Native Bees in Seed Production Fields in the Willamette Valley....59

(continued on inside front cover)

Department of Crop and Soil Science Ext/CrS 127, 3/08

Page

Progress in Developing a DNA Sequence-Based Test for Rapid Differentiation of Ryegrass Growth Types....63
Effect of Pre-Chilling Treatment on the Germination and Fluorescence of Perennial Ryegrass....67
Mineral Characterization of Temperate Grasses from a High Rainfall Environment....70
Genotypic Variability in Mineral Accumulation by Grasses from Low Rainfall Areas of the Western U.S.....73
Assessing Trade-Offs Between Crop Production and Ecological Services: The Calapooia Basin....78

The following authors have contributed to this report.

Cooperative Extension Service – OSU

R.P. Affeldt, Extension Agent, Jefferson County
S. Aldrich-Markham, Extension Agent, Yamhill County
G.A. Gingrich, retired Extension Agent, Marion County
M.E. Mellbye, District Extension Agent, Linn, Benton and Lane Counties
T.B. Silberstein, Extension Agent, Marion County

Department of Botany and Plant Pathology – OSU

T.S. Biboux, Undergraduate Student

Department of Crop and Soil Science – OSU

K.M. Ackerman, Faculty Research Assistant
R.E. Barker, Courtesy Professor Emeritus and Research Geneticist
N.W. Christensen, Professor Emeritus, Soil Fertility
L.D. Cooper, former Faculty Research Associate
D.W. Curtis, Faculty Research assistant
A.J. Dreves, Faculty Research Assistant
S.G. Elias, Assistant Professor, Seed Laboratory
G.C. Fisher, Professor, Extension Entomology
M.D. Flowers, Assistant Professor, Extension Cereals Specialist
A.E. Garay, Manager, Seed Laboratory
C.J. Garbacik, Senior Faculty Research Assistant
J.M. Hart, Professor and Extension Soil Scientist
B.J. Hinds-Cook, Faculty Research Assistant
A.G. Hulting, Assistant Professor, Extension Weeds Specialist
C.A. Mallory-Smith, Professor of Weed Science
S. Rao, Associate Professor, Entomology
W.P. Stephen, Professor Emeritus, Entomology
W.C. Young III, Professor and Extension Agronomist

Department of Economics

R.G. Fare, Professor
S.P. Grosskopf, Professor

Department of Fisheries and Wildlife

R.W. Colvin, Faculty Research Assistant
T.S. Garcia, Assistant Professor
W.J. Gerth, Faculty Research Assistant
J.A. Gervais, Wildlife Ecologist
G.R. Giannico, Assistant Professor
A.T. Herlihy, Research Associate

Department of Horticulture

J.E. Bergh, Undergraduate Student

Hermiston Experiment Station

N.L. David, former Plant Pathology Research Manager
P.B. Hamm, Superintendant and Extension Plant Pathologist
D.A. Horneck, Associate Professor and Extension Agronomist
S.I. Rondon, Assistant Professor and Extension Entomologist

National Forage Seed Production Research Center - USDA-ARS

S.C. Alderman, Professor and Research Plant Pathologist
G.M. Banowetz, Research Microbiologist and Research Leader
R.B. Confessor, Research Hydrologist
H.M. El-Nashaar, Research Molecular Biologist
W.E. Gavin, Faculty Research Assistant
S.M. Griffith, Assistant Professor and Research Plant Physiologist
G.W. Mueller-Warrant, Associate Professor and Research Agronomist
W.F. Pfender, Professor and Research Plant Pathologist
G.W. Whittaker, Research Hydrologist

Other

J.F. Cacka, Division Agronomist, Western Farm Service, Rickreall, OR
J.L. Carroll, Agronomy Field Representative, CHS, Madras, OR
B.C. McComb, Professor, Department of Natural Resources, University of Massachusetts - Amherst
S.E. Salisbury, Field Representative, Wilbur-Ellis Co., Shedd, OR
J.J. Steiner, National Program Leader, USDA ARS, Beltsville, MD

EXPLORING REMOTE SENSING APPLICATIONS IN PERENNIAL RYEGRASS SEED PRODUCTION

M.D. Flowers, J.M. Hart, W.C. Young III, N.W. Christensen, C.J. Garbacik, M.E. Mellbye, T.B. Silberstein and G.A. Gingrich

Introduction

Currently, growers rely on yield goal estimates and experience to formulate spring nitrogen (N) rates in perennial ryegrass. Using this approach, N rates may be insufficient or excessive in any given year. This approach results in reduced profitability for growers through reduced yields and/or increased fertilizer costs. Therefore, a method that would assist growers in optimizing spring N rates would be beneficial.

Recent research efforts have focused on soil based approaches. Previously, a successful soil based approach was developed for wheat in this region. However, a similar approach in perennial ryegrass has not proven as successful (Hart et al., 2006). Therefore, alternative methods for estimating spring N must be researched.

One method that has shown promise is in-season tissue testing. Hart et al. (2006) reported that 75% of the changes in N supply could be explained by in-season tissue tests. However, tissue tests have several limitations. They are relatively expensive, difficult, and time consuming to obtain when considering the number of samples required to accurately describe the within field spatial variability found in most Willamette valley fields.

Remote sensing in the form of aerial photographs or an on-the-go sensor might offer a solution to these limitations. Remote sensing works by measuring the energy reflected from the crop canopy (or soil background). Reflectance in the blue (B), green (G), and red (R) regions of the visible spectrum may be related to the chlorophyll and N concentration of plants (Gates et al., 1965; Knipling, 1970). Reflectance in the near-infrared (NIR) region of the spectrum may be related to the amount and vigor of vegetation (Knipling, 1970). Thus, similar to tissue tests, remote sensing may be related to whole-plant N concentration or N uptake. Additionally, remote sensing has the potential to capture the spatial variability found in most fields in a cost effective manner.

Beyond N management, remote sensing has other potential uses in perennial ryegrass. One potential application is the estimation of crop yield. In most crops, yield monitors are used to record the spatial variability in crop yield within a field. However, the adoption rate for yield monitors by grass seed growers is low. This is due in part to the difficulty of measuring yield with a mass flow sensor in a small seeded crop like grass seed. Therefore, alternative methods for capturing and describing the spatially variability in yield of grass seed fields are required. Based on research in other crops, remote sensing has the potential to capture these differences. As an added benefit, a technique such as remote sensing that estimates crop yield prior to harvest may assist growers in harvest scheduling and possibly marketing of their crop.

Given the potential applications of remote sensing in perennial ryegrass, a study was initiated in 2006. The study focused on two applications. First, we wanted to determine the potential of using remote sensing to predict spring N fertilizer rates. Secondly, we wanted to determine the potential of using remote sensing to estimate seed yield prior to harvest.

Methods

Site and Agronomic Description

Research was conducted at the Hyslop Crop Science Farm near Corvallis, Oregon in 2007.

A randomized complete block design with 21 N treatments and four replications was used. Nitrogen treatments were arranged in a factorial design with three fall N rates (0, 40 and 80 lb N/a) and seven spring N rates (0, 40, 80, 120, 160, 200 and 240 lb N/a). Treatments were applied to the perennial ryegrass variety 'Topgun', which was established on a Woodburn silt loam in the spring of 2006.

Both fall and spring N treatments were applied using an Orbit-Air seeder. Urea (46-0-0) was used as the N source for both applications. The fall application was made on Oct. 27, while the spring application was made on Mar. 6.

Treatments were sampled on Feb. 21 and Mar. 26 to determine in-season plant N status. A linear transect was used to determine sampling locations in each treatment. Samples were collected from one-foot sections of adjacent rows by clipping all plant tissue above the soil surface. Samples were analyzed for dry biomass and whole-plant N concentration. Nitrogen uptake for each treatment was calculated by multiplying dry biomass by whole plant N concentration.

Treatments were swathed on July 5 using a modified John Deere 2280 swather. After drying a Hege 180 combine was used to thresh the treatments on July 16. Seed was weighed and a bulk sample was taken for cleaning using a two-screen Clipper cleaner. Clean seed yield for each treatment was determined using the cleanout percentage from the bulk sample.

Aerial Images

Aerial images of the research site were obtained on Feb. 17, Apr. 3, and May 23. Imagery was provided by John Deere Agri Services and consisted of four spectral bands; B (400-500 nm), G (500-600 nm), R (600-700 nm) and NIR (700-900 nm). Spectral reflectance values for each band were derived using

ERDAS Imagine software. In addition to examining the reflectance from individual bands, several spectral indices were calculated and analyzed. These included, a normalized NIR, normalized difference vegetation index (NDVI), green normalized difference vegetation index (GNDVI), ratio vegetation index (RVI), difference vegetation index (DVI), soil-adjusted vegetation index (SAVI), and optimized soil-adjusted vegetation index (OSAVI).

Reflectance values from the individual bands and spectral indices were compared to the plant N status and yield obtained from each N treatment. The Feb. 17 and Apr. 3 images were compared to the dry biomass, whole-plant N concentration, and nitrogen uptake values determined on Feb. 21 and Mar. 26. The May 3 image was compared to the clean seed yield determined on July 16. Data were analyzed as Pearson correlations in SAS software. Both linear and quadratic relationships were examined.

Results and Discussion

Early-Season Image (17 FEB 2007)

Both N concentration and N uptake were significantly related to spectral measurements at this stage of plant development (Table 1). There was not a significant relationship between spectral indices and biomass at this growth stage. Both linear and quadratic models were evaluated and no advantage to curvilinear or quadratic models was found. Therefore, only linear models were examined in more detail.

Among spectral indices, NDVI and RVI appeared to be the most robust for both N concentration and N uptake. Figures 1 through 4 show the linear relationships between the spectral indices NDVI and RVI with N concentration or N uptake. Both spectral indices explained nearly two-thirds (67%) of the variability in N concentration due to fall N applications. This indicates that a successful remote sensing application could be developed to predict spring N application rates in grass seed production at this stage of growth. However, further research is required to determine if a robust model can be developed across sites and environments. Future research goals should include the development of a model directly with spring N application rate as well as the study of different e nvironments, tillage systems, and varieties.

Mid-Season Image (3 APR 2007)

Unlike the early season image, there was a statistically significant relationship between crop biomass and spectral indices at this growth stage. However, the relationship was weak (Table 2). This finding may have a significant impact on the current marketing of NDVI for the variable rate application of plant growth regulators in grass seed production. Currently, this system assumes a strong relationship between biomass, a surrogate for plant height, and NDVI. If these parameters are not closely related, than these applications are unjustified. Further research should be conducted to determine if a useful and practical relationship between crop biomass or plant height and spectral indices exists.

Both N concentration and N uptake were also significantly related to spectral measurements at this growth stage (Table 2). Both linear and quadratic models were evaluated, however the quadratic or curvilinear models more accurately represent the data. Therefore, only quadratic models were explored further.

At this stage, the single NIR band had the most robust relationship with both N concentration and N uptake. Figures 5 and 6 show these curvilinear relationships. The NIR band accounted for 56% and 68% of the variability in N concentration and N uptake respectively. These results indicate that a model maybe able to be developed that predicts spring N rate at this crop stage using spectral information. Future research should examine the relationships between spectral data and critical N concentrations at this growth stage. Future research should also study these relationships across multiple environments, tillage systems, and varieties.

Late-Season Image (23 MAY 2007)

Clean grass seed yield was significantly related to several spectral measurements approximately one month prior to harvest (Table 3). Both linear and quadratic models were evaluated, however quadratic or curvilinear models most accurately represent the data. Since many spectral indices were equal, NDVI was chosen for further study due to its wide use in remote sensing applications.

Approximately one month prior to harvest, NDVI explained 79% of the differences in clean grass seed yield (Figure 7). Based on this preliminary data remote sensing appears to be an excellent technique for estimating yield in perennial grass seed fields. Future research is needed to determine a robust relationship between clean grass seed yield and a spectral index across locations and environments.

Acknowledgements

The authors wish to thank John Deere Agri Services for providing the aerial images of the research site.

References

Gates, D.M., H.J. Keegan, J.C. Schleter, and V.R. Weidner. 1965. Spectral properties of plants. Appl. Optics 4:11-20.

Hart, J.M., M.E. Mellbye, T.B. Silberstein, N.W. Christensen, and W.C. Young III. 2006. Evaluation of the N mineralization test to refine spring nitrogen rate for western Oregon grass seed production. In: W.C. Young III (ed), *2006 Seed Production Research at Oregon State University USDA-ARS Cooperating*, Department of Crop and Soil Science Ext/CrS 126, 4/07, Corvallis, OR.

Knipling, E.B. 1970. Physical and physiological basis for the reflectance of visible and near-infrared radiation for vegetation. Remote Sens. Environ. 1:155-159.

Table 1. Early-season (17 FEB 2007) correlation coefficients (r) for biomass, N concentration, N uptake, and several spectral indices: the normalized difference vegetation index (NDVI), normalized NIR, ratio vegetation index (RVI), difference vegetation index (DVI), soil-adjusted vegetation index (SAVI), optimized soil-adjusted vegetation index (OSAVI), and green normalized difference vegetation index (GNDVI).

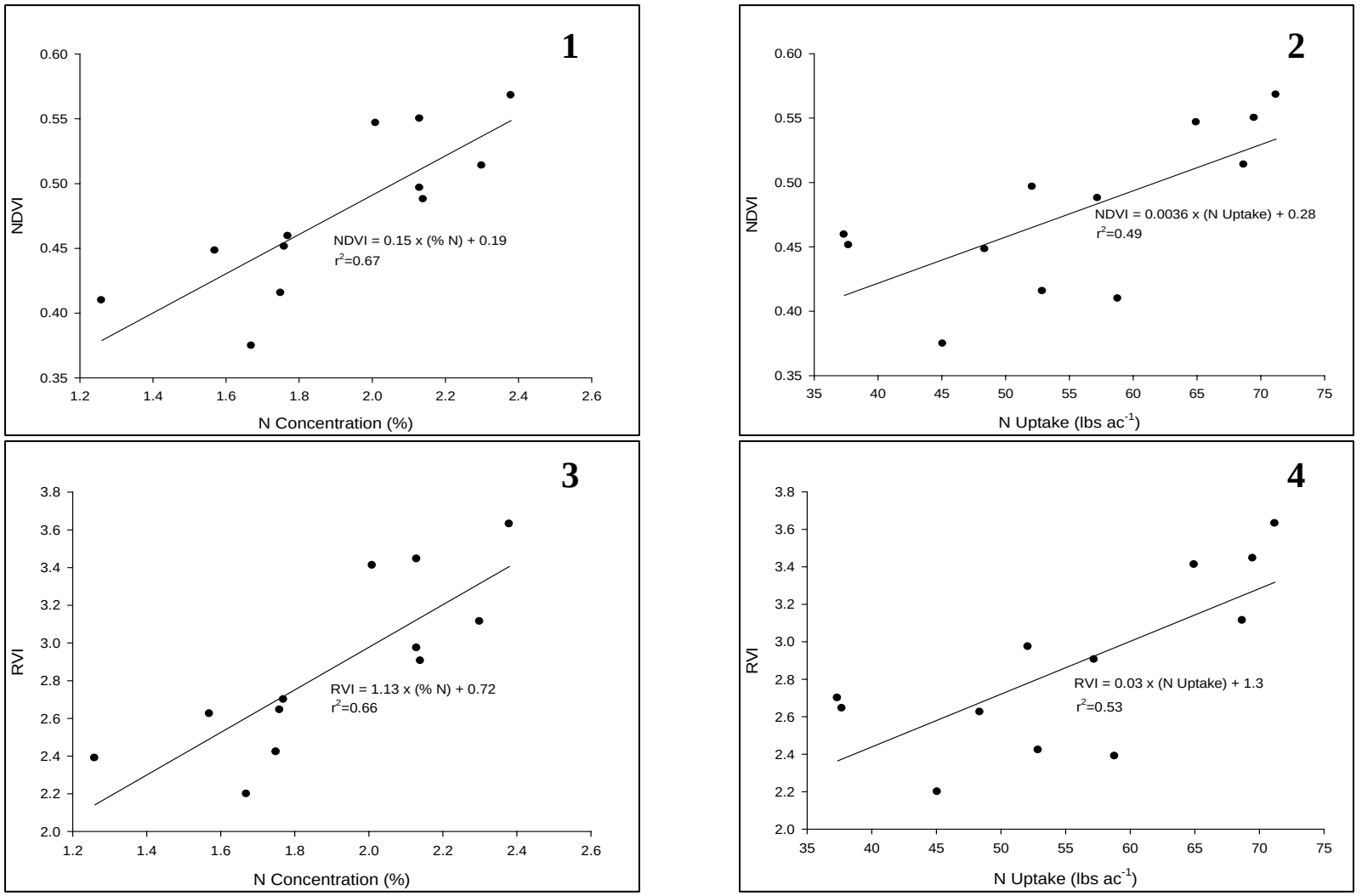
Linear Correlation Coefficients											
Variable	**Spectral Index**										
	NIR	Red	Green	Blue	NDVI	Normalized NIR	RVI	DVI	SAVI	OSAVI	GNDVI
Biomass (lb/a)	-0.03	0.07	-0.17	0.01	-0.06	-0.01	-0.03	-0.05	-0.06	-0.06	0.05
N (%)	0.76	-0.72	-0.47	-0.7	0.82	0.78	0.81	0.82	0.82	0.82	0.71
N Uptake (lb/a)	0.64	-0.62	-0.61	-0.61	0.7	0.7	0.73	0.69	0.7	0.7	0.69
Quadratic Correlation Coefficients											
Variable	**Spectral Index**										
	NIR	Red	Green	Blue	NDVI	Normalized NIR	RVI	DVI	SAVI	OSAVI	GNDVI
Biomass (lb/a)	-0.03	0.09	-0.17	0.02	-0.04	0.0	-0.0	-0.03	-0.04	-0.04	0.05
N (%)	0.75	-0.73	-0.47	-0.70	0.82	0.78	0.81	0.81	0.82	0.82	0.71
N Uptake (lb/a)	0.64	-0.61	-0.60	-0.61	0.72	0.71	0.75	0.71	0.72	0.72	0.70

Table 2. Mid-season (3 APR 2007) correlation coefficients (r) for biomass, N concentration, N uptake, and several spectral indices: the normalized difference vegetation index (NDVI), normalized NIR, ratio vegetation index (RVI), difference vegetation index (DVI), soil-adjusted vegetation index (SAVI), optimized soil-adjusted vegetation index (OSAVI), and green normalized difference vegetation index (GNDVI).

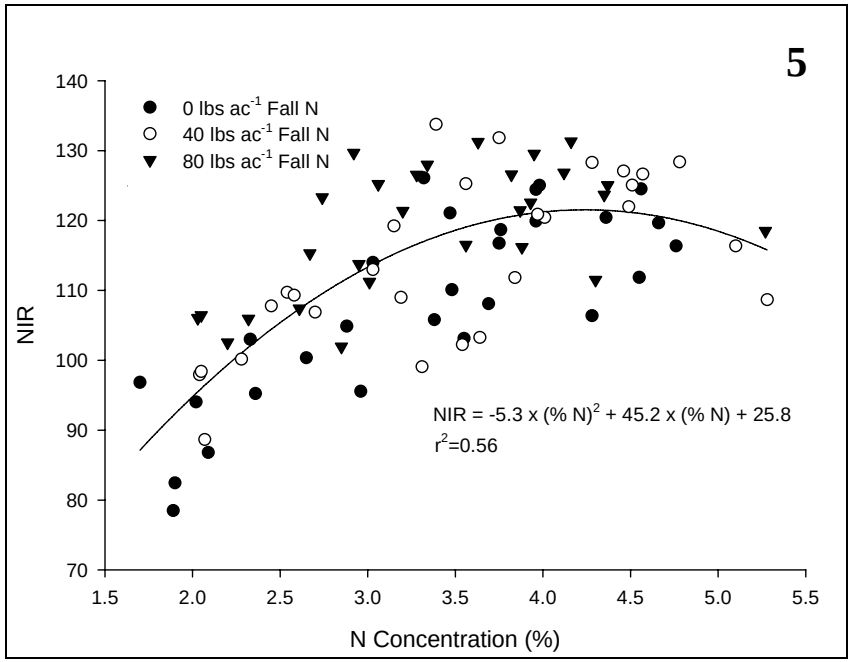
Linear Correlation Coefficients											
Variable	**Spectral Index**										
	NIR	Red	Green	Blue	NDVI	Normalized NIR	RVI	DVI	SAVI	OSAVI	GNDVI
Biomass (lb/a)	0.45	-0.45	-0.50	-0.42	0.46	0.48	0.50	0.46	0.46	0.46	0.48
N (%)	0.65	-0.47	-0.40	-0.43	0.55	0.54	0.51	0.59	0.55	0.55	0.54
N Uptake (lb/a)	0.77	-0.65	-0.63	-0.59	0.70	0.72	0.73	0.74	0.70	0.70	0.71
Quadratic Correlation Coefficients											
Variable	**Spectral Index**										
	NIR	Red	Green	Blue	NDVI	Normalized NIR	RVI	DVI	SAVI	OSAVI	GNDVI
Biomass (lb/a)	0.46	-0.43	-0.48	-0.41	0.48	0.49	0.50	0.48	0.48	0.48	0.51
N (%)	0.64	-0.48	-0.41	-0.44	0.53	0.53	0.46	0.56	0.53	0.53	0.50
N Uptake (lb/a)	0.77	-0.62	-0.62	-0.58	0.72	0.73	0.72	0.75	0.72	0.72	0.73

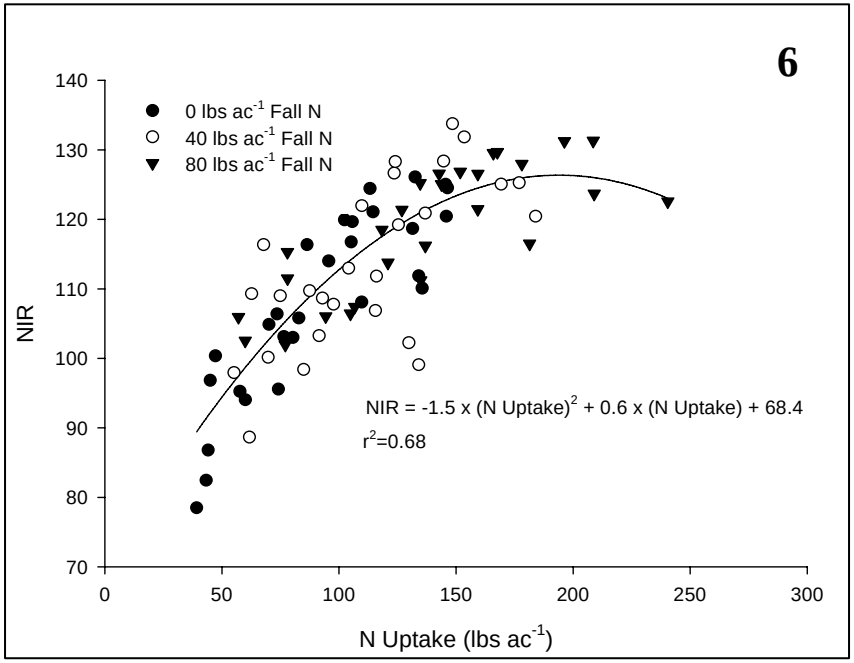
Table 3. Late-season (23 MAY 2007) correlation coefficients (r) for clean grass seed yield and several spectral indices: the normalized difference vegetation index (NDVI), normalized NIR, ratio vegetation index (RVI), difference vegetation index (DVI), soil-adjusted vegetation index (SAVI), optimized soil-adjusted vegetation index (OSAVI), and green normalized difference vegetation index (GNDVI).

Linear Correlation Coefficients											
Variable	**Spectral Index**										
	NIR	Red	Green	Blue	NDVI	Normalized NIR	RVI	DVI	SAVI	OSAVI	GNDVI
Clean Yield (lb/a)	0.82	-0.74	-0.64	-0.66	0.84	0.84	0.84	0.86	0.84	0.84	0.84
Quadratic Correlation Coefficients											
Variable	**Spectral Index**										
	NIR	Red	Green	Blue	NDVI	Normalized NIR	RVI	DVI	SAVI	OSAVI	GNDVI
Clean Yield (lb/a)	0.81	-0.72	-0.65	-0.65	0.84	0.84	0.81	0.83	0.84	0.84	0.83



Figures 1 – 4. Early-season (17 FEB 2007) relationships between plant N status (N concentration and N Uptake) and the Normalized Difference Vegetation Index (NDVI) and Ratio Vegetation Index (RVI) spectral indices.





Figures 5 - 6. Mid-Season (3 APR 2007) relationship between plant N status (N concentration and N Uptake) and the near-infrared (NIR) spectral band.

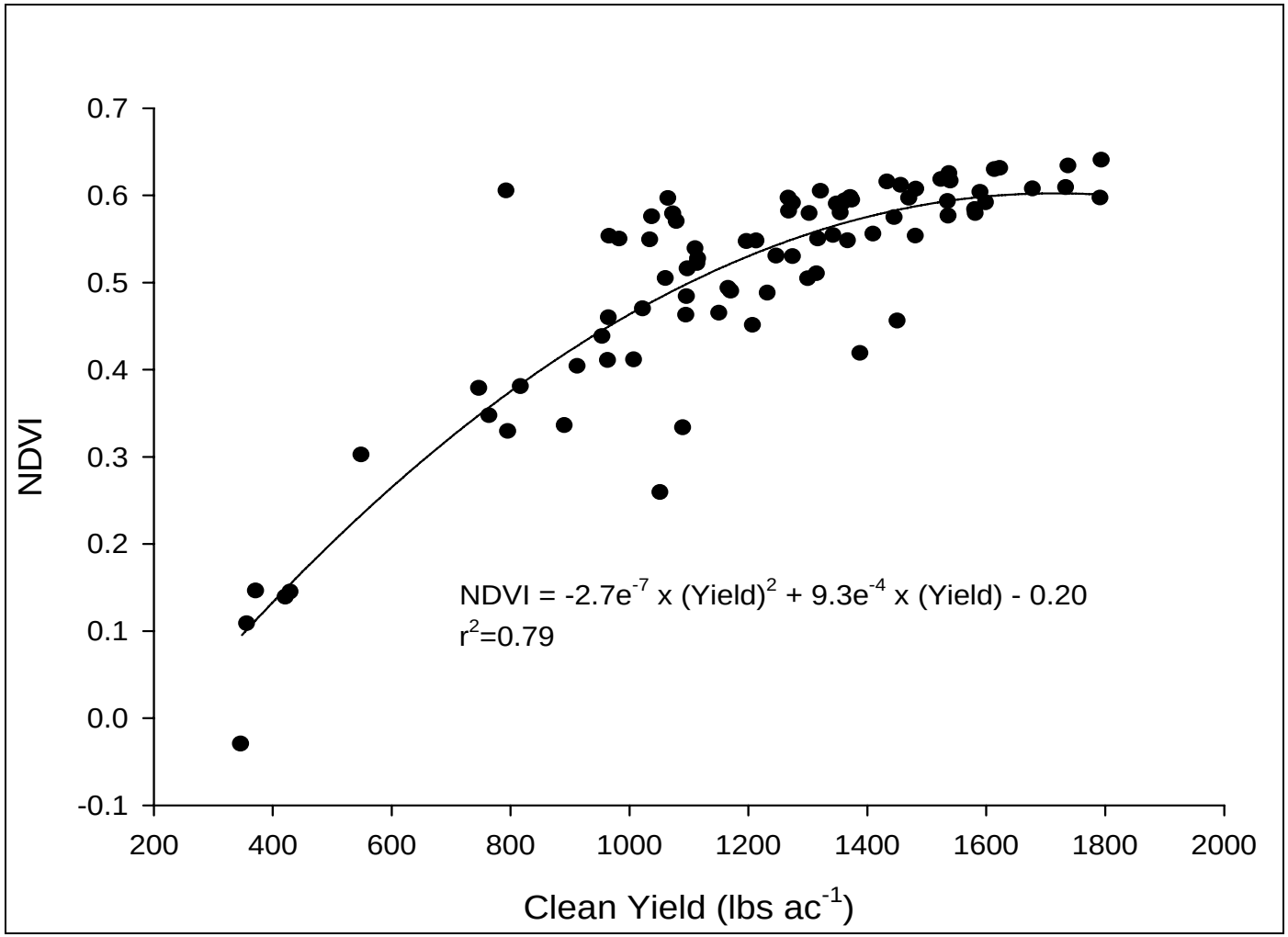


Figure 7. Late-season (23 MAY 2007) relationship between clean grass seed yield and the Normalized Difference Vegetation Index (NDVI) spectral index.

RESPONSE OF SEED YIELD TO SWATHING TIME IN TALL FESCUE AND CREEPING RED FESCUE

T.B. Silberstein and S. Aldrich-Markham

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. Research on seed moisture content 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).

With the improvements in swathing and combining equipment to increase overall speed and efficiency, growers are able to swath at a much faster rate and keep up with harvest maturation. Knowing the range of seed moisture contents that a grower could harvest at would be helpful in prioritizing when to begin swathing and which fields are critical to cut on any particular day. This information would then provide growers with the ability to prescriptively determine which fields need to be swathed each day (or night). Recent research efforts on perennial and annual ryegrass, reported in the 2004 and 2005 editions of this Seed Production Research Report series, detailed improvements in recommended seed moisture content ranges to begin harvest while maximizing seed yield. With interest from growers and the expanded recommendations on perennial and annual ryegrass, trials were started in 2006 in tall fescue and in fine fescue. These trials were designed to compare harvest at different seed moisture contents and verify recommendations previously available. This also provides an opportunity to compare the efficiency of more modern harvest equipment with what was used in previous studies by Klein and Harmond over 30 years ago.

Materials and methods

On-farm research plots were established in 2006 and 2007 in tall fescue (var Paraiso @ Christensen Farms, Polk County) and creeping red fescue (var Aruba @ Doerfler Farms, Marion County). Plots were swathed at predetermined seed moistures (Table 1) at approximately 7 AM each day and for harvest, all plots at each site were harvested when the rest of the grower field was combined. Both sites were managed by the growers and were treated with Apogee plant growth regulator. Harvested seed yield was determined using a Brent® yield cart to weigh combined plots. Sub-samples were also obtained at harvest 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. The two trials were designed as a three treatment randomized complete block with four replications. Analysis was done using Statistix® statistical software.

Table 1. Seed moisture content (%) and swathing dates for tall fescue and creeping red fescue, 2006-2007.

	2006 Moisture (%)		2007 Moisture (%)	
	Tall Fescue			
Date 1	June 30	50	July 3	45
Date 2	July 3	45	July 5	40
Date 3	July 7	41	July 6	34
	Fine Fescue			
Date 1	July 7	35	July 7	38
Date 2	July 10	24	July 10	24
Date 3	July 12	19	July 12	20

Results and Discussion

Tall fescue

Plots at Christensen Farms were swathed at three different maturities each year (see Table 1). In 2006 the first swath time was at 50% seed moisture. Seed yield swathed at 50% seed moisture (Table 2) was significantly less than at the later two dates. This timing is too early and the effect of waiting until the seed moisture dropped to 45% only 3 days later resulted in a seed yield increase of over 250 lb/a. Though seed size (Table 3) was not impacted by the first swath date, germination was (Table 4), indicating this is too early of a swathing time. Not only was germination lower but the 7 day and 14 day counts show a marked decrease in speed of germination. For 2007, the first swath date was moved to 45% seed moisture and then the second and third swathing times were decreased similarly. Plots harvested in 2007 were not subsampled for measuring seed quality differences. Combine "dirt" yields were analyzed and there were no differences in this yield. Swathing at seed moisture of 45% would be the earliest to begin. Seed yields were unaffected by the decrease in seed moisture into the mid 30's as shown for 2007. This gives a minimum range of 10% that a grower could swath the standing crop. Increases in shattered seed counts on the ground after swathing were observed as the seed moisture levels decreased (data not presented). Though there was seed shatter evident, yield was not yet impacted.

Table 2. Seed yield response to seed moisture at swathing time in tall fescue, 2006-07.

Seed moisture	2006	2007*
(%)	---------- (lb/a) ----------	
50	1206 b	----
45	1559 a	1318
42	1588 a	1270
34	----	1294
LSD 0.05	70	NS
P value	0.000	

* 2007 combine run 'dirt yield' only

Table 3. Harvest component responses to seed moisture at swathing time in tall fescue, 2006.

Seed moisture	Swath date	Seed yield	Clean-out	1000 Seed wt.
(%)		(lb/a)	(%)	(g)
50	June 30	1206 b	2.8	2.15
45	July 3	1559 a	2.7	2.19
42	July 7	1588 a	2.7	2.21
LSD 0.05		70	NS	NS
P value		0.000	0.862	0.421

Table 4. Seed germination responses to seed moisture at swathing time in tall fescue, 2006.

Seed Moisture	Swath date	---------- Germination ---------- 7day	14 day	total
(%)		---------- (%) ----------		
50	June 30	63.9 b	12.1 a	75.8 b
45	July 3	89.3 a	5.5 b	94.9 a
42	July 7	91.2 a	3.7 b	94.9 a
LSD 0.05		3.6	3.2	3.2
P value		0.000	0.002	0.000

Fine fescue

Seed yield response (Table 5) stable across a wide range of seed moisture contents in both years. The 15-18% range of seed moisture content measured in this trial all gave the same yields. Seed moisture content averaged about a 3% drop per day which is equal to about a five to six day period to do the swathing. Seed moisture content and dates of swathing are reported in Table 1. Seed cleanout (Tables 6-7) was unaffected by the differences in seed moisture, however, in both years seed size as measured by 1000 seed weight was increased as the seed moisture content at swathing decreased. The cause of this increase is not apparent from the data taken. Germination was the same across all treatments so the lower seed weight for the highest seed moisture swath time did not indicate any less viability. Germination in 2006 was good at all swathing dates and varied from 96.2 to 97.3 percent - a range of only 1.1 percent (Table 8). The germination results from 2007 are not available yet.

Table 5. Seed yield response to seed moisture at swathing time in fine fescue, 2006-07.

Seed moisture	2006	2007
(%)	---------- (lb/a) ----------	
35 (38*)	1610	1388
24	1622	1421
20	1616	1366
LSD 0.05	NS	NS

* 2007 seed moisture

Table 6. Harvest component responses to seed moisture at swathing time in fine fescue, 2006.

Seed moisture	Swath date	Seed yield	Clean-out	1000 Seed wt.
(%)		(lb/a)	(%)	(g)
34	July 7	1610	20.8	1.075 b
24	July 10	1622	18.8	1.094 a
19	July 12	1616	20.6	1.107 a
LSD 0.05		NS	NS	0.017
P value		0.943	0.541	0.012

Table 7. Harvest component responses to seed moisture at swathing time in fine fescue, 2007.

Seed moisture	Swath date	Seed Yield	Clean-out	1000 Seed wt.
(%)		(lb/a)	(%)	(g)
38	July 7	1388	26.2	0.218 b
24	July 10	1421	25.6	0.255 a
20	July 12	1366	25.6	0.273 a
LSD 0.05		NS	NS	0.017
P value		0.943	0.856	0.0708

Table 8. Seed germination responses to seed moisture at swathing time in fine fescue, 2006.

Seed moisture	Swath date	Germination 7day	Germination 14 day	Germination total
(%)		(%)	(%)	(%)
34	July 7	94.7	1.5	96.2
24	July 10	95.5	0.7	96.2
19	July 12	96.7	0.6	97.3
LSD 0.05		NS	NS	NS
P value		0.317	0.232	0.604

Conclusions

Tall fescue - From this data, a range from the mid 30's to 45% will work for tall fescue, but it is not known how far below 35% the crop can be swathed without having a significant loss in seed yield due to shatter. The 50% seed moisture is definitely too high to start harvest. Though there is about a 10% range of seed moisture to work with in this trial, on hot windy days the seed moisture can decrease 5% or more per day so it is important to follow the crop carefully. Continued research will be needed to determine how low of seed moisture can be approached without losing yield and to determine when seed shattering is impacting yields.

Fine fescue. – The flat response in seed yield to a wide range of seed moistures indicates that the seeds are mature and can be harvested across a wide range of seed moisture. The increase in seed weight as the crop dried down is a consideration that would encourage delaying swathing until seed moisture is in the 20's and is not unlike current recommendations.

Both of these studies will be continued for another year to expand the reliability and measure additional factors to seed quality. The fine fescue trial was done on creeping red fescue and there is interest in looking at a similar trial on Chewings Fescue. Seed moisture content is a useful tool in determining the range of maturity for maximizing yield in grass harvested for seed and provide information to the grower to help manage the harvest.

References

Andersen, S. and K. Andersen. 1980. The relationship between seed maturation and seed yield in grasses. *In* Seed Production, Butterworth Publishers, Chapter 11.

Andrade, R.P., D.F. Grabe, and D. Ehrensing. 1994. Seed Maturation and Harvest Timing in Turf Type Tall Fescue. J. of Applied Seed Production, 12:34-46.

Klein, M.K. and J.E. Harmond. 1971. Seed Moisture – A harvest timing index for maximum yields. Trans. ASAE, 14:124-126.

Silberstein, T.B., M.E. Mellbye, T.G. Chastain, and W.C. Young III. 2005. Response of seed yield to swathing time in annual and perennial ryegrass. In: 2004 Seed Production Research Report, Ext/CrS 124. p27-30.

Silberstein, T.B., M.E. Mellbye, T.G. Chastain, and W.C. Young III. 2006. Response of seed yield to swathing time in annual and perennial ryegrass. In: 2005 Seed Production Research Report, Ext/CrS 125. p20-23

Acknowledgement

Special thanks to Christensen Farms and Doerfler Farms for their cooperation in conducting these trials

EFFECTS OF BAITS AND BAIT ALTERNATIVES ON SLUG MORTALITY, EGG PRODUCTION, AND SEEDLING SURVIVAL

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

Introduction

During the past twenty years, changes in management practices used in commercial seed production including improved soil drainage, reduced tillage depths, and reductions in the use of many chemicals harmful to wildlife and soil invertebrates, have been accompanied by improved soil health and large increases in earthworm (*Lumbricus terrestris* L.) populations (>80 cu ft) (Gavin et al., 2006a). Farming conditions that improved soil health along with winter weather conditions in western Oregon (<10 °C, soil moisture > 25%) have created an environment that also is highly favorable to the survival of the gray field slug, *Derocerus reticulatum* Mueller (Gavin et al., 2006b). Slug-associated damage to grass seed and other crops can be severe and consequently, there is need for effective means to reduce slug populations in production environments. In many cases, the use of slug baits to control these populations has been relatively ineffective. Recent research has shown that earthworms removed twenty percent of slug baits per night in western Oregon grass seed fields (Gavin et al., 2006a). Coupled with rapid biological breakdown of the active ingredient (metaldehyde, 4%) by soil microbes, controlling slugs with baits during winter remains problematic. Alternatives to standard commercial baits have been around for more than 15 years, but in the past, the field life of these products were considered too short (4-5 day active life).

We investigated the use of two non-bait products that are not attractive to earthworms including a granular, sand-based product, enhanced with an attractant and weathering protection: Durham 3.5 and 7.5 (3.5 and 7.5%, metaldehyde, respectively) and SlugFest AWF (all-weather-formula, 25%, metaldehyde), a liquid spray product. During the course of other investigations we discovered efficacy effects of a liquid fertilizer (Phor-Ti-Phy, 5.0% N, 25.0% P, 5.05% K, 0.205 Zn) as a feeding deterrent in field and greenhouse experiments. Other compounds tested, rates, and manufacturers are listed in Table 1.

Data presented here demonstrate the capability of egg-laying by slugs of eight arbitrary selected weight (age) classes. This experiment determined appropriate size class to be used in this and future egg fecundity studies. These data will be useful for determining egg potential in field crops and staging for outbreaks in subsequent rotated crops.

Since the introduction of various chemical products to control the gray field slug, little attention has been paid to their effects on egg fecundity (production). Attention has been centered at control of juveniles and adult stages creating direct impact on the crop. A successful control program must inflict long-term impacts on slug populations by hindering the production of offspring. During our greenhouse studies to screen candidate compounds, we observed differences between treatments in slug egg fecundity. In subsequent trials we quantified egg fecundity (total eggs laid, reported in this report), percent of surviving eggs, hatching success, and neonate (very young slugs, >8mg) survival (not reported in this report).

Other reports have demonstrated that eggs of the gray field slug require a chilling period of two to three weeks (3-5°C) followed by warming temperatures (17-19°C) for one to three weeks before normal egg hatch occurs (Kingston, 1966). This same author observed that egg laying by this species occurred from October through January with a peak during the month of December. Although these data were collected in laboratory conditions with controlled temperature variances, they correspond well with field and lab observations obtained in western Oregon in this study and others (G. Fisher, personal communications).

Laboratory Methods

Slugs were collected from the field and maintained in growth chambers (10° C, 8 h daylength) for three weeks before use in experiments. They received lettuce as a food source twice per week. Experiments were conducted in the growth chambers where ten gray field slugs (GFS) were placed in each round arena (30 cm diameter) covered with screened lids, and partially filled with native soil (Dayton/Woodburn, 25% soil moisture). Sixty perennial ryegrass (*Lolium perenne* L.) seeds were planted in a center row arrangement and emerged seedlings used when they were five days old.

A complete randomized-block design experiment was used to provide equal cooling and lighting, rotated every three days, and replicated eight times. Pre-moistened cotton felt pads (3mm thick) were used in each arena as slug rests and egg-laying sites. Experiments were conducted for two weeks after which seedling damage, slug mortality, and egg numbers were evaluated. Slugs were maintained in the arenas for an additional 14 days to evaluate their recovery. After eggs were harvested, they were placed in individual containers with moist soil (50% moisture), covered with moist felt pads to maintain humidity, and exposed to 3° C , 8 h day-length for two weeks. After the cool treatment they were exposed to 15° C until hatching.

We measured the effect of slug age (weight) on egg fecundity and total numbers by separating slugs by weight into eight size classes (Table 2). A 40mg buffer separated size classes to eliminate overlap. Ten slugs per soil filled arena were fed

lettuce as before with eight reps each. The experiment was terminated after 14 days and the number of dead slugs and number of eggs present were recorded. Eggs were treated as before. These data were used to identify appropriate size classes of slugs to be used in this and future fecundity experiments. Field observations on slug size / egg production and mating were verified with these data (Fisher, Gavin, personal observations).

Slug baits and non-bait formulations were obtained from local sources (Western Farm Service) and applied at field rates suggested by the manufacturer (Table 1). Liquid treatments were applied using a calibrated sprayer (15 psi; 20 gal/a rate; 80-02 nozzle, Tee-Jet®) and allowed to dry for thirty minutes. All other dry formulations were calibrated per surface area (60% of $1ft^2$).

Results

As earthworms become active with an increase in soil moisture, controlling slugs with baits becomes problematic. In an earlier report, we determined that the use of baits alone when earthworms were active protected only 25% of new seedlings. Alternatives to baits included Durham 7.5 and SlugFest AWF, two formualtions which do not attract earthworms. Slug mortality and seedling survival were enhanced when baits were combined with SlugFest AWF or Durham 7.5 (Tables 3, 4). Liquid Copper and Bordeaux Mixture increased seedling survival but did not decrease egg fecundity. Combinations of bait-plus-bait were less effective than bait-plus-non-bait. Granular Durham 7.5 can be applied in rows during planting or broadcasted during seedling emergence while Liquid SlugFest AWF can be used as an admixture with other topical applications throughout the season.

Slugs >200mg in weight (15mm in length when contracted) have the capability to produce eggs. As slugs mature egg output increases (Table 2). Relative to the un-treated control, all products reduced the number of eggs laid for the duration of this experiment (4 weeks). Dry fertilizer has been shown to decrease egg fecundity in slugs by 50% (Gavin, *unpublished data*). Bait performances were reduced in an earthworm simulated environment (Table 5). All products were enhanced by using higher rates (Table 5). An apparent reduction in egg production from poison-stressed slugs may help reduce populations to manageable levels when staging for the next crop. Repeat applications will be necessary to reduce egg output when populations are high.

Conclusions

The addition of two under-used products can enhance long-term reduction of slug population build-up in fields by increasing seedling survival and slug mortality, and by reducing the number of eggs laid. Research will continue on egg survivability and viability, and young slug survival. Field experiments will be conducted to verify and enhance these laboratory data.

Acknowledgements

We thank Bob Schroeder, Bob Spinney and Curt Dannen from Western Farm Service and Tom Peterson from OrCal for products and helpful suggestions; Glenn Fisher for his encouragement and helpful insights; and Rick Caskey for helpful design and research concepts, equipment design and construction, and field and laboratory help.

Literature

W.E. Gavin, G.M. Banowetz, S.M. Griffith, G.W. Mueller-Warrant, G.W. Whittaker. 2006a. Earthworms and their impact on slug control. *In* W.C. Young III (ed.), Seed Production Research, Oregon State Univ., Ext/CrS 126, 4/07 pp. 22-27.

W.E. Gavin, G.M. Banowetz, S.M. Griffith, G.W. Mueller-Warrant, G.W. Whittaker. 2006b. Behavioral and biological effects of weather on the gray field slug in western Oregon. *In* W.C. Young III (ed.), Seed Production Research, Oregon State Univ., Ext/CrS 126, 4/07 pp. 28-33.

N. Kingston. 1966. Observations on the laboratory rearing of terrestrial molluscs. *Amer. Midland. Nat., 76, 528-532.*

Table 1. Descriptions of slug control formulations tested.

Product	Ingredient, Formulation	Manufacturer
Bordeaux Mixture	13.9%, copper (metallic), fungicide	Gordon Corp., Kansas City, MO, USA
Deadline MP	4%, metaldehyde slug bait	Amvac, Los Angeles, CA, USA
Durham 3.5	3.5%, metaldehyde, granular	Amvac, Los Angeles, CA, USA
Durham 7.5	7.5%, metaldehyde, granular	Amvac, Los Angeles, CA, USA
Hot Pepper Wax	0.00018%, capsaicin, insect repellent	Hot Pepper Wax, Inc., Greenville, PA, USA
Liquid Copper	48%, copper salts, fungicide	Bonide Products, Inc., Oriskany, NY, USA
MetaRex orange	4%, metaldehyde, slug bait	De Sangosse SA, Pont Du Casse, FRANCE
Phor-Ti-Phy	5.0% (N), 25.0% (P205), 5.05 (K2O), 0.20% (Zn).	Western Farm Service, Fresno, CA, USA
Slug-Fest AWF	25%, metaldehyde, liquid spray	OR-CAL, Inc, Junction City, OR, USA
Sluggo	1 %, iron phosphate, slug bait	Lawn and Garden Products, Inc., Fresno, CA, USA

Table 2. The effect of slug size (weight) on egg fecundity in eight arbitrary size classes. A 40mg buffer separated size classes to eliminate overlap.

Size class	Weight	Average wt.	SEM[1]	Total eggs	Eggs per slug	SEM
	(mg)	(mg)		(no.)	(no.)	
1	< 180	156	2.44	5	0.10	0.63
2	200-300	248	2.57	248	4.96	8.28
3	300-400	339	2.59	530	10.60	5.63
4	400-500	439	2.43	631	12.62	19.40
5	500-600	534	2.50	918	18.36	24.40
6	600-700	629	3.05	1091	21.82	26.90
7	700-800	731	2.19	1796	35.92	22.20
8	800-1000	844	8.36	2140	42.80	29.70

[1]SEM=Standard error of the mean.

Table 3. The impact of supplementing slug bait treatments with non-bait alternatives. Tests were conducted in 10°C, 8h light, comparable to winter-time conditions in western Oregon. Significance levels are based on the comparison of bait alone vs. bait plus non-baits.

	Treatment	Seedling Survival (%)	*P- value*	Slug Mortality (%)	*P- value*	Number of eggs	*P- value*
Control		8		12		179	
DMP alone (10 lb/a)		19		33		98	
DMP (5 lb/a) plus:	Durham 7.5 (10 lb/a)	95	**	84	**	41	**
	Liquid Copper	83	**	74	**	60	*
	SlugFestAWF (1 qt/a)	80	**	59	**	57	**
	Bordeaux Mixture	79	**	78	**	51	**
	Hot Pepper Wax	74	**	85	**	64	**
	Durham 3.5 (10 lb/a)	70	**	44	**	67	**
	Sluggo (11 lb/a)	56	NS	41	**	28	**
	Phor-Ti-Phy (4 qt/a)	22	**	50	**	40	**
MetaRex alone (8 lb/a)		36		86		52	
MetaRex (4 lb/a) plus:	SlugFestAWF (1 qt/a)	92	NS	36	**	53	NS
	Durham 7.5 (10 lb/a)	92	**	79	NS	79	*
	Durham 3.5 (10 lb/a)	85	**	49	**	78	*
	Liquid Copper	80	**	31	**	42	NS
	Phor-Ti-Phy (4 qt/a)	80	**	41	**	73	NS
	Bordeaux Mixture	79	**	41	**	143	**
	Hot Pepper Wax	79	**	50	**	55	NS
	Sluggo (11 lb/a)	62	**	86	NS	60	NS
Sluggo alone (22 lb/a)		54		55		53	
Sluggo (11 lb/a) plus:	Durham 7.5 (10 lb/a)	92	**	85	*	85	NS
	Liquid Copper	74	**	53	NS	88	**
	Hot Pepper Wax	71	**	53	NS	71	NS
	Bordeaux Mixture	61	**	44	NS	141	**
	Durham 3.5 (10 lb/a)	59	NS	46	*	51	**
	SlugFestAWF (1 qt/a)	44	NS	28	**	39	NS
	Phor-Ti-Phy (4 qt/a)	9	**	38	*	39	NS
Durham alone 3.5 (10 lb/a)		28		28		43	
Durham 3.5 (10 lb/a) plus:	MetaRex (4 lb/a)	85	**	49	**	78	**
	DMP (5 lb/a)	70	**	44	*	137	**
	Sluggo (11 lb/a)	59	**	46	*	51	NS
	SlugFestAWF (1 qt/a)	56	**	28	NS	32	NS
	Phor-Ti-Phy (4 qt/a)	33	**	39	NS	26	NS
Durham alone 7.5 (10 lb/a)		54		40		63	
Durham 7.5 (10 lb/a) plus:	DMP (5 lb/a)	95	**	84	**	41	**
	MetaRex (4 lb/a)	92	**	79	**	79	**
	Sluggo (11 lb/a)	92	NS	85	NS	85	**
	SlugFestAWF (1 qt/a)	73	**	80	**	31	**
	Phor-Ti-Phy (4 qt/a)	62	*	53	*	91	**
SlugFestAWF alone (1 qt/a)		67		85		54	
SlugFestAWF (1 qt/a) plus:	MetaRex (4 lb/a)	92	**	36	**	53	NS
	DMP (5 lb/a)	80	*	59	**	57	NS
	Durham 7.5 (10 lb/a)	73	NS	80	NS	31	*
	Durham 3.5 (10 lb/a)	56	NS	28	**	32	*
	Sluggo (11 lb/a)	44	**	28	**	39	NS

* Significant at $P \geq 0.05$
** Significant at $P \geq 0.01$
NS, not significant at $P \geq 0.05$

Table 4. Slug mortality, perennial ryegrass seedling survival, and fecundity resulting from selected treatment approaches under experimental conditions.

Bait with Bait Alternatives	Slug Mortality (%)	*P-value*
Control	12	
DMP (5lb/a) + SlugFestAWF (1 qt/a)	93	**
MetaRex (4 lb/a) + Sluggo (11 lb/a)	86	**
MetaRex (8 lb/a)	86	**
Sluggo (11 lb/a) +Durham 7.5 (10 lb/a)	85	**
DMP (5 lb/a) + Hot Pepper Wax	85	**
SlugFestAWF (1 qt/a)	85	**
DMP (5 lb/a) + Durham 7.5 (10 lb/a)	84	**
Durham 7.5 (10 lb/a) + SlugFestAWF (1 qt/a)	80	**
MetaRex (4 lb/a) + Durham 7.5 (10 lb/a)	79	**
DMP (5 lb/a) + Bordeaux Mixture	78	**

Bait with Bait Alternatives	Seedling Survival (%)	*P-value*
Control	8	
DMP (5 lb/a) + Durham 7.5 (10 lb/a)	95	**
MetaRex (4 lb/a) + SlugFestAWF (1 qt/a)	92	**
MetaRex (4 lb/a) + Durham 7.5 (10 lb/a)	92	**
Sluggo (11 lb/a) + Durham 7.5 (10 lb/a)	92	**
MetaRex (4 lb/a) + Durham 3.5 (10 lb/a)	85	**
DMP (5 lb/a) + Liquid Copper	83	**
MetaRex (4 lb/a) + Liquid Copper	80	**
DMP (5 lb/a) + SlugFestAWF (1 qt/a)	80	**
MetaRex (4 lb/a) + Phor-Ti-Phy (4 qt/a)	80	**
MetaRex (4 lb/a) + Bordeaux Mixture	79	**

Bait with Bait Alternatives	Number of Eggs	*P-value*
Control	179	
DMP (5lb/a) + SlugFestAWF (1 qt/a)	22	**
Durham 3.5 (10 lb/a) + Phor-Ti-Phy (4 qts/a)	26	**
MetaRex (4 lb/a) + SlugFestAWF (1 qt/a)	27	**
DMP (5lb/a) + Sluggo (11 lb/a)	28	**
Durham 7.5 (10 lb/a) + SlugFestAWF (1 qt/a)	31	**
Durham 3.5 (10 lb/a) + SlugFestAWF (1 qt/a)	32	**
Sluggo (11 lb/a) + Phor-Ti-Phy (4 qt/a)	39	**
Sluggo (11 lb/a) + SlugFestAWF (1 qt/a)	39	**
DMP (5lb/a) + Phor-Ti-Phy (4 qt/a)	40	**
DMP (5 lb/a) + Durham 7.5 (10 lb/a)	41	***

** Significant at $P \geq 0.01$
*** Significant at $P \geq 0.001$

Table 5. Three rates of baits and non-baits compared to simulated earthworm removal depleting baits.

Treatment	Seedling survival (%)	*P-value*	Slug death (%)	*P-value*	Number of eggs	*P-value*
Control	3		10		187	
DMP (16-0 lb/a) depleting	32		33		125	
DMP (8 lb/a)	17	*	51	**	54	**
DMP (12 lb/a)	42	NS	55	**	47	**
DMP (16 lb/a)	73	**	68	**	34	**
Durham 7.5 (10 lb/a)	58	**	48	*	69	**
Durham 7.5 (20 lb/a)	83	**	53	**	62	**
Durham 7.5 (30 lb/a)	87	**	66	**	17	**
SlugFest AWF (1.0 qt/a)	5	**	25	NS	107	NS
SlugFest AWF (2.0 qt/a)	64	**	36	NS	23	**
SlugFest AWF (3.0 qt/a)	92	**	73	**	12	**
MetaRex (9-0 lb/a) depleting	28		33		38	
MetaRex (5 lb/a)	42	*	29	NS	62	NS
MetaRex (7 lb/a)	32	NS	35	NS	156	**
MetaRex (9 lb/a)	39	NS	43	NS	139	**
Durham 7.5 (10 lb/a)	58	**	48	*	69	*
Durham 7.5 (20 lb/a)	83	**	53	**	62	NS
Durham 7.5 (30 lb/a)	87	**	66	**	17	NS
SlugFest AWF (1.0 qt/a)	5	*	25	NS	107	**
SlugFest AWF (2.0 qt/a)	64	**	36	NS	23	NS
SlugFest AWF (3.0 qt/a)	92	**	73	**	12	NS
Sluggo (22-0 lb/a) depleting	58		66		64	
Sluggo (11 lb/a)	53	NS	55	**	140	**
Sluggo (16 lb/a)	52	NS	63	NS	110	*
Sluggo (22 lb/a)	48	NS	70	NS	115	**
Durham 7.5 (10 lb/a)	58	NS	48	**	69	NS
Durham 7.5 (20 lb/a)	83	**	53	*	62	NS
Durham 7.5 (30 lb/a)	87	**	66	NS	17	*
SlugFest AWF (1.0 qt/a)	5	**	25	**	107	*
SlugFest AWF (2.0 qt/a)	64	NS	36	**	23	*
SlugFest AWF (3.0 qt/a)	92	**	73	NS	12	**

* Significant at $P \geq 0.05$
** Significant at $P \geq 0.01$
NS, not significant at $P \geq 0.05$

SUMMER TIMING FOR CONTROL OF GRAY FIELD SLUG IN NON-IRRIGATED WHITE CLOVER

G.C. Fisher, A.J. Dreves and S.E. Salisbury

Introduction

Increasingly large and damaging populations of gray field slug, *Deroceras reticulatum* (GFS), cause economic damage in many reduced and no-till grass and clover seed fields grown in the Willamette Valley, OR. Damage can persist even when multiple applications of metaldehyde and/or iron phosphate baits are applied for their control. Subsequent seedings into these fields have been seriously damaged by GFS.

The standard practice used by growers is to broadcast 7 to 15 lb/a of 3.5 to 4% metaldehyde bait (or now, 1% iron phosphate bait) over infested fields when slugs and damage is noticed in the fall, winter or spring. We recommend that baits be used in the late summer or early fall whenever sufficient rain results in consistent above-ground activity by slugs. This is because at this time many of the slugs are mature and capable of laying large numbers of eggs in response to soil moisture. By controlling GFS at this time, fewer eggs and resultant juveniles, which tend to be more difficult to control with baits, will be encountered in spring seedings. This program can be effective when combined with some type of tillage or when slug populations are light and/or baiting episodes are preceded and followed by a few days of cool, moist weather with calm nights that favor slug activity, bait discovery and acceptance.

Too often this relatively easy and effective method of chemical slug control does not provide adequate protection, particularly when no-till seeding into ground with significant vegetative residues on the soil. For these conditions, we believe poor control of GFS is based in part on the following:

1) Insufficient slug control the previous season. Often this is coupled with our 2nd point below.

2) Weather. Conditions for good baiting episodes in fall are not that common as there is a relatively narrow window of time. This window opens when sufficient fall rains have stimulated consistent above-ground GFS activity. It closes when daily temperatures drop to levels that inhibit the time GFS spends above ground to find, eat and die from baits. In some years the entire month of October may be without rainfall, which leaves a very narrow window in the fall for control with baits before the effects of consistent rain, wind and cold temperatures reduce bait visitation. In 2006, we documented that by mid-November; common commercial baits of metaldehyde were attracting and killing only negligible numbers of GFS. Consistent winds, rain and cold temperatures prevailed, reducing bait visitation by slugs to significantly short periods of time. Also, the few slugs collected around the baits and confined in the field for observation, had very low mortality rates across all baits evaluated.

3) Age structure of the GFS population. Age of a slug influences bait visitation and therefore the result of baiting. Published literature, and our observations, indicate that juveniles are more difficult to draw to baits than adults. This is particularly evident during inclement weather.

4) Post-harvest field residue (PHR). Thick layers of PHR on soil surfaces are observed to reduce visitation of baits by slugs. These residues impede bait pellets from reaching the soil surface where slugs are active and feeding on vegetation under the PHR. If bait encounters by GFS are random, as some researchers believe, then the opportunity for GFS to encounter pellets in this situation is greatly reduced.

5) Bait disappearance. Large populations of earthworms occurring in no-till fields have been observed removing up to 25% of pelleted slug baits during the first night after application (personal communication W.E. Gavin). The worms collect and store bait pellets within caches of their tunnel systems, making them unavailable for slug control.

Previously it had been observed that GFS is active in white clover (*Trifolium repens* L.) seed crops much later in the season than in neighboring grass seed fields. During hot and dry periods, the slugs crawl about and feed at night after dew collects on foliage of the canopy. At this trial site most of the slugs were mature. Feeding, mating and/or egg laying occurred whenever moisture was sufficient in or on the soil during this trial. We hypothesized that controlling these slugs prior to fall rains, would result in fewer slugs and reduced crop damage in the fall and following spring. The reasoning is that summer timing would minimize weather as a factor, because we are directing efforts at mature slugs which generally respond better to bait than do juveniles. The timing also offers an opportunity to control slugs before any significant egg laying is initiated in the fall. It is believed that earthworm removal of mini-pellet baits would be minimal during this time period compared to late fall, winter and spring when above ground activity is greatest. Additionally, it was believed that liquid metaldehyde sprays to foliage would be less susceptible to removal by rainfall and loss through hydrolysis when applied in the summer. In short, we felt summer timing of slug control would occur early enough in the annual feeding and reproductive cycle of GFS that it would greatly reduce slug activity, crop damage and reproduction of GFS compared to controls applied later In the fall, winter or spring.

Methods

Field Trials. Two trials were initiated in a white clover field in Linn County to examine the effectiveness of different materials applied for GFS control in July 2007. This second seed year field (seeded in 2005 and grazed with sheep) was observed to have a large and uniform population of mature GFS actively feeding on foliage through mid-July. However, GFS activity was restricted only to periods in the early morning when sufficient dew was on foliage and wind was negligible at crop level. Slugs would emerge from large cracks in this Dayton-series soil and feed for a few hours, before returning to the deep cracks in the soil as the foliage began to dry. Some evenings when the crop remained dry or persistent winds prevailed, GFS did not emerge from cracks in the soil to feed. Twice in this study, after rainfall events, eggs were deposited on or very near the soil surface. More than 98% of the slugs in this field were mature based on weight and daily egg-laying activity was observed under moist blankets used to monitor populations. The average weight of each slug was 0.69g ±0.21g when the trial was initiated in July (n = 100), compared with the average weight in February of 0.15g ± 0.08g. If small and mid-size GFS were present in this field, they were not present under the blankets used as harborage. Of the hundreds of GFS observed in this trial, less than 10% were immature (small and medium size). We do not know, however, if there were smaller slugs in the soil that never emerged from the cracks.

The plots, 50 x 50 ft (0.0574 acre) were replicated 3 times in a randomized complete block design. A CO_2 powered backpack sprayer was used at 35psi, 40 GPA with a 6 ft boom and four 8004 flat fan nozzles (8 passes). A rotary bait spreader was used for Sluggo® and Metarex® baits. In both trials, applications of sprays were made in the morning when dew and GFS were active on clover foliage.

Trial #1: A conventional products trial was initiated on July 10, 2007. Treatments included: Slugfest® liquid at 1.5 qt/a was applied @ 5:30 AM; Sluggo iron phosphate bait at 15 lb/a bait applied @ 6:15 AM and Metarex bait at 15 lb/a @ 3 PM.

Trial #2: Previously, in 2006, it was observed that a micro-nutrient spray (containing Zn) provided some slug control when applied as a foliar feed with bifenthrin (for clover seed weevil control) to a clover crop. A replicated study under controlled conditions later confirmed an approximate 30% kill of GFS when WFS Phor-Ti-Fy® was applied as a topical spray to a mixed age of GFS. A foliar feed spray trial was initiated on July 12, 2007. Wilbur-Ellis foliar nutrient feed, Foli-gro @ 1 qt/a and a Western Farm Service product, Phor-Ti-Fy® @ 3 qt/a were applied to white clover in the morning from 5:15 - 6:30 AM. Slugs were present on foliage when applications were made. Clover crop was about 80% pollinated but with enough green to attract and hold feeding adult slugs. Crop covered about 90% of the soil surface in plots. Grower had applied bifenthrin for clover seed weevil control at the end of July, however this chemical appeared to have reduced populations of Carabid beetles.

Evaluation

Relative slug populations were evaluated prior to- and post-application of test materials. Slug blankets (2) were randomly placed in each plot on June 28. The blankets were 19x19 inch square, reflective, insulated, designed and provided by Liphatec Inc. Blankets were first soaked in water and randomly placed on soil scraped away of vegetation in the plots. Slugs are attracted to the moisture blankets. Slugs crawl under these blankets and use them as harborage or shelter during the day. Here they may also be seen to mate and lay eggs. As days go by, increasingly more GFS may use these blankets as shelter. In this trial, slug numbers generally increased or stabilized through time. However, if blankets or soil were not kept sufficiently wet, numbers of slug would be reduced from previous day when blankets were wetter. Slugs would disappear into cracks under blankets. We recorded numbers of GFS at daily intervals both prior to as well as post-application of treatments.

In Trial 1, numbers of GFS per blanket were recorded @ 4 days prior to application of treatments, 2 hours post application, and at 1, 2, 3, 9 and 10 DAT. Slugs were counted under both blankets per plot beginning each day at 7:30 AM. The slugs observed in the trial were mature (98%). Very few juveniles were seen.

In Trial 2, numbers of GFS per blanket were recorded @ 1 day prior to application of treatments and again at 1, 7, and 8 DAT. Slugs were counted under both blankets per plot beginning each day at 7:30 AM.

Table 1. Mean number of mature gray field slugs (± SE) per 2 blankets per plot.

Treatment	4D pre *7/6/07*	2h post *7/10/07*	1 DAT *7/11/07*	2 DAT *7/12/07*	3 DAT *7/13/07*	9 DAT *7/19/07*	10 DAT *7/20/07*
	----------(Number of slugs per 2 blankets/plot)----------						
Slugfest	32.7[*1]	18.7	2.0	4.0	1.7	1.7	3.0
	±2.2a	±2.2a	±1.0a	±1.2a	±0.3a	±0.9a	±0.0a
Sluggo	18.0	23.0	33.0	26.0	3.0	7.3	4.7
	±1.5a	±2.9a	±3.5b	±1.5b	±0.6a	±0.7ab	±0.4a
UTC	22.0	30.7	47.7	36.7	21.7	14.7	25.3
	±2.6a	±8.4a	±8.2b	±2.0b	±4.3b	±4.2b	±10.4b
Metarex	26.7	26.7	40.0	44.7	24.7	10.0	12.0
	±5.0a	±2.0a	±4.4b	±11.1b	±2.7b	±2.5b	±3.1ab
F-value	2.80	1.19	16.13	9.43	28.87	4.71	3.52
$P < 0.05$	0.1086	0.37	0.0009	0.0053	0.0001	0.0487	0.0687

[*1] Means (±SE) separated by Fisher's LSD. Means with same letter are not significantly different.

Results - Conventional Products Trial

Slug numbers recorded under blankets generally increased in the UTC through 7/12 (2 DAT) (Table 1). This was followed by a dip in numbers on 7/13 and 7/19 with an increase on 7/20. Interestingly, 4 day pre-treat counts of GFS in the UTC were comparable to post-treat UTC counts 12 days later (22 vs 25 slugs per blanket).

It was critical to keep blankets moist and to count slugs under blankets at the same time each day (about one hour beginning 7:30 AM after their morning feeding activity ceases). We feel the decrease in UTC numbers at 3 and 9 DAT was related to sub-optimal moisture under blankets.

Slugs were observed to feed at night anytime when dew point was reached and calm conditions prevailed within the crop canopy. If it was windy during the night, little dew formed. However, breezes and light winds were often sufficiently blocked by foliage. Slugs were often seen feeding in the canopy prior to and at dawn. Interestingly, GFS laid eggs continually under the wet blankets during the trial period. Less than 2% of slugs observed in these two trials were of small size.

Some rain fell during these trials and slugs were seen above ground and on foliage in all plots on and shortly after those dates receiving rainfall. Pelleted baits used persisted on plot soil through the duration of the trial. By 9 DAT, pellets not yet consumed averaged about 2/sq. ft for Sluggo® and 8/sq. ft for Metarex® plots. Sluggo pellets had a soft, gooey and wet appearance. Metarex pellets were rather hardened and dry. No mold was observed on bait. Earthworms collected and stored pellets of both Sluggo® and Metarex® baits under blankets used to monitor slugs in these trials. This removal of baits was not deemed to be a factor in GFS control in these trials as baits were evident on soil surface through the trial period.

Slugfest® liquid gave immediate, effective and permanent reduction of GFS. After just 1 DAT, numbers of GFS dropped 94% from pre-treat numbers. Sluggo provided 83% reduction in GFS at 3 DAT. Metarex provided nearly 50% control of GFS by the end if tge trial. Slugfest® and Sluggo® plots had significantly fewer numbers of GFS than Metarex and UTC plots. We believe that insufficient precipitation to make Metarex pellets moist and attractive to GFS reduced their effectivity.

Table 2. Mean number of mature gray field slugs per 2 blankets per plot.

Treatment	pre- *7/12/07*	1 DAT *7/13/07*	7 DAT *7/19/07*	8 DAT *7/20/07*
	----------(Mean no. of slugs per 2 blankets/plot[1]) ----------			
Foli-Gro	41.3 ± 17.8	28.0 ± 19.6	13.3 ± 6.7	26.7 ± 10.7
Phor-Ti-Fy	48.3 ± 15.8	27.3 ± 9.4	14.3 ± 3.8	20.7 ± 7.8
UTC	39.7 ± 11.3	33.7 ± 17.7	16.0 ± 6.4	29.3 ± 13.4
F-value	0.09	0.05	0.05	0.17
$P < 0.05$	0.9129	0.9556	0.9479	0.8499

[1]No data transformation could equalize variances within treatments to meet the basic assumptions for ANOVA. Thus, no differences between treatments were found.

Results - Foliar Nutrient Sprays for Summer Slug Control

At 8 DAT, both Foli-Gro and Phor-Ti-Fy foliar nutrient sprays appeared to have reduced populations of GFS by more than half when compared to their respective pre-treatment numbers (35% and 57% reduction). However, populations also declined by 26% in the UTC. Although it appears both products have some activity on GFS, neither nutrient spray gave statistically significant population reductions of GFS in this trial.

Significant numbers of slug eggs were deposited within each 24 hour period. It should be noted that with the exception for the days that precipitation occurred, few to no eggs were observed to be deposited on the soil in the absence of blankets. We believe that these mature slugs feed through the summer when opportunities arise. When fall rains begin and temperatures cool, they will begin laying eggs immediately after soil surface activity commences. The potential therefore exists for large numbers of GFS eggs to be deposited in just a few days if one delays applying bait in the fall. Properly timed summer bait or spray programs may reduce fall pressure from GFS in grass and clover seed crops in the Willamette Valley.

CHOKE IN ORCHARDGRASS: RESEARCH UPDATE AND POTENTIAL CONTROL

S.C. Alderman and S. Rao

Choke, caused by the fungus *Epichloë typhina,* is a serious and persistent problem in orchardgrass seed production fields. The fungus resides within the plant as an endophyte. Once plants are infected they remain infected for the life of the plant. However, *E. typhina* in orchardgrass differs from the common endophytes or other *Epichloë* species in that there are no documented cases of transmission of *E. typhina* in orchardgrass seed. *Epichloë typhina* produces no survival propagules and does not survive outside of the plant; it is totally dependent on its host for growth and survival. For most of the year, infected plants appear normal, despite the fact that the fungus can be found growing on and within the leaves throughout the plant. However, in the spring, growth of the fungus is stimulated in the reproductive tillers. The fungus proliferates and completely engulfs the very young, developing panicle. The stalk continues to elongate, and a 2 to 6 inch white to grayish, velvety fungal stroma emerges instead of a seed head (Figure 1).

We know from previous studies that *E. typhina* has two mating types. Conidia produced on the surface of a stroma will be of one of two mating types. Typically, on an infected plant, all the stromata that emerge from that plant will have conidia of the same mating type. For sexual reproduction (i.e., production of ascospores), conidia of one mating type must be transferred to stromata of another mating type to initiate fertilization. In both unmanaged (natural or native) and managed (cultivated) habitats, the transfer of conidia is accomplished by species of flies that have a close affinity to *E. typhina*. As the flies feed on various stromata, they invariably encounter stromata of both mating types. Conidial transfer occurs through the ingestion and defecation of conidia on the stromata. The fly lays one to several eggs on the surface of the stromata. By the time the stromata begin maturing, larvae hatch from the eggs and feed on the stromata. The fertilized stromata are about one to two mm thick, providing both a substantial food source and protection while the larvae feed and develop beneath the stroma surface. As the fertilized stromata mature, the stromata color changes to yellowish to yellowish orange (Figure 2). Ascospores are produced in specialized structures (perithecia) in the outer surface of the stromata. Ascospores are forcibly ejected and wind disseminated. Thousands of ascospores can be ejected from a single stroma per day for weeks.

Within the past year we discovered that not only conidia, but ascospores can fertilize stromata. This is very significant because the earliest fertilized stromata produce and release ascospores that can be widely dispersed by wind. As more stromata are fertilized, still more ascospores are dispersed, fertilizing more stromata or infecting plants. The ascospores are believed to be the primary means of new plant infections. A stroma will produce and release ascospores for at least a couple of weeks, as long as it remains attached to the plants and conditions are not very dry. Ascospores will also be released from cut stromata for several days to a week, as long as they remain moist and do not dry out. Stromata that dry out after cutting no longer produce or release ascospores. When released into the air, ascospores can survive for at least 3 days, even under dry conditions, with no loss in viability.

We observed that ascospores on healthy leaves germinate to produce secondary spores or limited hyphal growth. However, ascospores at wounds sites, including cut leaf surfaces or puncture wounds, germinate and produce extensive hyphal growth at the wound site. Studies are in progress to determine the environmental requirements and time period required for *E. typhina* to become established in a plant.

Control of choke has been elusive. Fungicide trials have been applied in an attempt to prevent infection. They have not proven effective. However, an alternate management approach is fungicide application for prevention of fertilization of the stromata. We recently determined that *E. typhina* is sensitive to copper, with no germination of *E. typhina* ascospores in copper sulfate solutions as dilute as 0.01%. Fungicides directed at the stromata, while they are still white and before they turn orange, may be more efficacious than preventing infections. At the stromal stage, the fungus is exposed on the plant surface and more vulnerable than the fungus deep within the plant. Although infected plants would remain infected, the potential for new plant infections would be reduced indirectly by reducing the inoculum, i.e., ascospores from fertile stromata. In a cooperative project, including growers, Western Farm Service, OSU and USDA, field trials are planned for the spring of 2008 to determine whether fungicide application can effectively prevent fertilization of stromata of *E. typhina* in orchardgrass.

Figure 1. Unfertilized stroma of *E. typhina*, white in color.

Figure 2. Fertilized stroma of *E. typhina*, yellow to orange in color.

INSECTS, SLUGS, AND MITES ASSOCIATED WITH CHOKE IN ORCHARDGRASS IN THE WILLAMETTE VALLEY

S. Rao, K.M. Ackerman and T.S. Biboux

Introduction

Epichloë typhina, a fungus native to Europe, and the causal agent of the disease choke in orchardgrass, was first detected in the Willamette Valley in 1996 (Alderman et al., 1997). The disease spread rapidly through the valley (Pfender and Alderman, 1999). By 2003, 90% of the survey fields were infested (Pfender and Alderman, 2006). As the fungus continues to spread, impacts on seed production in the Willamette Valley increase since infected tillers are prevented from producing the inflorescence, and thus seed yield is directly affected.

E. typhina is an endophytic fungus that initially develops internally without any external symptoms. The first sign that an orchardgrass plant is infected is the appearance in early spring of large white stromata covering emerging tillers. When the stroma is fertilized, orange perithecia develop and disperse large numbers of ascospores which infect new plants. In the Willamette Valley, this usually occurs in late June, just before the orchardgrass seed is harvested.

Currently there is little information on the mechanism by which ascocpsores enter new plants. Billbugs, mites, slugs, thrips and aphids feed on various plant tissues and could potentially inadvertently infect plants through wounds produced during feeding. Wounds produced during egg laying could also serve as an entry point for the choke pathogen. A fly species, *Botanophila lobata*, which develops on the stroma (Rao and Baumann, 2004), is reported to be critical for fertilization of the fungus (Bultman and White, 1988). The fly is present in high numbers in orchardgrass fields in the Willamette Valley (Rao and Baumann, 2004) but its role in the spread of the disease is unclear. Insects and related organisms could thus serve as vectors in the spread of choke disease. Hence, in 2007, we conducted a survey to determine the presence of insects, slugs, and mites associated with choke in orchardgrass in the Willamette Valley.

Methods and Materials

Two studies were conducted to determine possible interactions between insects and related organisms, and choke disease in orchardgrass – a field survey where observations were made directly in the field, and microscope examination of tillers for detection of minute insects and mites including eggs and immatures.

Field Survey: In spring of 2007, we surveyed three fields every other week from May 1 through June 28. In each field, along each of 4 transects in a diamond pattern, 40 sites 10 steps apart were selected, and a 0.25 m^2 PVC rectangular frame was placed over orchardgrass plants. The number of diseased tillers inside the frame was recorded. The number of slugs and the presence of insects and mites detected within the PVC frame were also recorded.

Examination of tillers. From each field, 100 infected tillers were collected and transported to the lab. In the lab, the 300 stromata were examined under a stereomicroscope and the size of the stroma, extent of fertilization, and the numbers of each species of insects (eggs, immatures, and adults), and mites were recorded.

Results and Discussion

Field Survey

Incidence of choke: An abundance of choked tillers was observed during each sampling event at each of the 40 locations in each of the three fields included in the study. There was variation across the three fields in the numbers of infected tillers in the 10 m^2 (40 locations per field x 0.25 m^2 / location) area surveyed in each field (Figure 1). We recorded the highest number of infected tillers at Site 1 across all five sampling days. At Sites 2 and 3, the numbers of choked tillers increased and then decreased through the survey period. As the incidence of choke cannot reduce through a season, this variation is likely due to variation in selection of sampling locations during each sampling day. We believe that this documents variability in the incidence of choke within fields. There are hot spots in some areas whereas at others, the incidence is low.

Presence of insects, slugs and mites: There were more slugs than any insect or other arthropod within the grids used in the field survey. Slugs were recorded only during the first three weeks of the survey (Figure 2). During the last two sampling periods, slugs were probably not visible above ground due to the dry conditions. Besides slugs, we recorded the presence of springtails, aphids, spittle bugs, leafhoppers, stink bugs, the cereal leaf beetle, lady beetles and ground beetles.

Association of insects and mites with infected tillers. In every field, during each of the five weeks when the survey was conducted, the there were many more large stromata compared with the number of small or medium stromata. By May 17, in every field, all stromata exhibited some level of fertilization (Figure 3). A majority of the stromata were well fertilized over the entire length of the stroma.

Close examination of each tiller under the microscope revealed the presence of a diversity of insects and mites. High numbers of mite eggs were observed on infected tillers collected until May 17 at Sites 2 and 3. However, few adults were observed. It is possible that the mites had dropped off the stroma or

remained hidden during examination under the microscope. Aphids were observed during the last three sampling days beginning from May 31. Thrips and springtails were recorded but their numbers were low. The most abundant insect was the fly, *Botanophila lobata.* Both eggs and immatures were recorded. There was variation across fields and within the same field over time suggesting that the fly had a clumped distribution. A greater number of flies were associated with the fertilized stoma early on, suggesting that they played a greater role in fertilization of the fungus early in the season. Ascospores produced early in the season could be involved in fertilization of late developing stroma (Alderman, personal communication)

The survey will be repeated in 2008 with modifications. In the field survey, the number of plants with choke rather than the number of tillers with choke will be recorded. In addition, a study will be conducted to get a better understanding of the spatial distribution of choke across fields. Future research is planned to determine if insects have the potential to infect plants with ascospores.

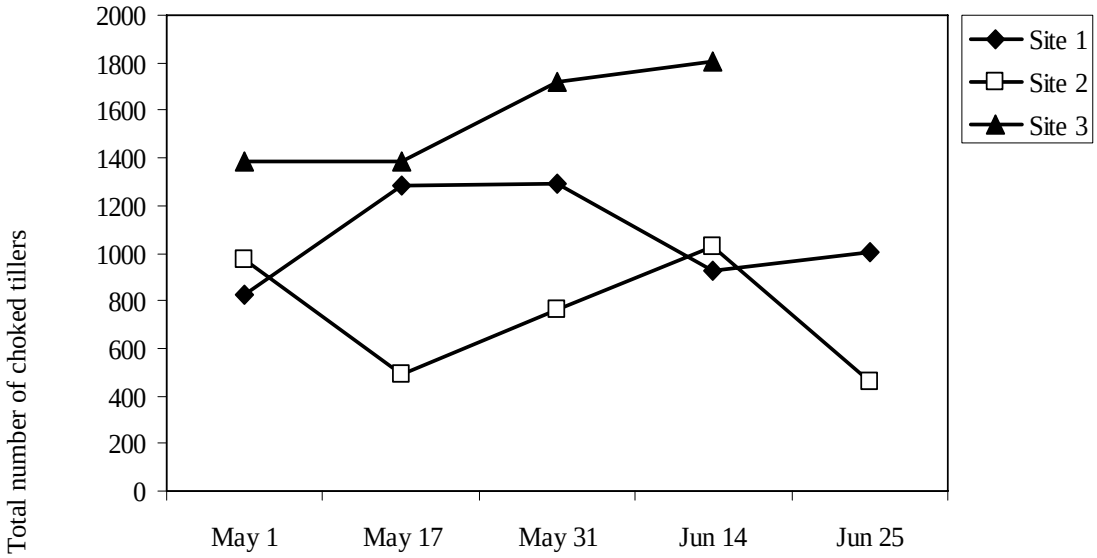


Figure 1. Incidence of choke in three orchardgrass fields surveyed every other week.

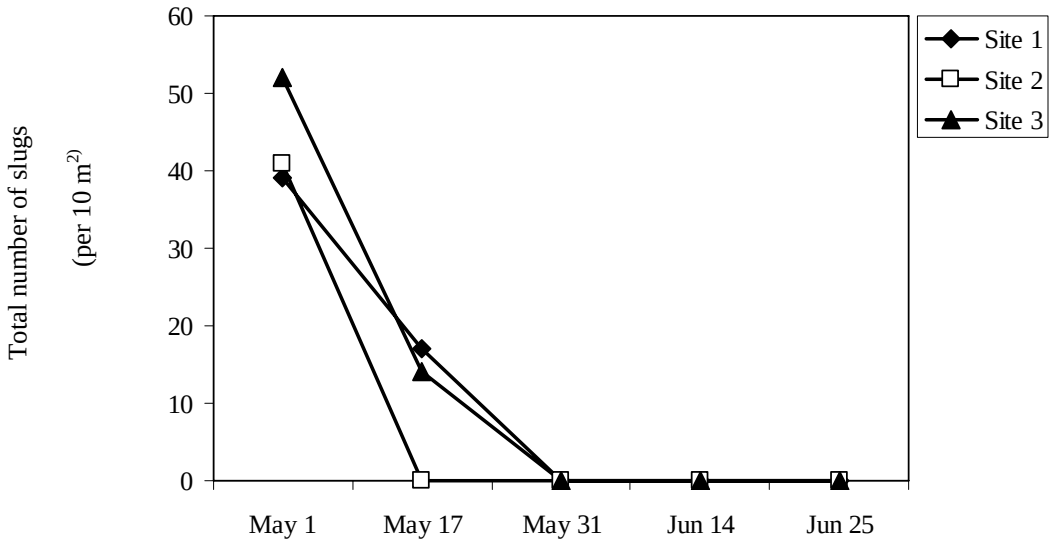


Figure 2. Abundance of slugs in three orchardgrass fields surveyed every other week.

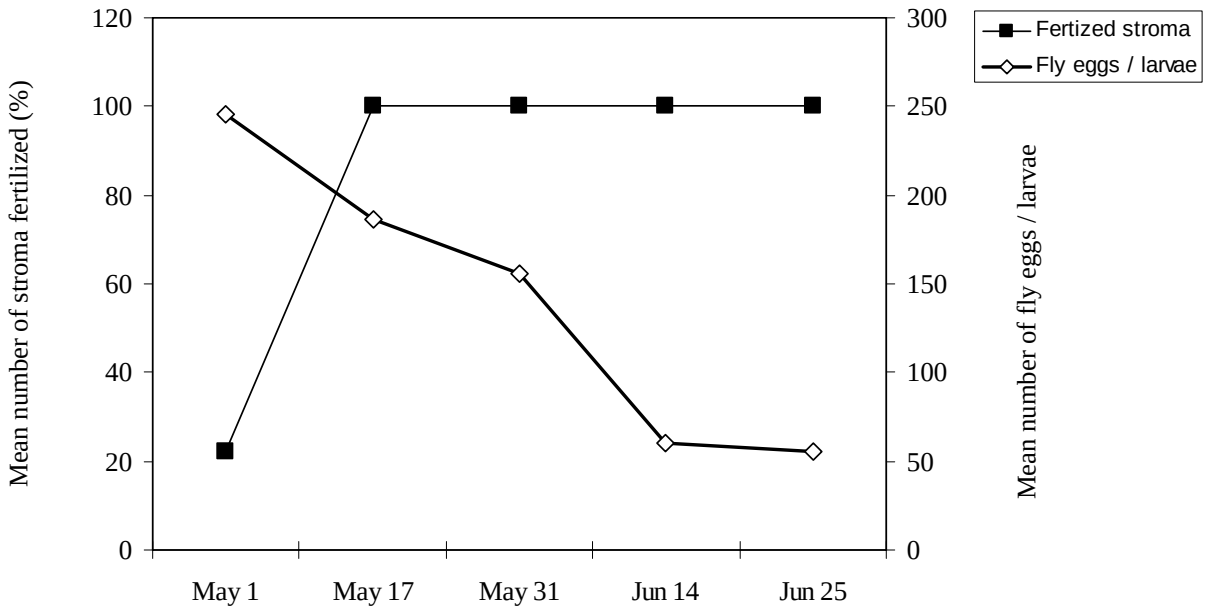


Figure 3. Mean number (%) of stroma that were partly or fully fertilized and mean number of fly eggs or larvae present on the 100 stromata that were collected each week for orchardgrass fields surveyed every other week.

References

Alderman, S.C., Pfender, W.F. Welty, R.E., Mellbye, M.E., Cook, R.L. Spatafora, J.W., and Putnam, M. 1997. First report of choke, cause by *Epichloë typhina*, on orchardgrass in Oregon. *Plant Disease* 81:1335.

Bultman, T.L and White, J.F. 1988. "Pollination" of a fungus by a fly. *Oecologia* 75: 317-319.

Pfender, W.F. and Alderman, S.C. 1999. Geographical distribution and incidence of orchardgrass choke, caused by *Epichloë typhina,* in Oregon. *Plant Disease* 83: 754-757.

Pfender, W.F. and Alderman, S.C. 2006. Regional development of orchardgrass choke and estimation of seed yield loss. *Plant Disease* 90: 240-244.

Rao, S. and Baumann, D. 2004. The interaction of a *Botanophila* fly species with an exotic *Epichloë* fungus in a cultivated grass: fungivore or mutualist? *Entomological Experimentalis et Applicata* 112: 99-105.

CONTROL OF MANNAGRASS IN GRASSES GROWN FOR SEED

B.J. Hinds-Cook, D.W. Curtis, C.A. Mallory-Smith and A.G. Hulting

Introduction

Mannagrass (*Glyceria spp*.) infests wet grass seed fields in the Willamette Valley, Oregon. The development of resistance to ethofumesate (Nortron) through repeated use has left no effective control for managing mannagrass in Italian ryegrass, seedling perennial ryegrass, or seedling tall fescue, grown for seed. Besides being competitive with the crop, the presence of mannagrass seed in Italian ryegrass seed lots has created marketing difficulty. A herbicide screening trial at the Hyslop Crop Science Farm near Corvallis and two studies in Italian ryegrass production fields in Linn County were conducted during the 2006-2007 crop year to identify possible control measures.

Methods

Experimental design utilized in all studies was a randomized complete block. The screening trial had 8 ft by 70 ft plots and four replications. Two rows each of 25 species – mostly grasses – were seeded across each plot. The mannagrass seed was obtained from a field near Lebanon. Treatments were applied with a bicycle wheeled, compressed air sprayer which delivered a spray volume of 20 gpa at 20 psi. Mannagrass control and crop injury ratings were obtained by visual evaluation. Four herbicide treatments from the screening trial are included in this report. Ethofumesate was included as the standard treatment. The three other chemical treatments are from a class of herbicides called HPPD enzyme inhibitors. Mesotrione (Callisto) is scheduled to be registered for use in certain grasses grown for seed during 2008. Pyrasulfotole-bromoxynil (Huskie) was recently labeled for use in wheat, but will not be labeled for use in grass for another year or two. Topramezone (Impact) is a corn herbicide and is not currently being developed for use in grass grown for seed. These herbicides are used primarily for broadleaf weed control.

The production field studies were 8 ft by 25 ft plots with three replications. Italian ryegrass seed yield was obtained by hand harvesting 27 sq ft in each plot then threshing the seed with a small plot combine. The seed was cleaned on a Clipper Cleaner prior to weighing. Pyrasulfotole-bromoxynil was the only herbicide treatment evaluated in the field studies.

Table 1. Conditions at time of application, and plant growth stages at three locations.

Location:	Corvallis	Tangent	Lebanon
Application date	November 17, 2006	February 9, 2007	February 9, 2007
Air temperature (F)	40	60	64
Soil temperature (F)	40	61	62
Relative humidity (%)	80	75	71
Soil moisture	muddy	muddy	muddy
Soil texture	silt loam	silty clay loam	silty clay loam
Soil pH	5.4	5.7	4.9
Soil O.M. (%)	2.2	6.0	4.6
CEC (meq/100g)	14.1	31.4	17.7
Mannagrass	1 tiller	4 leaf to 2 tillers	2 tillers
Italian ryegrass	2 tiller	2 leaf to 4 tillers	2 to 4 tillers
Perennial ryegrass	3 leaf to 1 tiller		
Tall fescue	2 leaf		

Results

Visual evaluations of the effects of the four herbicide treatments on four of the plant species included in the screening study are presented in Table 2. The standard ethofumesate treatment provided essentially no control of the mannagrass and caused minor stunting of Italian ryegrass and tall fescue. The HPPD inhibitors controlled 98-100% of the mannagrass with excellent crop safety.

Table 2. Mannagrass control and grass crop injury, Corvallis, 2007.

Treatment	Rate	Mannagrass control[1]	Italian ryegrass injury[1]	Perennial ryegrass injury[1]	Tall fescue injury[1]
	(lb a.i./a)	(%)			
Check	0.00	0	0	0	0
Ethofumesate	1.00	12	8	0	18
Mesotrione	0.09	100	0	0	0
Pyrasulfotole - bromoxynil	0.03 0.20	98	0	0	0
Topramezone	0.02	100	0	0	0
LSD (0.10)		13	NS	NS	12

[1]Evaluated February 26, 2007

Control ratings of mannagrass in the two Italian ryegrass production fields (Table 3) were lower than those in the screening trial; the reduction in control was caused by advanced growth stages. Mannagrass stand density was much greater at the Lebanon site, which depressed ryegrass seed yield in the check plots. The results of these studies show that HPPD inhibitor herbicides can provide excellent mannagrass control when applied at an early growth stage and that grass seed yields can be increased where mannagrass populations are dense. Preliminary results from field studies initiated in the fall of 2007 confirm the excellent mannagrass control with these herbicides at early application timings.

Table 3. Mannagrass control and Italian ryegrass injury and seed yield, Tangent and Lebanon, 2007.

Treatment	Rate	Mannagrass control[1]		Italian ryegrass Injury[1]		Italian ryegrass Seed yield[2]	
		Tangent	Lebanon	Tangent	Lebanon	Tangent	Lebanon
	(lb a.i./a)	(%)				(lb/a)	
Check	0.00	0	0	0	0	1221	694
Pyrasulfotole - bromoxynil	0.03 0.20	78	82	0	0	1258	1285
LSD (0.10)		13	13	0	0	NS	575

[1]Evaluated April 26, 2007
[2]Harvested June 26, 2007

KENTUCKY BLUEGRASS TOLERANCE TO PRIMISULFURON

R.P. Affeldt and J.L. Carroll

Introduction

Primisulfuron (Beacon®) is the only effective herbicide option registered for controlling rough bluegrass *(Poa trivialis*) and downy brome (*Bromus tectorum*) in seedling Kentucky bluegrass. Beacon can severely injure Kentucky bluegrass, but the injury varies from year to year and the factors that lead to this injury are unclear. It is conventionally believed that some varieties are much more sensitive to Beacon than others and that Beacon use on sensitive varieties should be completely avoided. Furthermore, Mueller-Warrant et al. (1997) reported differences in varietal sensitivity to Beacon. Finding the optimal timing for this herbicide is critical because it has a low margin for selectivity on these two weeds.

Materials and Methods

Kentucky bluegrass varietal response to Beacon was evaluated in five trials conducted in commercial fields near Madras, Oregon. Varieties selected were 'Julia', 'Bar-Impala', 'Abbey', 'Merit', and 'Shamrock'. Beacon was applied at 0.018 lb a.i./a (0.38 oz product/a) at three timings in the fall: 2-leaf, 4-leaf, and tillered. The three fall-applied treatments were also followed by additional Beacon in the spring at 0.018 lb a.i./a, for a total of six treatments. All five trials consisted of 10 by 25-ft plots arranged in randomized complete blocks replicated four times. Beacon was applied with a CO_2-pressurized backpack sprayer delivering 20 gal/a at 20 psi. Crop injury was evaluated visually at vegetative and reproductive stages with a 0 to 100% rating scale.

Results and Discussion

Beacon applications were made based on crop growth stage rather than calendar date (Table 1). Therefore growing conditions at the time of application varied for each treatment across trials because of varying planting dates and irrigation methods. Kentucky bluegrass growth stage at the time of application strongly influenced sensitivity to Beacon: 2-leaf timings generally caused more injury than 4-leaf timings, which generally caused more injury than tillered timings (Table 2). Also, Beacon applied in the fall followed by another application in the spring resulted in more injury than Beacon in the fall only.

Varietal response to Beacon in order of least to most sensitive based on visual evaluations made 23 May 2007 was as follow: 'Julia', 'Shamrock', 'Abbey', 'Merit', and 'Bar-Impala'. This is not a statistically established ranking. Results from Mueller-Warrant et al. with three of these varieties ('Shamrock', 'Abbey', and 'Merit') indicated different levels of tolerance than what was observed here. However, the influence of varietal response is unclear because these trials were not side-by-side comparisons of varieties. Based on these results, it seems possible that crop growth stage and growing conditions at the time of application more strongly influence crop tolerance than varietal response.

References

Mueller-Warrant, G.W., D.S. Culver, S.C. Rosato, and F.J. Crowe. 1997. Kentucky bluegrass variety tolerance to primisulfuron. *In* W.C. Young III (ed.) Seed Production Research, Oregon State Univ. pp 51-52.

Table 1. Primisulfuron (Beacon®) application dates on seedling Kentucky bluegrass varieties near Madras, OR.

Growth stage	'Abbey'	'Bar-Impala'	'Julia'	'Merit'	'Shamrock'
	(Application date)				
2-Leaf	15 Sep 2006	6 Oct 2006	28 Sep 2006	14 Sep 2006	6 Oct 2006
4-Leaf	6 Oct 2006	28 Oct 2006	6 Oct 2006	28 Sep 2006	28 Oct 2006
Tillered	28 Oct 2006	12 Dec 2006	28 Oct 2006	28 Oct 2006	12 Dec 2006
Spring	19 Mar 2007	19 Mar 2007	19 Mar 2007	19 Mar 2007	19 Mar 2007

Table 2. Response of first year stands of Kentucky bluegrass varieties to Primisulfuron (Beacon®) herbicide near Madras, OR, 2007.

Growth stage at Application[1]	'Abbey'		'Bar-Impala'		'Julia'[4]	'Merit'		'Shamrock'	
	10 Apr[2]	23 May[3]	10 Apr[2]	23 May[3]	10 Apr[2]	10 Apr[2]	23 May[3]	10 Apr[2]	23 May[3]
	(% Injury)								
2-Leaf	23	28	35	40	0	0	30	24	39
4-Leaf	10	16	18	23	0	3	26	4	5
Tillered	5	13	13	18	0	0	13	3	3
2-Leaf + Spring	30	45	55	70	0	6	38	45	55
4-Leaf + Spring	24	29	40	48	0	0	70	20	23
Tillered + Spring	25	14	43	38	0	9	19	18	19
Check	0	0	0	0	0	0	0	0	0

[1] Beacon was applied at 0.018 lb a.i./a with a non-ionic surfactant at 0.25% v/v.
[2] Kentucky bluegrass was in vegetative growth stage.
[3] Kentucky bluegrass was in reproductive grown stage.
[4] Field had a severe infestation of downy brome that prohibited a visual evaluation on 23 May.

EVALUATING VOLE MONITORING TOOLS FOR GRASS SEED PRODUCTION

J.A. Gervais

Voles have emerged as significant crop pests in the Willamette Valley following the 2005 population outbreak that caused millions of dollars in crop losses to grass seed, nursery crops, vineyards, and trees. One of the significant features of vole biology is the highly variable population densities, where low densities incurring limited damage may persist for years in between outbreaks. Available evidence suggests that population peaks are best controlled early in the buildup phase (e.g., Pech et al., 1992; Stenseth et al., 2001), before densities reach levels that make control difficult. Monitoring populations is necessary to determine when they are beginning to build, and when intervention may be necessary to prevent densities causing significant crop losses.

Monitoring populations of small rodents has most frequently been done using traps, but this can be labor-intensive and also requires handling the animals. In addition, risk of disease transmission from handling either live rodents or their carcasses has made it even more desirable to develop methods to estimate population sizes using sign indices. I undertook this study to compare several indices of vole sign such as burrows and runways in conjunction with a trapping survey to determine whether these indices might adequately reflect real numbers and thus could be used by growers or other land managers to quickly, easily, and cheaply monitor vole numbers. Methodology was based on a protocol used in northern England that had been evaluated and found to adequately reflect real population trends (Lambin et al., 2000).

This research was conducted at the OSU Hyslop Crop Science Research Farm, six miles north of Corvallis, Oregon. Twenty-four enclosures of 0.2 hectares (approximately 0.5 acres) each have been used extensively in the past to study vole populations. The enclosures consist of a mixture of pasture grasses and annual and perennial broadleaf plants. The enclosures are typically mowed twice a year for vegetation control. Eight enclosures were mowed in early May 2006. These enclosures, and an additional 8 unmowed enclosures, were used in this study to compare index performance with respect to mowing.

I set trapping grids consisting of 64 stations in each of the enclosures. Traps were pre-baited for a week prior to setting and then were set at dusk and checked at dawn for 4 consecutive days. I tagged each captured vole with a uniquely numbered ear tag prior to releasing it. These data were then analyzed to estimate population sizes in each of the enclosures using capture-mark-recapture analysis.

Immediately prior to trapping, I measured several indices that have been suggested for use on voles. These included strip transects of three widths (line intercept or zero width, 50 cm or approximately 20 inch width, and 1 m or approximately 40 inches width), and quadrats measuring 50 cm square placed in a grid throughout the enclosure.

For each method, all burrows, runways, dropping piles, grazed plants, or piles of clipped vegetation that were still green were noted. For the line-intercept transect, I counted vole sign that fell directly below the measuring tape. For 0.5 and 1.0 m width transects and the quadrat survey, I counted all sign that fell within the boundaries of the measured area. These sign surveys were then correlated with estimated population abundance in each of the enclosures.

The quadrat survey based on the protocol used in northern England performed least well for all sign types. The correlation coefficients (r^2) ranged from 0.00 to 0.26. This method does not hold much promise for use in grass seed production systems or in less managed systems such as grassland restoration projects. The method performed best with counts of occurrences of droppings in unmowed systems (r^2=0.25) but this likely not a strong enough relationship to justify its use in tracking vole populations for management purposes.

The line transect method performances varied by mowing treatment and by sign index. In the unmowed enclosures, runways and droppings in line transects gave the best indication of vole population size, with r^2 values of 0.74 and 0.63, respectively. For these two sign indices, all transect widths were similar in performance. In the mowed enclosures, none of the indices performed acceptably for even very rough indications of vole population size. These methods have little promise for use in production grass seed for monitoring changes in vole population size.

It should be noted that counts of burrows performed very poorly, with correlation coefficients of 0.02 for the quadrat technique and 0.00 to 0.24 for the transect methods. Because burrows may persist for months without occupants, and cannot be dug by voles during the dry season, they cannot reflect population changes on a time scale of less than several months, and will not be adequate to assess population buildup within a season. Although burrows are easy to see and to count, they do not provide information that is reflective of population changes.

Growers wishing to monitor vole population changes should focus on areas where past experience suggests that populations build up first, and should begin monitoring while populations are known to be low, so that changes through time will be apparent. Further work in grass seed fields will be needed to evaluate other techniques for quantifying abundance to aid in

timely management. In the meantime, there is little to substitute for personal experience and familiarity with one's fields.

Acknowledgements
I thank Tom Manning, Dan Rosenberg, and Deeana Sanders for assistance with various aspects of vole catching.

References:

Lambin, X., S. J. Petty, and J. L. MacKinnon. 2000. Cyclic dynamics in field vole populations and generalist predation. Journal of Applied Ecology 69:106-118.

Pech, R.P., A.R.E. Sinclair, A.E. Newsome, and P.C. Catling. 1992. Limits to predator regulation of rabbits in Australia: evidence from predator-removal experiments. Oecologia 89:102-112.

Stenseth, N. C., H. Liers, S. Mercelis, and P. Mwanjabe. 2001. Comparing strategies for controlling an African rodent: an empirically based theoretical study. Journal of Applied Ecology 38:1020-1031.

USE OF ESN® FOR SPRING NITROGEN FERTILIZER MANAGEMENT IN TALL FESCUE SEED PRODUCTION

T.B. Silberstein and J.F. Cacka

Nitrogen is the most limiting macro-nutrient in grass seed production systems of the Willamette Valley. Oregon grass seed growers typically do not monitor crop or soil nitrogen (N) levels during the growing season and often apply fertilizer N in excess of recommended rates. In addition to excessive fertilizer N use resulting in leaching losses, recent increases in N fertilizer prices have caused seed growers to monitor application rates more closely. Most grass seed growers apply N in split applications as a way to overlap and even up applications and cover more acreage with a first application. Additional reasons to split apply can be to minimize potential leaching losses early in the season on some soil types if there are heavy rainfall events and also provide adequate supplies to the plant across the full growing season. However, later applications can also cause crop damage and resultant yield losses in tall fescue due to the large footprint of the machinery used to apply the fertilizer.

Continued improvements in durability and costs of polymer coated "controlled release" fertilizers are increasing interest in using these materials to allow seed growers to apply all of the material in one application and provide for a season long "feeding" of the nutrient to the plant. One of the current materials being marketed is Environmentally Smart Nitrogen (ESN®) by Agrium. In order to determine if this material can improve nitrogen management and uptake in tall fescue seed production, a series of spring applied N trials were established at three locations in the Willamette Valley (Table 1).

Table 1. Site information for ESN trials, 2007.

Location:	Linn County	Yamhill County	Polk County
Soil type:	Dayton	Amity	Concord/Dayton
Farm:	Smith Farms	Sitton Farms	Prairie Farms

Table 2. Treatment schedule for ESN mixtures in tall fescue, 2007.

Tmt	AmS *20.5-0-0-24*	Urea *46-0-0*	ESN *44-0-0*	Total N lb N/a
	--------[lb N/a (lb fert.)] --------			
Urea	21 (105)	119 (258)	---	140
½ Urea ½ ESN	21 (105)	59 (129)	59 (135)	140
ESN	21 (105)	---	119 (270)	140
Urea	21 (105)	98 (214)	---	120
½ Urea ½ ESN	21 (105)	49 (107)	49 (112)	120

Materials and Methods

Three tall fescue seed fields were identified and the ESN trials were set up in each field. Experimental design was a five treatment (Table 2) randomized complete block with three replications at each site. Current OSU recommendations for tall fescue range from 90-140 lb N/a depending on soil type and cropping history. The 120 lb N/a rate using the 50/50 mix with ESN has the same cost as using 140 lb N/a with straight urea. Plots were approximately 25 ft x 300 ft, and fertilized using precision application equipment. Fertilizer applications for all three sites were done March 16-17, 2007. Fall fertilizer (2006) was applied at the Linn County site (55 lb N/a) and at the Yamhill County site (40 lb N/a), there was no fall application at the Polk County site. Plots were swathed and combined by growers with the rest of the field. Seed yield was measured using a weigh wagon and sub-sample taken for cleanout and 1000 seed weight measurements.

Cleanout was determined by using an M2-B clipper cleaner, seed size was measured by taking 1000 seed weights from combine run samples. Analysis was done using Statistix® statistical software.

Results and discussion.

There were no differences in seed yield, cleanout, or seed size (Tables 3-5) at any of the three locations due to different N fertilizer rates/mixtures of fertilizer. Cleanout was higher at the two lowest yielding sites, but cleanouts were the same for all treatments at each location. The 120 lb N/a rate was high enough to provide maximum yields in this trial at all sites. It would be good to continue this research and try the ESN mixtures at lower N threshold totals to see if there would be a differential response at sub-optimal rates.

Table 3. Seed yield response to spring N and Urea/ESN mixtures in tall fescue. 2007.

Spring N	Smith Farms	Sitton Farms	Prairie Farms	Avg.
(lb N/a)	---------- (lb/a) ----------			
140 Urea	2148	749	646	1181
140 ½ Urea ½ ESN	2130	819	687	1212
140 ESN	2095	720	629	1148
120 Urea	2098	737	601	1145
120 ½ Urea ½ ESN	2203	728	585	1172
LSD 0.05	NS	NS	NS	----
P value	0.951	0.528	0.781	

Table 4. 1000 seed weight response to spring N and Urea/ESN mixtures in tall fescue. 2007.

Spring N	Smith Farms	Sitton Farms	Prairie Farms	Avg.
(lb N/a)	---------- (g) ----------			
140 Urea	2.50	2.44	2.67	2.54
140 ½ Urea ½ ESN	2.52	2.43	2.61	2.52
140 ESN	2.49	2.44	2.57	2.50
120 Urea	2.49	2.45	2.64	2.52
120 ½ Urea ½ ESN	2.48	2.41	2.64	2.51
LSD 0.05	NS	NS	NS	----
P value	0.622	0.852	0.659	

Table 5. Seed cleanout response to spring N and Urea/ESN mixtures in tall fescue. 2007.

Spring N	Smith Farms	Sitton Farms	Prairie Farms	Avg.
(lb N/a)	---------- (%) ----------			
140 Urea	7.2	14.7	16.4	12.8
140 ½ Urea ½ ESN	6.6	12.6	18.3	12.5
140 ESN	6.7	11.8	15.4	11.9
120 Urea	7.3	13.0	15.3	11.3
120 ½ Urea + ½ ESN	6.9	10.8	13.5	10.4
LSD 0.05	NS	NS	NS	----
P value	0.709	0.179	0.151	

Acknowledgement:
Special thanks to Western Farm Service for arranging growers and supplies and to the grower-cooperators for providing the sites and harvesting the plots.

LONG-TERM ANNUAL RYEGRASS FIELD TRIAL ESTABLISHED AT HYSLOP FARM

W.C.Young III, M.E. Mellbye and C.J. Garbacik

The establishment of long-term field experiments is not a new concept. In fact, the oldest continuously running agricultural experiment in the world was established in 1843 at the Rothamsted Research Station in Hertfordshire, UK. In the US, the oldest continuous agricultural research experiment was established in 1876 at the University of Illinois Urbana-Champaign campus. These trials, known as the Morrow Plots were actually designated a National Historical Landmark by the Federal Government in 1968.

In Oregon, the OSU Columbia Basin Agricultural Research Center, near Pendleton, is home to the oldest continuous cropping experiments in the Pacific Northwest. The Crop Residue Management Experiment was initiated in 1931, and has been monitoring the history of most cropping systems in use in the region ever since.

Thus, the idea that taking a longer view of crop rotations and management in understanding the affects agriculture may have on the earth is not new. Nor is the idea that evaluating the results from long-term studies may guide future agricultural development. The concept at the beginning of any long-term study is to provide a baseline for comparisons that will allow future scientists to identify changes that may result.

A "long-term" trial also has many benefits in the short-term. These, most noticeably, are the ability to measure yields and costs of production associated with various production systems. Thus, it is with these goals that a long-term annual ryegrass trial was established in 2005 at the Hyslop Crop Science Research Farm by the authors

Annual ryegrass is one of Oregon's leading seed crops and is grown on approximately 130,000 acres, mostly on the poorly drained soils of the southern Willamette Valley. Annual ryegrass has been grown continuously on many fields due to limited crop rotation options. Some fields have been in continuous production for over 40 years. Historically, much of the annual ryegrass acreage was open field burned, and a portion of that was no-till or "grassland drill" planted. Currently, due to the phase down in field burning that began in 1992, less than 20% is open field burned. Approximately 70% or more is conventionally tilled and planted each year. The remainder is established in the fall using no-till or volunteer methods of production.

The cost of conventional tillage, seedbed preparation, and planting is significant and increasing with rising fuel, labor, and machinery costs. Current estimates (OSU Extension annual ryegrass enterprise budget EM 8635. Nov. 2007) show the costs of conventional tillage in annual ryegrass seed production is $89 per acre, which does not include planting or seed costs. In addition to the costs of production, tillage in late summer and early fall when conditions are dry and calm creates visible dust. While it has not been documented that dust from tillage in Willamette Valley grass seed fields contributes to poor air quality, there is growing concern about the issue of agricultural dust and air quality in the Western United States.

In continuous annual ryegrass seed production, there are several approaches to reducing tillage costs, including no-till and volunteer methods of establishment, and production systems that alternate between tillage and no-till methods. In 2005, we established a long-term trial to evaluate the economics of these types of reduced tillage systems and to measure their effect on soil properties. One of the goals of the trial was to provide a site for cooperating OSU and USDA-ARS scientists and students to study changes in soil physical properties, soil carbon sequestration, and pest shifts over time. The trial is designed to run for 9 years and serve as both a research and Extension demonstration trial.

Methods

The long-term annual ryegrass trial was established in 2005 at Hyslop Research Farm using the cultivar Gulf. The field selected had already been in Gulf annual ryegrass for 2 years. Six treatments were established and replicated 3 times in a Randomized Block Design with individual plots 25' x 125'. The soil type is Woodburn silt loam with a pH of 5.4 and soil test P, K, Ca, and Mg well above levels considered adequate for seed production. The trial is designed to compare continuous or yearly conventional tillage methods of seed production with continuous no-till and with systems that alternate tillage with no-till or volunteer methods. The resulting treatments include tillage every year, every second year, or once out of 3 years:

1. Continuous conventional tillage and planting system (plow/disk and seed every year)

2. Continuous no-till (flail chop full straw, sprout spray, and plant every year)

3. Spray and no-till/conventional tillage rotation (alternate year tillage)

4. Volunteer/conventional rotation (alternate year tillage)

5. Burn and no-till/conventional tillage (alternate year tillage)

6. Volunteer/no-till/conventional rotation (tillage every 3rd year)

All treatments leave straw in the field, where it was flail chopped after harvest (except for the open field burn treatment). Tillage was accomplished using a plow and/or disk, followed by harrowing to prepare a conventional seedbed. A Great Plains no-till drill was used to plant both conventional and no-till treatments. Seeding rate in the trial was 17 lb/acre. In the volunteer treatments, the crop is grown from seed left on the soil from the previous harvest. During the volunteer year the plots were split and half were row-sprayed with glyphosate (strip spraying with herbicide to establish rows using 40 oz/acre Roundup, 10 inch row spacing with a 5-7 inch spray band) in November. Seed yield was obtained from both treatments. Fertilizer rates (120 – 130 lb N/acre), herbicide use, and pest control (slugs and voles) were conducted according to OSU recommendations and industry standards using only labeled products and rates of application. Plots were swathed in late June using a modified JD 2280 swather and combined in mid-July with a Hege 180 plot combine.

Results

The seed yield obtained during the first two years of this long-term study ranged from 1475 to 2036 lb/acre. To date, the highest yielding treatment over two years of production was the alternate year tillage system that started with volunteer + row spray (2006) followed by conventional tillage in year two (2007). In addition, the cost of this alternate year treatment was $43/acre less/year than a typical continuous tillage system using costs reported in the current OSU Enterprise for annual ryegrass (EM 8635, Nov. 2007), the break-even price of production is lower, and hence the profitability over these first two years of production was greater than the other treatments. However, this is a very preliminary observation and we offer it to illustrate the type of agronomic evaluation we hope to refine in the coming years.

During the 2006 production year, volunteer treatments were included in the study and an increase in seed yield of 417 lb/acre was measured from row spraying. The increase in seed yield from row spraying is well-documented, and in this trial we consider the volunteer + row spray treatment to be the volunteer "system of choice" for the trial (grazing, another effective volunteer management strategy, was not used in this study).

Overall, the seed yield averaged across treatments was 1740 lb/acre, somewhat below the industry average of 1883 lb/acre in 2006 and 1853 lb/acre in 2007, and below the yield potential of this site (over 2500 lb/acre Gulf annual ryegrass in 2004). It is not clear what limited yields in 2006 and 2007, but the weather pattern and excessive stand density may have been factors.

Future progress reports will include an evaluation of changes in soil physical properties, soil carbon dynamics, and pest problems associated with the different tillage systems. Additional years of seed production will also aid in developing an economic evaluation of reduced tillage systems for annual ryegrass seed production.

Reference

Eleveld, Bart, Mark Mellbye, Bill Young, Emily Lahmann and Cody Younger. 2007. Enterprise Budget: Annual Ryegrass Seed, Conventional Till, South Willamette Valley Region. Oregon State University Extension Service. EM 8635 (preliminary), December 2007.

THREE-YEAR GIS OF WESTERN OREGON GRASS SEED CROPPING PRACTICES

G.W. Mueller-Warrant, G.W. Whittaker, S.M. Griffith, G.M. Banowetz, T.S. Garcia, G.R. Giannico and B.C. McComb

High quality georeferenced data on crop production practices and other land uses is critical but often lacking in undertakings, such as the USDA Conservation Effects Assessment Program (CEAP), that seek to measure the effectiveness of conservation practices in achieving their goals and the general impact of human activities on ecosystem services. Ecosystem services include factors ranging from food production to water purification, from capture of carbon dioxide to release of oxygen, and from reproduction of salmon to provision of habitat for birds, amphibians and other wildlife. Research on the effects of humankind on the environment must ultimately provide problem-solving answers to be effective. If studies such as CEAP are to succeed, they must provide policy makers and the general public with detailed pictures of the trade-offs between economic and environmental objectives, including the functioning of multiple ecosystem services. A multi-year CEAP project involving collaboration between USDA-ARS-NFSPRC and OSU's Dept. of Fisheries and Wildlife was designed to identify and characterize the tradeoffs among ecosystem services inherently present in current agricultural production systems in the Willamette Valley. The broad objective of this research is to identify sets of production practices that optimize the achievement of economic and environmental sustainability for producers while meeting societal expectations for food and fiber supplies and natural resource quality.

The relationships between diverse sets of land use across the landscape and ecosystem services are not well understood. While urban and rural land use in the Willamette Valley is quite varied, and each has input into ecosystem services, this study focused on agricultural production practices. In order to determine whether relationships exist between crop management practices (e.g., tillage, nitrogen fertilization, or reestablishment of forested riparian zones) and ecosystem services (e.g., grass seed production, reproduction of native birds, fish, or amphibians) the following activities are required: (1) identifying the scale over which most interaction might occur, (2) identifying pre-existing variation in management practices, and (3) quantifying the functioning of ecosystem services and management practices at similar scales. Given the documented differences in soil erosion rates between stands of established perennial grasses and conventionally tilled fields, the strongest signal we are likely to detect is one between turbidity of water in streams and prevalence of tillage across the watershed upstream from sampling points. A computer model designed by USDA-ARS scientists in Temple, Texas, the Soil-Water-Assessment Tool (SWAT), models the impact of soil disturbance and rainfall on soil erosion and water quality, but requires Geographic Information System (GIS) input of field locations and management practices across the watershed. Where high quality data are available, SWAT has proven to be an excellent approach to determine whether relationships between management practices and water quality exist and to model these relationships across the range of scales that will almost certainly include variation in occurrence, abundance, and diversity of wildlife.

To enable the application of SWAT to our research problem, we established a three-year GIS of western Oregon grass seed cropping practices for use by the CEAP project using information from two sources. First, fall and spring drive-by censuses were conducted from 2004 through the present of most grass seed fields in the Calapooia River watershed. Spring drive-by surveys of randomly selected fields from stratified samples of agricultural fields also were conducted in neighboring counties. Second, fields from the Calapooia census and the multi-county survey were used to train the classification of series of commercially available Landsat satellite images taken during each growing season. Remote sensing classification allows the GIS to expand from the fields actually visited in the drive-by census and survey to nearly the entire Willamette Valley. In order to conduct remote sensing classification, it is necessary to convert the relatively detailed information collected about each field into a simpler set of 16 to 20 categories describing combinations of crop type, stand establishment status, and other selected aspects of crop production management. The 20 categories listed in Table 2 represent approximately 97% of all agricultural fields visited each year in the Calapooia census, and in most of the remaining cases we were unable to determine enough about particular grass seed fields to assign them to a particular category.

The most striking trend present in the GIS was a reduction in the number of perennial ryegrass fields with a corresponding increase in tall fescue. The total number of tall fescue fields in the Calapooia River watershed increased from 551 in the the 2004-2005 growing season to 709 in the 2006-2007 growing season, while perennial ryegrass dropped from 464 to 356 fields over the same period (Table 1). Similar, although slightly less dramatic, trends were present in the 20-category classification data when restricted to fields categorized in all three years (Table 2). A related trend was the increase in number of spring plantings of grass seed crops from 46 fields in the first year to 122 fields in the third year, mostly tall fescue (Table 2). Use of full straw chop volunteer stand reseeding in annual ryegrass also increased over the three year period in absolute numbers of all fields (Table 1) and in the proportion of fields with unchanged boundaries classified in all three years (Table 2). Even with the increase in full straw chop volunteer stand reseeding of annual ryegrass, this production approach appears to be only used on approximately 20% of all annual ryegrass fields. Quantifying the adoption of volunteer stand

reseeding of annual ryegrass is complicated by the difficulty in differentiating between it and conventional tillage methods, especially in fields visited several months after germination has occurred. We failed to distinguish between the two methods in 20% of all annual ryegrass fields in the 2004-2005 growing season (Table 2). Increasing familiarity with the appearance of fields managed using volunteer stand reseeding reduced the number of instances in which we were unable to distinguish between the two methods to 5% by the third year. Both clover and meadowfoam increased over time, with the biggest increase in meadowfoam occurring between the first and second year. The biggest increase in clover occurred between the second and third year. Wheat decreased between the first and second year, and then increased between the second and third year. Further increases in wheat have been noted in the current 2007-2008 growing season census.

Remote sensing classification was conducted using six Landsat images in the 2004-2005 growing season, five images in the next growing season, and six images in the most recent growing season for all 20 categories in Table 2 and for the 16 most consistently useful ones (omitting categories 11, 12, 13, and 14). Category number 11 (Other annual ryegrass) included a mix of fields that were really category 2 or 15. Category number 12 (Perennial ryegrass – other fall plant) only occurred in significant numbers the first year, and was poorly identified in Landsat images even then. Category number 13 (Noncrop) represented a mix of landuses ranging from temporarily abandoned fields to early stages of urban development, and was poorly identified in Landsat images. Category number 14 (Hybrid poplar trees) was well indentified in Landsat images, but nearly all the fields were harvested in 2005, eliminating the point of retaining this class. Overall classification accuracy for the 16 categories was 76.7 and 72.7% in 2004-2005 and 2005-2006. Categories classified at better than these average accuracies included established perennial ryegrass, established orchardgrass, established tall fescue, established mint (2004-2005 only), bare/disturbed ground – annual ryegrass, and meadowfoam (2005-2006 only). Remote sensing classification for the 2006-2007 growing season is underway but not yet complete. Accuracy appears likely to be similar to that in the previous two years. Comparison of remote sensing classification and OSU Extension Service grass seed acreage estimates by county revealed close agreement for total grass seed acreage, with remote sensing overestimating total multi-county grass seed acreage by 13 and 11% in 2004-2005 and 2005-2006. For multi-county totals by crop type, agreement between the two methods was closest for orchardgrass and tall fescue in 2004-2005 and for perennial ryegrass in 2005-2006.

The Calapooia River watershed GIS was used to measure the proportion of bare soil within sub-basins in order to identify drainages with contrasting amounts of soil disturbance to insure that water quality and wildlife biology data were collected over the widest possible range of conditions. Analysis of relationships between soil disturbance (or other crop management or conservation practices) and ecosystem service indicators will be simplest for drainages that are independent (i.e., sub-basins within which seasonal stream networks originate and out of which they flow at single 'pour-points'). More complex, nested drainages can also be analyzed using SWAT to model water flow into and out of drainages. Pooling established perennial grasses, full straw volunteer annual ryegrass, and no-till planting as conservation techniques, sub-basins in which water quality and wildlife biology data are being collected ranged from lows of 18, 19, and 22% conservation practice on agricultural land in 2006-2007 to highs of 86, 88, and 99% conservation practice. The biggest single factor in these conservation practice calculations was whether established perennial grass seed stands were taken out of production and replanted to new crops in any particular year. Because of this, sub-basins with high or low percentage of conservation practices in 2006-2007 were not necessarily those with highest or lowest percentage in previous years. Indeed, the three sub-basins with lowest conservation practice percentage in 2006-2007 had 66, 24, and 35% conservation practice averaged over the two previous years, while the three sub-basins with highest conservation practice percentage in 2006-2007 had 63, 97, and 40% conservation practice averaged over the two previous years. Year-to-year changes in tillage practices within sub-basins may represent another factor influencing diversity, abundance, and reproductive success of wildlife, and will require multiple years of data to understand. It is too soon in the collection and analysis of data to draw any conclusions on relationships between crop management and conservation practices and wildlife biology, except to note that variation exists across the landscape in abundance and diversity of fish, amphibians, and birds, and large fractions of that variation are associated with previously know drivers, including distance to perennial water for fish and percentage tree cover for birds. The establishment of this GIS will enable the further use of SWAT to determine whether other relationships exist and to provide sets of options to help producers manage these relationships economically.

Table 1. Number of fields by crop type, residue management practice, and stand establishment status in the Calapooia River watershed GIS for 2004-2005, 2005-2006, and 2006-2007 growing seasons.

GIS database domains	Growing season 2004-2005†	2005-2006	2006-2007
	(number of fields)		
Crop type			
Annual ryegrass	1348	1483	1437
Perennial ryegrass	463	428	356
Orchardgrass	126	119	125
Tall fescue	551	604	709
Mixed grass pasture	205	404	434
All others	450	521	642
Residue management‡			
Full straw load chop	458	392	505
Residue removed	575	878	695
Bare (worked or herbicide kill)	1072	1359	1365
All others‡	984	930	1138
Establishment status§			
Previously established	1190	1481	1478
Volunteer stand reseeding	171	457	476
Conventional drill (fall)	251	1071	967
Fallow	164	160	136
All others§	1350	393	646

† Census in 2004-2005 growing season did not include many pastures on lower slopes of hills bordering the valley floor and many small fields adjacent to housing developments that were included in the following years.

‡ Other post-harvest residue management practices included haycrop harvest, pasture grazing, undisturbed residue, and unknown or unidentifiable practices.

§ Other establishment status conditions included carbon band planting in fall, no-till planting method in fall, fall plant method not known, spring planting, urban development, and questionable.

Table 2. Number of fields in each of 20 classification categories in the Calapooia River watershed GIS for 2004-2005, 2005-2006, and 2006-2007 growing seasons.

No.	Category description	Growing season 2004-2005	2005-2006	2006-2007
		-------- (number of fields in GIS in all years†) ----------		
1	Bare/disturbed ground – other crops (not 15-18)	144	135	161
2	Full straw load chop annual ryegrass	162	189	233
3	Spring plant of new grass seed crop	46	50	122
4	Established perennial ryegrass	272	303	203
5	Established orchardgrass	117	106	98
6	Established tall fescue	456	468	497
7	Mixed-grass pasture	176	208	222
8	Established clover	32	43	71
9	Established mint	15	7	6
10	Hay crop	19	29	18
11	Other annual ryegrass (not 2 or 15)	261	86	64
12	Perennial ryegrass – other fall plant (not 16)	33	1	8
13	Noncrop	18	27	34
14	Poplar trees	8	1	2
15	Bare/disturbed ground – annual ryegrass	899	1049	944
16	Bare/disturbed ground – new perennial ryegrass	122	75	83
17	Bare/disturbed ground – new tall fescue	34	38	19
18	Bare/disturbed ground – new clover	26	53	41
19	All wheat	80	21	47
20	All meadowfoam	9	40	56
	Total of 20 classes	2929	2929	2929

† Fields not classified into one of these 20 categories in each of the three years have been removed from the table in order to facilitate consistent year-to-year comparisons.

IMPACT OF SEED-FEEDING THRIPS PEST IN GRASS SEED PRODUCTION FIELDS IN THE WILLAMETTE VALLEY

S. Rao and K.M. Ackerman

Introduction

The new seed feeding thrips pest, *Chirothrips manicatus*, was first detected in florets of bentgrass in seed production fields in the Willamette Valley during a survey conducted in 2004 (Rao and Alderman, 2005). Florets infested with the thrips had no trace of a caryopsis, and hence the presence of one thrips represented the loss of one bentgrass seed. While *C. manicatus* had been reported earlier from Oregon from flowers of various plants (Post, 1947), this was the first report of its developing in florets of a cultivated crop.

In New Zealand, *C. manicatus* is a pest in orchardgrass (Doull, 1956a; Morrison, 1961), and has been reported to cause over 30% damage to the seeds (Doull, 1956b). A survey conducted in Oregon in 2005 indicated low levels of infestation of orchardgrass in seed producing fields in the Willamette Valley. In addition, annual ryegrass, perennial ryegrass, and fine fescue were also found to be infested with *C. manicatus* in 2005. We also detected the presence of a second thrips species, *Limothrips cerealium*, within florets of these grasses. No thrips was detected in any of the three tall fescue fields that were included in the study.

The current study was conducted to determine changes, if any, in infestation levels, and to estimate the impact of the thrips on seed yield in grasses that are raised for seed production in the Willamette Valley.

Materials and Methods

Field Survey: In 2006 we surveyed seed production fields of orchardgrass, bentgrass, tall fescue, fine fescue, annual ryegrass, and perennial ryegrass in the Willamette Valley. Three fields of each crop were surveyed. For each crop, approximately 50 inflorescences (panicles or spikes) from each field were collected at random locations.

Seed Loss: From the 50 inflorescences that were collected, a random sample of 3,000 florets were further selected. The lemma and palea of each individual floret were separated, and the floret examined under a stereo microscope using dark field illumination with transmitted light to detect the presence of thrips. The number of thrips detected in 3,000 florets per field was used to estimate percent seed loss as the presence of one thrips resulted in the loss of one seed. Overall 54,000 florets were examined for determining the impact of the thrips in grass seed production fields in the Willamette Valley.

Results and Discussion

Thrips were detected in all six grass seed crops that we surveyed (Figure 1). Overall, thrips were detected in 17 out of the 18 fields (94.4%). Only one field of orchardgrass was observed without any thrips in the 3,000 florets that were examined. The estimated seed loss across the six grasses that were evaluated ranged from 0.23% to 4.42% (Figure 1).

We observed immature and adult stages of the thrips in grass florets. No eggs were detected in any grass seed crop probably due to their small size. The majority of thrips observed in orchardgrass, annual ryegrass, perennial ryegrass, tall fescue and fine fescue were in the larval and pupae stages. These were not visible from the outside of the floret. Occasionally adults were also detected (Figure 2). The location of thrips within the floret was dependent on the size and growth stage of the seed. If the seed was mature, the thrips were found at the apex of the floret with the head either towards the seed tip or floret tip. In early stages of development of the seed, the thrips were found near the base of the floret by the ovule or where the edges of the lemma and palea are folded over with the head facing toward the base of the floret. In all infected florets, there was evidence of feeding on the developing embryos.

The majority of thrips found in bentgrass were adult females. These could be observed as a dark shadow from the outside using a magnifying lens. When adult thrips were observed, the entire embryo was consumed.

This is the first report of the presence of the thrips in tall fescue. In our earlier study (Rao and McKinnis, 2006), while tall fescue fields were surveyed, no thrips were detected in the 1,000 florets that were examined. It is not known if the thrips remained undetected in the earlier survey due to a low level of infestation or whether tall fescue were infested by the pest for the first time in 2005.

The impact of the thrips varied with the grass seed crop. The highest level of infestation was observed in perennial ryegrass. Out of 9,000 florets examined, 4.42% were observed to be infected (Figure 1). The second highest infestation was observed in bentgrass fields followed by fine fescue. The seed crop with the lowest infestation was orchardgrass. Only two of the three fields surveyed were infested, and the mean seed loss was 0.23%. In the survey conducted earlier (Rao and McKinnis, 2006), infestation in all crops except bentgrass was lower than what was observed in 2006.

Detection of the thrips, especially the immature stages, is labor intensive and time consuming, as each floret needs to be examined under a microscope. Nonetheless, surveys are required in future years to determine if the trend in increase in infestation persists. Future studies are also required to determine the

life cycle of the pest for identification of periods when pest management tactics, if required, need to be applied for maximum reduction of the pest.

References

Doull, K. M. 1956a. Thrips infesting cocksfoot (*Dactylis glomerata*) in New Zealand. I. The thrips fauna of a cocksfoot seed crop. NZ J. Sci. Tech. (A). 38: 52-55.

Doull, K. M. 1956b. Thrips infesting cocksfoot in New Zealand. II. The biology and economic importance of the cocksfoot thrips *Chirothrips manicatus* Haliday. NZ J. Sci. Tech. (A). 38: 56-65.

Morrison, L. 1961. Thrips infestation of cocksfoot seed crops. NZ. J. Agric. Res. 4: 246-252.

Post, R.L. 1947. The Thysanopters of Oregon, Ph.D Thesis. Oregon Sate University.

Rao, S., and Alderman, S. 2005 Infestation of bent grass by a new seed pest, *Chirothrips manicatus* (Thysanoptera: Thripidae), in Oregon. *Journal of the Entomological Society of British Columbia* 102: 77-78.

Rao, S., and McKinnis, A. 2006. Two seed-feeding thrips pest species detected in grass seed production fields in the Willamette Valley. *In* Young, W. C., Ed., Seed Production Research, Oregon State University Publication 125: 36-38.

.

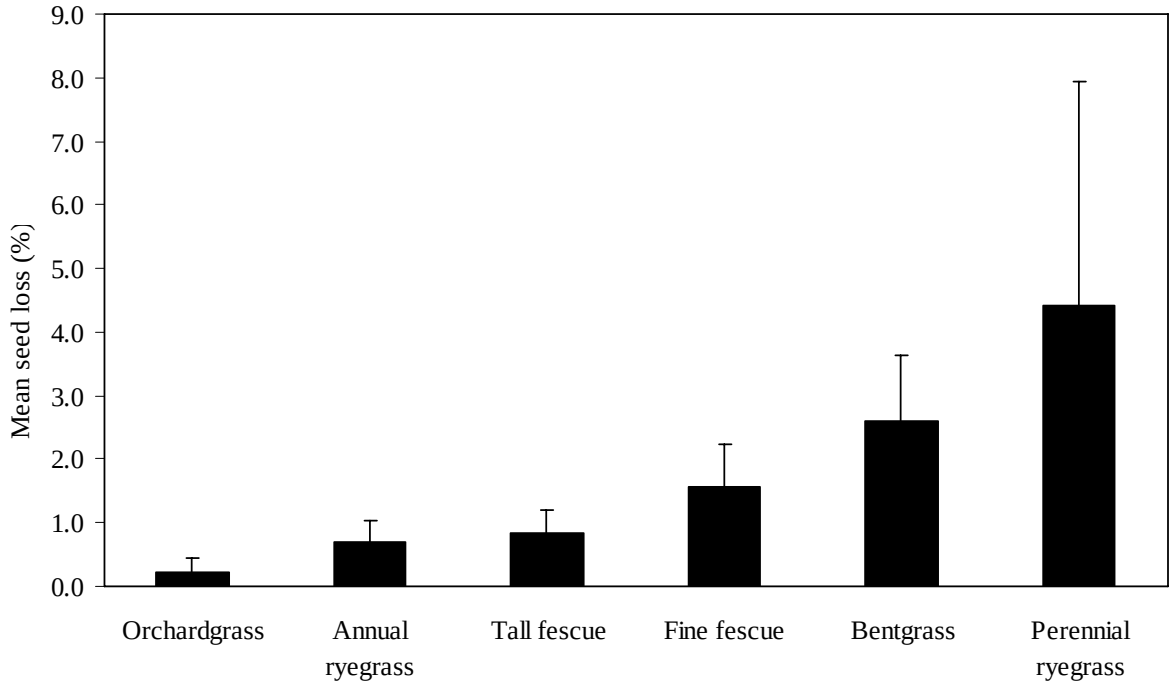


Figure 1. Impact of seed feeding thrips on grasses grown for seed in the Willamette Valley. Three fields were surveyed for each grass seed crop. A total of 9,000 florets were examined for each grass seed crop.

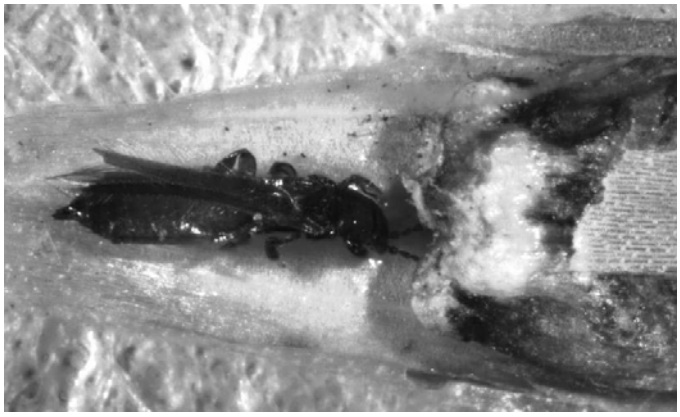


Figure 2. Adult thrips feeding on a developing ovule inside a perennial ryegrass floret.

SOD WEBWORMS IN WESTERN OREGON GRASS SEED FIELDS

G.C. Fisher and A.J. Dreves

Introduction

Three species of webworms have been recorded from grass seed fields based upon observations by former USDA entomologist, J.A. Kamm. However, two species have not been associated with the extensive economic damage caused in grass seed fields. Thus, when they are present it is important to identify them and understand their life stages. The sod webworm (also known as the cranberry girdler), *Chrysoteuchia topiaria* Zeller, is by far the most common and damaging species in western OR.

Identification. Sod webworms are cream to grayish colored larvae with brown heads. Full grown larvae are about ¾ inch long. Larvae are often associated with silk and frass in crowns of grasses. The larvae in this family (Pyralidae) have 5 pairs of prolegs. The hooks or crochets on the apical ends of prolegs form a complete circle. Another pest, the glassy cutworm, *Apamea devastator* Brace, may also occur in crowns of grasses. To separate the two pest species, examine the crochets on larvae. Those of cutworms form half circles as opposed to the sod webworm's full circle.

The young larvae of the two species can also be differentiated on behavioral traits. Webworms are hyper active, twist and "back pedal" vigorously when held in the hand. Cutworms tend to curl into a C-shape or move slowly away in a forward and linear movement. Glassy cutworms are a dull, translucent gray color with chestnut brown heads. Full grown larvae of cutworms can exceed 2 inches in length by spring time. Sod webworms and cutworms are found together only in early fall. Any larvae found in grasses during the winter (after November 15) are likely to be cutworms. This is because the sod webworm larvae complete feeding in late October and November, and then spin cocoons (hibernacula) in which to overwinter.

Life History. The sod webworm has one generation per year. First adults may be seen as early as late May, but usually begin emergence in the field first week in June, and fly between early June through early July depending on weather. The female moths deposit eggs among crowns of grasses the end of May, June and July. Eggs hatch within a couple of weeks, and the larvae feed on roots and crown tissue of grasses beginning from late June through early July. Damage occurs from mid-July through mid-October. However, by late September, some larvae mature, cease feeding and spin cocoons in which to overwinter. By approximately mid-October, about 80% larvae have spun cocoons. By November 1, less than 10% of the remaining larvae will not have spun cocoons and die over the winter. The following spring the larvae pupate within the cocoons. Moths emerge and mate within hours. In western OR, this moth tends to have peak flight around late June. Other webworm species have larval stages that may resume feeding (causing, at times, serious injury in April and May) in the spring before pupation. Additional damage and an opportunity for control with insecticides can occur in the spring with these species. It is important to note that in late September and October bird activity (e.g., starlings, black birds and killdeer) in grass seed fields can indicate an infestation of sod webworm (in addition to slugs, crane flies, wireworms and march flies).

Damage. Sod webworm larvae injure, weaken and kill crowns of established grasses. Damage is usually first noticed by failure of fall regrowth. Infestations are cyclical and often occur in concert with cutworms and billbugs.

Methods

Field Test. Two insecticides (Lorsban, an organophosphate and Baythroid® XL, a pyrethroid) were applied in mid-October to an established tall fescue field near Halsey, OR for control of sod webworm. Many crowns at the field site were without green regrowth. The trial consisted of a randomized complete block design with three replications and a plot size of 6 ft. x 20 ft. A CO^2 pressurized backpack sprayer (30 psi and 100 GPA with 8004 nozzles and 50 mesh screen) was used to apply insecticides. Treatments were applied on October 16, 2007 between 8:00 to 9:30 AM. Application was followed immediately by approximately 1.5 inches of rain over a 2 day period at the trial site. The population of larvae in this field consisted of mature and full grown larvae, prepupae and prepupae within hibernacula (silk cocoons) in which the larvae overwinter.

A pre-treatment count (1 day prior to treatment) of sod webworm populations took place on October 15 and post-evaluations at 3 and 10 days after treatment on October 19 and October 26, respectively. Five, 6-inch cores of grass crown with approximately 50% green regrowth at a depth of 4 inches were removed from each plot at the post-evaluation dates. Each core was dissected for live, dead and moribund larvae and pre-pupae. The pre-treatment evaluation consisted of 6 cores randomly sampled within the trial site.

Methods

It was noted that dead crowns with less than 5 green shoots had no live larvae present and were punctuated with signs of bird predation. All larvae and prepupae present in dissected cores were counted before and after treatments as reported in Table 1. The 3 DAT sod webworm samples were collected and brought back to a room temperature lab and reviewed for mortality after 3 days (Table 1).

Results

Numbers of sod webworms declined greatly in all plots including the untreated control plots. A large flock of starlings was consistently roosting in trees within 300 yards of the trial. These birds were probably responsible for the precipitous decline in larval numbers in both the treated plots as well as untreated.

Bird predation has been noted to reduce populations by 80% according to a previous USDA researcher, Dr. James Kamm. Had the infestation been diagnosed earlier, there is a possibility that rains experienced in late September 2007 might have been sufficient to work insecticides into the crown for effective larval control. Applying insecticide in mid-October after most of the larvae have matured and ceased feeding is probably too late for any economic benefit.

Mortality and sickness most likely from insecticide poisoning were not noticed in the experimental field plots until 10 DAT. When larvae were brought back to the lab from 3 DAT collections, additional mortality occurred; some from unknown causes. No parasites emerged from the bodies of the larvae held in the lab. This lack of immediate mortality in the field could be attributed to: 1) cold soil temperatures, 2) larvae going into pre-pupal diapause and therefore not actively feeding, or 3) possibly it took a longer period of time for the insecticide that is not adsorbed to straw/soil to reach and kill larvae.

The lack of timely rainfall is a continuing problem for effective pest control in the production of grass seed crops without irrigation in western OR. For insecticides to be effective in controlling soil pests such as sod webworm, irrigation or sufficient rainfall is necessary to move insecticide into the crown and soil where pests occur before they cause economic damage. Control of larvae is best when they are small, before plant damage. This timing occurs from mid-August to early September.

Table 1. Mean number of sod webworm (SWW) larvae/pre-pupae per tall fescue crown at 0, 3 and 10 days after treatment. Additional percent reduction reported from 3 DAT larval/pre-pupae collection brought to lab.

Treatment	0 DAT pre- *10/15/07*	3 DAT *10/19/07*	10 DAT *10/26/07*	3 day lab *observation*[2]
	---------- (Mean number of SWW larvae per crown[1]) ----------			(% SWW reduction[3])
UTC	8.00 ± 0.54	1.06 ± 0.07	0.66 ± 0.18	11
Baythroid XL (4 oz/a)		1.60 ± 0.64	0.13 ± 0.08	30
Lorsban 4E (2 qt/a)		1.87 ± 0.33	0.27 ± 0.07	22

[1] No differences in numbers of larvae were seen between treatments.

[2] Larvae and pre-pupae were transported back from 3 DAT evaluation and observed for 3 days.

[3] Pathogens and physical injury resulted in additional mortality of larvae in the untreated control. Additional mortality in treatments probably due to insecticides. No parasites emerged from SWW.

THE EFFECT OF FUNGICIDE APPLICATIONS ON SEED YIELD IN PERENNIAL RYEGRASS, AND EVALUATION OF THE RUST MODEL DECISION AID

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

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. Perennial ryegrass and tall fescue are particularly susceptible to rust infections. Under severe rust pressure seed yields can be reduced over 70% when rust is not controlled. Oregon grass seed growers spend approximately $15 to $20 million annually for rust control programs, making stem rust the most costly disease problem in Pacific Northwest grass seed production. Severity of rust, and therefore the need for fungicide applications, can differ among fields and from year to year. In order to develop Best Management Practices, a model of stem rust is being developed by researchers at USDA-ARS as a tool to help decide if and when sprays are needed.

This is the fifth year of on-farm fungicide trials conducted to evaluate the effect of various fungicide applications and treatment timings on the seed yield of perennial ryegrass. Our specific objectives were to (1) compare the effectiveness of different fungicide products, (2) determine the effect of an early strobilurin fungicide treatment on rust control and seed yield and (3) continue evaluating the operation of the stem rust model as a decision aid for fungicide applications.

Methods

Results in this report were obtained from large scale, on-farm yield trials conducted on turf type perennial ryegrass fields. Field trials were conducted at two locations: (1) a fall planted first year field in Marion County near Silverton (var. VNS perennial ryegrass, dryland), and (2) a spring planted first year field in Linn County near Shedd (var. VNS perennial ryegrass, dryland). Fungicides used were:

Propiconazole (Tilt 428 GS)
Azoxystrobin (Amistar, Quadris)
Pyraclostrobin (Headline)
Azoxystrobin/Propiconazole (Quilt)
Strobilurin/De-Methylation Inhibitor (DMI) fungicide mix (Absolute)

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. Spray adjuvant (COC or MSO) 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 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. Among the experimental treatments at each location was one in which spray decisions were made based on the rust model outputs, derived by operating the publicly-available stem rust estimator webpage (http://pnwpest.org/cgi-bin/stemrust1.pl). Automated weather stations located at each site were among the 15 stations throughout the Willamette Valley that provided weather data for running the model on the website.

Results

During the 2007 crop year, rust infections were low to moderate on most perennial ryegrass fields. The fall and winter weather pattern resulted in a low level of rust going into the spring, and rust infections were late developing in most fields. The Marion County location had very little rust pressure throughout the season in 2007 and fungicide applications did not result in higher seed yields. In contrast, the spring planted field in Linn County developed severe rust pressure by mid-June and seed yield was reduced by 28 to 38% without disease control (Table 2). The average increase in seed yield from fungicides treatments at the Linn County site was 645 lb/acre. While less than that observed in 2005 and 2006, the increase in seed yield (over $400/acre) was still economically significant and more than justified fungicide treatment costs ($33 to $47/acre depending on treatment) .

The first objective of this trial was to compare fungicide products, including products approaching registration such as Absolute. All fungicide treatments in 2007 provided acceptable rust control when compared to the untreated check. Two of the products tested (Quilt and Absolute) are tank-mixtures of a strobilurin and a DMI (Tilt-type) fungicide. Both products provided rust control and seed yield comparable to Headline and Quadris treatment sequences. The strobilurin plus DMI tank-mix products have provided good control in our Extension fungicide trials and offer a tool for resistance management; however, it is critical to use these product mixtures at an adequate rate to achieve acceptable rust control.

The second objective of the trial was to evaluate the effect of early strobilurin fungicide treatments on rust control and seed yield. The strobilurin product Headline was used as the “early” treatment, and was applied in early May prior to the appearance of rust. Application was at the normal timing for plant growth regulator application (2-node stage/early flag leaf emergence). There was no increase in seed yield or rust control as a result of this early treatment in 2007. In previous years, under severe rust pressure, there has been a trend toward higher levels of rust control as a result of the early treatment. Over five years of field testing, early fungicide treatments

resulted in an increase in seed yield in three of eleven field tests. The results of this study suggest a benefit to early fungicide applications only under severe and early rust pressure.

The third objective was evaluation of the stem rust model (year four of this comparison). At the Linn County site the rust model called for two fungicide applications, the same number that was used in the standard application schedule for this field. The model suggested a slightly different timing of fungicide applications, a few days to a week earlier than the standard treatments. Seed yield in the rust model treatment was not significantly different from the yield in highest-yielding treatment (the Quadris sequence). The fungicides used in the rust model treatment were two applications of Quilt. It is interesting to note that the other treatment that used two applications of Quilt (treatment 2), but with a different application timing from the rust model treatment, produced a yield that was significantly less than the highest-yielding treatment. This result suggests that the rust model improved the efficacy of the fungicide program through better timing of applications than the standard program. At the Marion County site the rust model called for no fungicide application to be made, whereas the standard treatment had one fungicide application. There was no significant difference in the seed yield among treatments at this site. That is, the rust model treatment produced similar yields as the other fungicide programs, but with one less fungicide application. Overall for the 2007 trials, treating according to the rust model produced the same yield as the highest-yielding treatment, with the same or fewer fungicide treatments as used in standard practice.

A well timed fungicide program remains a good investment for perennial ryegrass seed producers in western Oregon, and currently labeled fungicide products do an effective job of providing control. The USDA-ARS rust model has begun to show its usefulness in helping farmers reduce fungicide spray costs and improve spray application timing. Importantly, over four years of testing, use of the rust model has not resulted in reduced seed yields when compared to standard spray programs.

Appreciation

Appreciation is extended to BASF, Bayer CropProtection and Syngenta 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 assist with the seed harvest.

Table 1. Treatment table: fungicide application rates and timings, 2007.

Treatments	Application dates and rates (product/acre)		
Linn County site	5/11/07 2-3 node	5/28/07 early heading	6/15/08 peak anthiesis
Early fungicide/Quilt sequence	Headline (6 oz.)	Quilt (20 oz.)	Quilt (20 oz.)
Quilt sequence	-	Quilt (20 oz.)	Quilt (20 oz.)
Absolute sequence	-	Absolute (7.5 oz).	Absolute (7.5 oz).
Quadris sequence	-	Quadris (9 oz.)	Quadris (9 oz.)
Headline sequence	-	Headline (9 oz.)	Headline (9 oz.)
Rust model (Quilt 2x at 20 oz.)	-	Quilt on 5/25	Quilt on 6/8
Marion County site	5/25/07 2-node	6/14/07	
Early fungicide/Quilt sequence	Headline (6 oz.)	Quilt (20 oz.)	
Quilt sequence	-	Quilt (20 oz.)	
Absolute sequence	-	Absolute (7.5 oz).	
Quadris sequence	-	Quadris (9 oz.)	
Headline sequence	-	Headline (9 oz.)	
Rust model	-	-	

Table 2. The effect of fungicide treatments on stem rust severity and seed yield of perennial ryegrass on two Willamette Valley fields, 2007.

Treatments	Rust on 7/11/07	Seed yield	Additional seed[2]	Cleanout
	(%)	(lb/a)	(lb/a)	(%)
		Linn County site (var. VNS)		
Untreated check[1]	72	1362	0	4
Early fungicide/Quilt sequence (3x)	1	1903	541	4
Quilt sequence (2x)	2	1888	526	4
Absolute sequence (2x)	3	1956	594	4
Quadris sequence (2x)	1	2201	839	4
Headline sequence (2x)	4	1984	622	4
Rust model treatment (Quilt 2x)	3	2145	783	4
Field treatment (3x fungicide applications)	4	1937	575	5
LSD (0.05)	6	275		NS
		Marion County site (var. VNS)		
	on 7/1/07			
Untreated check[1]	<1	1475	0	15
Early fungicide/Quilt sequence (2x)	<1	1201	0	20
Quilt sequence (1x)	<1	1218	0	17
Absolute sequence (1x)	<1	1469	0	18
Quadris sequence (1x)	<1	1405	0	16
Headline sequence (1x)	<1	1378	0	16
Rust model treatment (no fungicide)	1	1294	0	16
LSD (0.05)	---	NS		NS

[1] The check was harvested as one strip and not included in statistical analysis for seed yield.
[2]The additional seed yield above the untreated plots.

EFFECT OF WATER VOLUME WHEN APPLYING SYSTEMIC FUNGICIDES FOR ERGOT CONTROL IN SEEDLING PERENNIAL RYEGRASS VAR. *AMERICUS* IN THE SOUTHERN COLUMBIA BASIN

N.L. David and P.B. Hamm

Introduction

Ergot (*Claviceps purpurea*) is a fungal pathogen that infects the flowers of many wild and cultivated grass species including ryegrass *(Lolium spp.)*, bluegrass *(Poa spp.)*, and fescue *(Festuca spp.)*. Ergot is classified as inert material by the Oregon Seed Certification Service, and certified blue tag perennial ryegrass, Kentucky bluegrass, and tall fescue are allowed a maximum of 3, 5 and 2% inert material by weight, respectively. Seed lots with ergot above the allowable tolerance must be cleaned again decreasing the amount of saleable seed and increasing cleaning costs.

The fungus overwinters as sclerotia (hard, mycelial structures) and requires 4-8 weeks of temperatures near freezing for germination to occur. Sclerotia germinate in the spring and forcibly eject ascospores (primary source of inoculum) into the air. Successful infection of the grass plant only occurs if ascospores land on the stigma (the female portion of the flower that receives the pollen) of an unfertilized ovary or on an unfertilized ovary directly. Consequently, ascospores that land on any other part of the plant or on fertilized flowers will not result in ergot infection. Five to seven days after infection the fungus produces conidia (secondary source of inoculum) which exude from florets and are referred to as "honeydew" because of their sticky nature. Insects are attracted to the honeydew and aid in the dispersal of conidia from flower to flower. How much secondary spread occurs from insect movement is unknown. Finally, sclerotia begin to develop and mature around 2 and 5 weeks after infection where a viable seed would normally develop.

In order for chemicals to reduce ergot, they must protect the stigma or ovary from infection. Even though protectant and systemic fungicides can suppress ergot in grass seed, systemic fungicides have been shown to reduce ergot infection below the 3% tolerance by weight in perennial ryegrass (Hamm and David, unpublished), while protectants have not.

While growers who raise grass seed using over-head irrigation generally have the ability to chemigate (apply the chemical directly through the center-pivot irrigation system) pesticides, many apply fungicides by airplane or ground applicator. Fungicides applied by aerial means are usually delivered in 5 gallons per acre (gpa) of water, while ground applications are usually delivered in (15-20 gpa). At these volumes, complete coverage of the inflorescence (the portion of the plant that must be protected) with chemical may not occur, allowing ergot spores to successfully infect flowers. However, increasing the amount of water applied may provide more complete coverage of the inflorescence and reduce the number of ovaries infected by the fungus. Most center-pivots irrigation systems in the Columbia Basin can operate at speeds that will allow a chemical to be applied in as little as 0.15 – 0.25 acre-inch of water (3,900-6,500 gallons per acre). Recent studies (in 2006) at the Hermiston Agricultural Research and Extension Center suggest that increasing the amount of water systemic fungicides are delivered in from 20 to 200 gpa may increase ergot control in grasses grown for seed. However, evaluating the effect of chemigating fungicides in 0.15-0.25 acre-inch of water has never been investigated.

Objective

The purpose of this trial was to determine if applying three different systemic fungicides (azoxystrobin, propiconazole, and thiophanate-methyl) by chemigation in 0.15 or 0.30 in. water increases the efficacy of the chemical to control ergot compared to a low volume application (20 gpa).

Materials and Methods

Perennial ryegrass var. *Americus* was planted on August 25, 2006 in the NE quadrant of Pivot 3 at the Hermiston Agricultural Research and Extension Center near Hermiston, Oregon. Irrigations were made based upon local evapo-transpiration rates for grass seed. The trial was fertilized with 187 lb/a nitrogen, 54 lb/a phosphorus, 54 lb/a potassium, 54 lb/a sulfur, 14 lb/a magnesium, and 0.4 lb/a zinc by October 30, 2006. An additional 100 lb/a nitrogen and 124 lb/a sulfur was applied as ammonium sulfate on January 30, 2007. All plots were inoculated with 157 ergot sclerotia/ft^2 on November 8, 2006. The plant growth regulator Apogee® was applied at 7 oz/acre on April 26 and 30 as the flag leaf was emerging to shorten internode length and reduce lodging. Initial flowering occurred around June 1st in this experiment. Plots were swathed on July 2 and combined on July 13, 2007.

Three groups [Methyl Benzimidazole Carbamates (FRAC code 1), DeMethylation Inhibitors (FRAC code 3), and Quinone outside Inhibitors (FRAC code 11)] of site specific mode-of-action fungicides (Table 1) were applied in three different volumes of water (20 gpa, 0.15 acre-inch, and 0.30 acre-inch) along with an untreated control. Each were evaluated for ergot control. Treatments were assigned in a randomized complete block design with four replications within a two way factorial experiment in which the factors were fungicide and water volume. Individual plots were 4 ft wide x 25 ft long. Chemical applications were made on May 25 and June 8. Low-volume ground applications were made using a CO_2 back-pack sprayer that delivered 20 gallons per acre per acre of water using XR-8002 teejet nozzles at 30 psi. Chemigation applications were made using a sidemount

boom pulled by a tractor at a speed of 0.24 feet/second that delivered 0.15 acre-inch of water per pass at 15 psi.

Table 1. FRAC code, common name, and product name of single-site, mode-of-action fungicides that were evaluated.

FRAC	Common name	Product
1	Thiophanate-methyl	Topsin M
3	Propiconazole	Tilt
11	Azoxystrobin	Quadris

Plots were combined with a Hege 140 plot combine. Immediately following combining, percent ergot contamination was determined by hand separating ergot sclerotia from a 25-g subsample of field-run seed. Seed yield was then determined after cleaning with a Clipper Eclipse 324 seed cleaner utilizing a 10 round scalper screen, a 1/18 slot top split flow screen, and a 6/40 mesh bottom split flow screen. Analysis of variance was performed using PROC GLM in SAS v.9.1 and when significant means were separated using Duncan's test.

Results

Statistical analysis: Analysis of variance revealed there was no interaction between fungicide and water volume on ergot levels or seed yield. This indicates that the effect of the different fungicides and water volumes on seed yield and ergot infection was not dependent upon the other variable. For example, the effect of Topsin M on ergot infection was the same at all water volumes tested. As a result, the main effects of fungicide (Table 2) and application method (Table 3) on seed yield and ergot levels are reported.

Table 2. Effect of fungicides on seed yield and percent ergot in seedling perennial ryegrass var. *Americus*

Treatment	Product	Clear seed yield	Ergot infection[1]
	(rate/a)	(lb/a)	(%)
Control		1,433	6.6 a[2]
Topsin M	24 oz	1,538	6.9 a
Tilt	8 oz	1,511	3.8 b
Quadris	12 oz	1,506	3.2 b
P- value		NS[3]	≤.0001

[1]Percent ergot contamination by weight
[2]Numbers within a column followed by different letters are significantly different at the P- value indicated according to Duncan's multiple range test.
[3]NS = not significantly different

Effect of fungicide on seed yield and ergot levels: Untreated plots yielded 1,433 lb/a of cleaned seed during 2007 (Table 2). Applying Topsin M, Tilt, and Quadris increased seed yield by 7, 5 and 5%, respectively, but these increases were not significant due to the variability in the experiment. Ergot levels in untreated plots averaged 6.6% during the 2007 growing season, well above the 3% allowable tolerance. Two applications of Topsin M did not reduce ergot levels (6.9%) compared to the untreated control. However, two applications of Tilt (3.8%) or Quadris (3.2%) significantly reduced ergot levels by 48 and 52%, respectively, compared to the untreated control.

Effect of fungicide application method on seed yield and ergot levels: When left untreated, perennial ryegrass var. *Americus* yielded 1,433 lb/a (Table 3) of cleaned seed. Applying fungicides in 20 gpa (1,503 lb/a), 0.15 acre-inch (1,551 lb/a), or 0.30 acre-inch (1,506 lb/a) of water increased seed yield by 5, 8 and 5%, respectively, but was not significant due to experimental variability. However, applying fungicides in 20 gpa water (4.1% ergot), 0.15 acre-inch (4.1% ergot), or 0.30 acre-inch (5.3% ergot) significantly reduced ergot levels by 38, 38 and 20%, respectively, compared to the untreated control.

Table 3. Effect of amount of water used to deliver fungicides on seed yield and percent ergot in seedling perennial ryegrass var. *Americus*

Treatment	Clean seed yield	Ergot infection[1]
	(lb/a)	(%)
Control	1,433	6.6 a[2]
20 gpa	1,503	4.1 b
0.15 acre-inch	1,551	4.1 b
0.30 acre-inch	1,500	5.3 b
P- value	NS[3]	≤ 0.06

[1]Percent ergot contamination by weight
[2]Numbers within a column followed by different letters are significantly different at the P value indicated according to Duncan's multiple range test.
[3]NS = not significantly different

Summary

Propiconazole and azoxystrobin was effective in reducing ergot in grass seed, but thiophanate methyl was not. All three increased seed yield over the untreated control, but this increase was not significant. Ergot suppression was equal between fungicide treatments and significantly less than the untreated control when applying these chemicals in 20 gpa water or chemigating them in either 0.15 or 0.30 acre-inch of water. Although two applications of propiconazole or azoxystrobin beginning one week prior to flowering on a bi-

weekly schedule suppressed ergot, the reduction was not reduced below the 3% allowable tolerance. As a result additional or more frequent applications may be necessary.

CONTROLLING ERGOT WITH FOLIAR APPLIED FUNGICIDES IN SEEDLING PERENNIAL RYEGRASS VAR. *AMERICUS* GROWN FOR SEED IN THE SOUTHERN COLUMBIA BASIN

P.B. Hamm, N.L. David, and D. A. Horneck

Introduction

Ergot (*Claviceps purpurea*) is a fungal pathogen that infects the flowers of many wild and cultivated grass species including ryegrass *(Lolium spp.)*, bluegrass *(Poa spp.)*, and fescue *(Festuca spp.)*. Ergot is classified as inert material by the Oregon Seed Certification Service, and certified blue tag perennial ryegrass, Kentucky Bluegrass, and tall fescue are allowed a maximum of 3, 5 and 2% inert material by weight, respectively. Seed lots with ergot above the allowable tolerance must be cleaned again decreasing the amount of saleable seed and increasing cleaning costs.

The fungus overwinters as sclerotia (hard, mycelial structures) and requires 4-8 weeks of temperatures near freezing for germination to occur. Sclerotia germinate in the spring and forcibly eject ascospores (primary source of inoculum) into the air. Successful infection of the grass plant only occurs if ascospores land on the stigma (the female portion of the flower that receives the pollen) of an unfertilized ovary or on an unfertilized ovary directly. Consequently, ascospores that land on any other part of the plant or on fertilized flowers will not result in ergot infection. Five to seven days after infection the fungus produces conidia (secondary source of inoculum) which exude from florets and are referred to as "honeydew" because of their sticky nature. Insects are attracted to the honeydew and aid in the dispersal of conidia from flower to flower. How much secondary spread occurs from insect movement is unknown. Finally, sclerotia begin to develop and mature around 2 and 5 weeks after infection where a viable seed would normally develop.

Objective

This study was initiated in the fall of 2006 on seedling perennial ryegrass to determine if systemic and protectant fungicides would reduce ergot contamination below 3%.

Materials and Methods

Perennial ryegrass var. *Americus* was planted on August 25, 2006 in the NE quadrant of Pivot 3 at the Hermiston Agricultural Research and Extension Center near Hermiston, Oregon. Irrigations were made based upon local evapo-transpiration rates for grass seed. The trial was fertilized with 187 lb/a nitrogen, 54 lb/a phosphorus, 54 lb/a potassium, 54 lb/a sulfur, 14 lb/a magnesium, and 0.4 lb/a zinc by October 30, 2006. An additional 100 lb/a nitrogen and 124 lb/a sulfur was applied as ammonium sulfate on January 30, 2007. All plots were inoculated with 157 ergot sclerotia/ft^2 on November 8, 2006. The plant growth regulator Apogee® was applied at 7 oz/a on April 26 and 30 as the flag leaf was emerging to shorten internode length and reduce lodging. Initial flowering occurred around June 1st in this experiment. Plots were swathed on July 4 and combined on July 16, 2007.

Two groups (DeMethylation Inhibitors and Quinone outside Inhibitors) of site specific mode-of-action fungicides (Table 1 and 2), two multi-site mode-of-action fungicides (Table 3), one minor nutrient, and fulvic acid (Table 4) were tested in this trial. Treatments were assigned in a randomized complete block design with four replications. Individual plots were 5 ft wide x 30 ft long. Chemical applications were made on May 18, 23, 28, June 2 and 7. All foliar fungicide applications were mixed with 1% crop oil and applied in 16 gallons per acre of water using XR-8002 teejet nozzles at 30 psi.

Table 1. Common name, product name, and manufacturer of single site mode of action DMI (DeMethylation Inhibitors) fungicides used.

Common name	Product	Manufacturer
Propiconazole	Tilt	Syngenta
Flusilazole	Punch	DuPont

Table 2. Common name, product name, and manufacturer of single site mode of action QoI (Quinone outside Inhibitors) fungicides used.

Common name	Product	Manufacturer
Azoxystrobin	Quadris	Syngenta
Pyraclostrobin	Headline	BASF

Table 3. Common name, product name, and manufacturer of multi-site mode of action fungicides used.

Common name	Product	Manufacturer
Chlorothalonil	Bravo WS	Syngenta
Mancozeb	Dithane F-45	Dow Agro

Table 4. Common name, product name, and manufacturer of minor nutrients and fulvic acid used.

Common name	Product	Manufacturer
Boron	Cobo	Helena
Fulvic Acid	Fulvic 6000	Horizon

Plots were combined with a Hege 140 plot combine. Immediately following combining, percent ergot infection was determined by hand separating ergot sclerotia from a 25-g subsample of field-run seed. Seed yield was then determined after cleaning with a Clipper Eclipse 324 seed cleaner utilizing a 10 round scalper screen, a 1/18 slot top split flow screen, and a 6/40 mesh bottom split flow screen. Analysis of variance was performed using PROC GLM in SAS v.9.1 and when significant means were separated using Duncan's test.

Results

Disease pressure was high during the 2007 growing season with 11% ergot infection by weight in the untreated plots, well above the allowable tolerance of 3% (Table 5). Boron, Dithane, and Bravo reduced ergot contamination by 32, 42 and 64%, respectively, compared to the control. Additionally, Bravo performed better than boron or Dithane. Although applying the micronutrient boron and the protectant fungicides Dithane and Bravo reduced ergot, the reduction was not below the 3% tolerance. However, all the systemic fungicides tested reduced ergot contamination below 3% limit set by seed certification standards. The QoI fungicides, Quadris and Headline, significantly reduced ergot by 94% each, while the DMI fungicides, Punch and Tilt, reduced it by 96 and 85%, respectively. There was no difference in protection provided by the QoI or DMI fungicides. Additionally, there was no benefit to combining QoI and DMI fungicides (Quilt) or in adding Bravo or Fulvic Acid to the DMI fungicides.

Untreated plots yielded 1,514 lb/a of cleaned seed during 2007. While there appeared to be a trend of increased seed yield with fungicide use, the differences were not significant due to high variability in the experiment.

Summary

The information reported here indicates that five foliar applications of a protectant or systemic fungicide, as well as boron every five days beginning 14 days prior to flowering can reduce ergot infection. However, only the systemic fungicides reduced ergot infection to commercially acceptable levels. Furthermore, the DMI and QoI fungicides worked equally well by themselves and there was no additional benefit to mixing the two chemistries together or adding a protectant or fulvic acid. Future work to determine the proper application frequency of DMI and QoI fungicides for ergot control is warranted. Because of the high fungicide use in this experiment, additional research is needed to determine any effect on seed germination following repeated use during flowering.

Table 5. Effect of fungicide on seed yield and percent ergot in seedling perennial ryegrass var. Americus

Treatment	Product	Clean seed yield	Ergot infection[1]
	(rate/a)	(lb/a)	(%)
Control		1,514	11.0 a[2]
Boron	0.5 lb	1,533	7.5 b
Dithane F-45	1.6qt	1,621	6.3 b
Bravo WS	1.5 pt	1,642	4.0 c
Tilt	8 oz	1,904	1.6 d
Punch	8 oz	1,650	0.4 d
Quadris	12 oz	1,621	0.7 d
Headline	12 oz	1,854	0.7 d
Punch +	8 oz		
Bravo	1.5 pt	1,875	0.4 d
Tilt +	8 oz		
Bravo WS	1.5 pt	1,725	0.9 d
Tilt +	8 oz		
Fulvic Acid	1 qt	1,813	1.3 d
Quilt	14 oz	1,554	1.3 d
P-value		NS[3]	≤ 0.001

[1]Percent ergot contamination by weight

[2]Numbers within a column followed by different letters are significantly different at the P value indicated according to Duncan's multiple range test.

[3] NS = not significantly different

ARTHROPODS COMMONLY FOUND IN GRASS SEED FIELDS IN EASTERN OREGON

S.I. Rondon

Introduction

Grass seed crops are grown on nearly 500,000 acres in Oregon with a farm gate value of over $480 million dollars. Approximately 92% of grass seed is produced in the Willamette valley. Changes in production practices and the cancellation of key pesticides have significantly increased losses from insects, mites and slugs. Cultural, biological and other non-chemical measures are important, but they must be supplemented annually with an appropriate pesticide.

Since grass seed production represents an important rotational crop for the Columbia Basin area of eastern Oregon, a survey of arthropods in grass seed fields was carried out in 2006 and 2007 using pitfall traps, sweep net and sod samples. To our knowledge, there are no records of arthropods surveys in eastern Oregon. Results indicated the presence of springtails, mites, spiders, flies, and various families of beetles in the area.

Materials and Methods

Six commercial Kentucky bluegrass fields were included in the 2006 and 2007 survey. Fields were split in replicated plots. Pitfall traps, sweep net and sod samples were taken in each section of each field. Six pitfall traps replicated four times were placed at each location to collect insects that were moving in the field. Ten sweeps replicated four times were taken in each field. Six sod samples 1 ft in diameter by 4 inches deep replicated four times were collected at each location. In both

Table 1. List of arthropods collected with pitfall traps in Kentucky bluegrass in Hermiston OR, 2006 and 2007.

Order	Family	Genus	Common name	Role*
Acari	? **	?**	Mites	Uk
Arachnida	Lycosidae	Tarantula	Spiders	PB
	Linyphiidae	Frontinella	Spiders	PB
Collembola	Entomobryidae	Isotoma	Springtails	
	Entomobryidae	Sinella	Springtails	Uk
Orthoptera	Acrididae	Melanopus	Grasshoppers	P
Thysanopetera	Thripidae	Thrips	Thrips	P
Hemiptera	Cicadellidae	Dikraneura	Leafhoppers	Uk
	Cicadellidae	Ceratagallia	Leafhoppers	Uk
	Cicadelidae	Colladonus	Leafhoppers	Uk
	Cicadelidae	Macroteles	Leafhoppers	Uk
	Nabidae	Nabis	Damsel bug	PB
	Rophalidae	?**	Plant bug	Uk
Homoptera	Aphididae	Aphis	Aphids	P
Coleoptera	Silphidae	Nicrophorus	Carrion beetle	S
	Staphilinidae	Philanthrus	Rove beetle	PB/S
	Coccinellidae	Hippodamia	Lady beetle	PB
		Coccinella	Lady beetle	PB
	Carabidae	Harpalus	Ground beetle	PB
		Pterostichus	Ground beetle	PB
	Scarabaeidae	?**	Scarab beetle	Uk/P
	Tenebrionidae	?**	Darkling beetle	Uk/S
Diptera	Sciaridae	Corynoptera	Fungus gnats	Uk
		Sciaris	Fungus gnats	Uk
	Drosophilidae	Drosophila	Fruit flies	S
		Cacoxenus	Fruit flies	Uk
Hymenoptera	Formicidae	Formica	Ants	Uk
	Tenthrenidae	?**	Sawflies	Uk

* P= Pest; PB=Predator or Beneficial; Uk= Unknown; S=Saprophyte

** Not determined

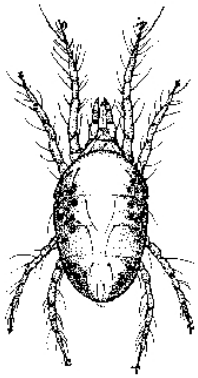
years, insects were collected from the traps weekly from March to June. In 2006, a handful of species were selected based on their high number and role in the grass ecosystem for investigation the following year. Preliminary research showed that millions of springtails can be present in the grass crop. Growers have indicated their concern regarding these high numbers and the potential effect springtails may have in transmitting diseases in their crops. It remains unanswered if the presence of springtails relates to disease incidence such as ergot or if springtails can cause secondary damage. Only pitfall trap data will be presented on this article.

Results and Discussion

A list of arthropods (Order, Family and Genus) collected in Kentucky bluegrass in eastern Oregon in 2006 and 2007 is presented in Table 1. Table 2 shows the average number of arthropods per Order per week. The most abundant groups were: springtails, mites, spiders, flies, and various families of beetles.

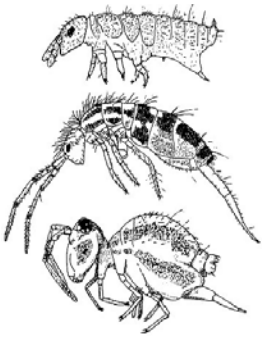
Table 2. Average number of individuals per Order per week collected with pitfall traps in Kentucky bluegrass in Hermiston OR, 2006 and 2007.

Order	Common name	Average number per week	
		2006	2007
Acari	Mites	60	163
Arachnida	Spiders	75	605
Collembola	Springtails	36748	13485
Orthoptera	Grasshoppers	16	4
Thysanopetera	Thrips	3	13
Hemiptera	True bugs	74	37
Homoptera	Leafhoppers	102	120
Coleoptera	Beetles	133	858
Diptera	Flies	224	229
Hymenoptera	Wasps	2	2



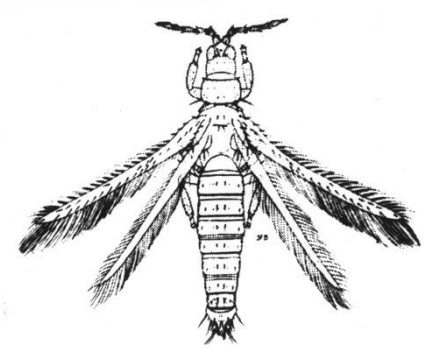
Mites. Actual size 1 mm. Mites can be recognized for the fused cephalothorax and large abdomen.

Spiders have eight legs and an un-segmented body.



Springtails. Small (1-2 mm long). They jumped due to their "tail".

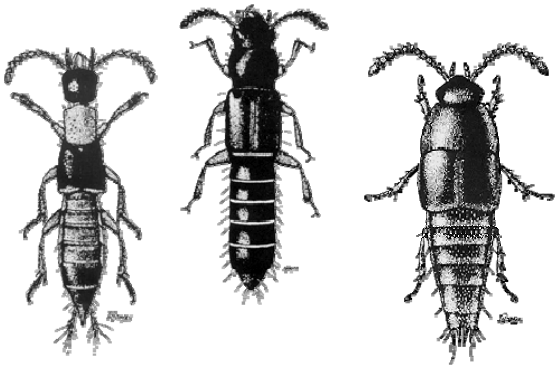
Grasshoppers. First and second pair of legs for walking; third pair of legs for jumping.



Thrips. Fringed wings. Less than 1mm in length. Slender shape.

True bugs

Leafhoppers (left) and aphids (right). Aphids can be ID due to the presence of cornicules at the tip of the abdomen.



Rove beetles. Medium size (4-8mm). Credit. M.C.Thomas, UF

Springtails (Order Collembola) are part of the community of decomposers that break down and recycle organic wastes. They are extremely abundant in certain habitats. In general, their relative abundance in the soil tends to increase as the mean annual temperature decreases; thus the reason why high numbers were observed in the winter months in our area. Population densities exceeding millions of individuals per acre have been found in some grassland communities; however, a few species feed on living plants and are occasionally regarded as pests. Springtails can be identified because they "hop" by snapping their furcula ('tail') against the substrate; they may propel themselves up to 20 cm in the air. Also, their wide variety of colors, including white, pink, yellow, green, orange, red, and blue can be distinctive. The two species identified in eastern Oregon were *Isotoma* and *Sinella*. Information regarding both species is limited. Due to their large numbers in the area, growers are concerned. Springtails have been observed "jumping" all over grass leaves. However, their role in the grass ecosystem is still unclear. Although it is unlikely they are causing damage to grass plants or are having a detrimental effect on yield, we speculate that they could potentially move disease spores; however this hypothesis needs further investigation.

Spiders (Order Arachnida) are well represented in the grass system with the two families Lycosidae and Linyphiidae being the most abundant. Both families are beneficial. It is rarely useful to apply pesticides to control or eliminate spider infestation. Even if infestations are extreme, only the local spider population will be affected and spiders from the surrounding areas will simply move in and take advantage of the "vacancies."

Six different families of beetles (Order Coleoptera) were found during our survey. One of the most predominant is the rove beetles (Family Staphilinidae), which occurs in a variety of habitats. Some species are considered beneficial since they feed on insect pests. Rove beetles have short wings, exposing 3 (usually) or 5-6 abdominal segments. Their bodies are long and sender body with short antenna.

Conclusions and Final Comments

The grass seed industry is facing an increasing loss from insects and mites throughout the state in response to no-till, direct seeding, and reduce field burning residue management. Additionally, new pest species such as slugs are adding to the challenges. This is further compounded by the lack of new products being registered for use in the grass seed industry.

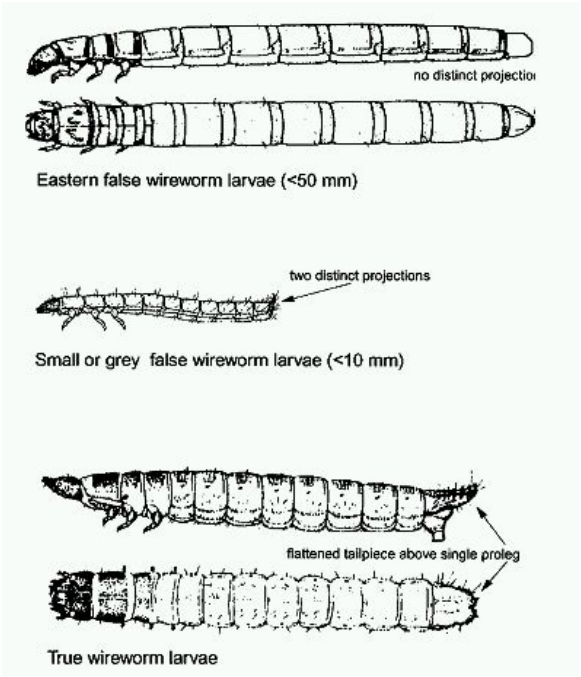
Some emerging concerns are:

Wireworms

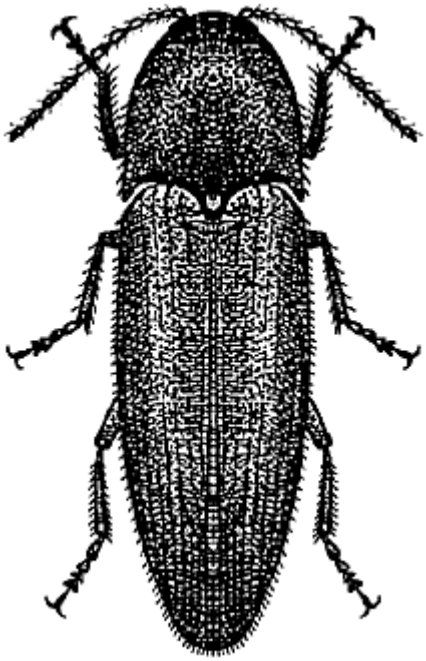
- Greatest numbers occur in no-till grasses and/or grass following cereals.
- Summer and fall plowing reduces wireworm damage about 20-40% by removing food and crushing or destroying susceptible stages (i.e., larvae).

How to ID wireworms:

- Wireworm larvae are hard, smooth and slender
- Worms varying from 1 to 2 inch in length when mature.
- Adult wireworms or "click beetles" are bullet-shaped, hard-shelled beetles that are brown to black in color.
- The common name "click beetle" is derived from the clicking sound that the insect makes when attempting to right itself after landing on its back.



Immature stage of the wireworm.
Credit: unknown



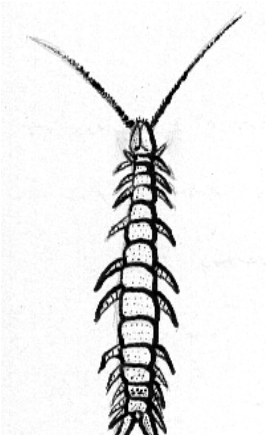
Adult form of the wireworm, known as click beetle. Credit. UF

Symphyla

- They normally consume decaying vegetation but can cause harm by feeding on seeds, root hairs, and roots in cultivated soil.
- Cultivation prior to planting can reduce numbers by 30%.
- Cultivation allows seed to germinate and roots to elongate and establish.

How to ID Symphyla:

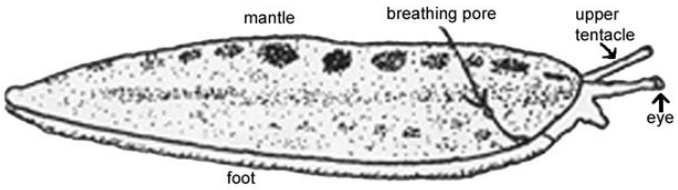
- Translucent and elongate.
- Juveniles have 6 pair of legs but over a lifetime of several years, they add an additional pair at each molt so the adults can have as much as twelve pairs of legs.

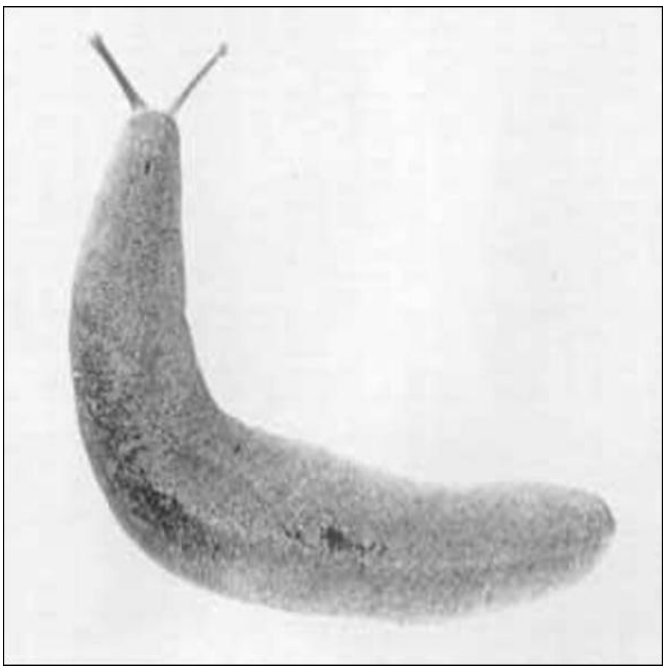


Symphyla adult. Credit UF.

Slugs

- Each slug has both female and male reproductive organs but usually they cross-fertilized
- Slugs become reproductively mature in about a year.
- They can live up to 30-36 months.
- Mature slugs lay 20-30 eggs at a time.
- Almost immediately after young hatch, they begin to move and feed.
- Bait station: use a 1 ft x 8 in area scraped to bare soil and place 3 pellets of metaldehyde slug bait (large pellets) in each. Set up baits in late afternoon.
- Biological control: blackbirds, ducks, ground beetles, and nematodes.





Slugs. Credit. DPA, UF. OSU pictures at http://oregonstate.edu/Dept/nurspest/Limaxmaximuscourtship.htm

COMPARISON OF RED CLOVER POLLINATION BY COMMERCIAL AND NATIVE BEES IN SEED PRODUCTION FIELDS IN THE WILLAMETTE VALLEY

S. Rao, W.P. Stephen and J.E. Bergh

Introduction

Red clover is an important forage crop that is raised for seed in the Willamette Valley. It is self incompatible, and hence a critical factor affecting seed production is pollination. Bees are the primary pollinators of red clover, and growers typically rent 1-2 honey bee hives per acre. However, due to diseases caused by the tracheal mite and the Varroa mite, and the recent colony collapse disorder, the availability of honey bees has decreased while the cost of renting hives has increased. In addition, honey bees are not considered to be the most effective pollinators of red clover. Native bees, especially bumble bees, are believed to be better pollinators of red clover compared with honey bees (Anderson and Wood, 1944). A study conducted in 2006 by Rao and Stephen (2007) indicated that 15 species of native bees were present during the period of bloom around clover fields in the Willamette Valley. The most common was the bumble bee species *Bombus vosnesenskii*. In Minnesota, where native bee species differ from those in the west, bumble bees are reported to be 2.5 times as efficient as honey bees in red clover (Peterson et al., 1960). Currently there is no information about the pollination services in red clover provided by native bees in the Willamette Valley.

One reason for the limited information on native bee pollinator impact on red clover seed production in Oregon is the lack of access to commercial nest / hives for the required studies. Bumble bees can be purchased in other states but their sale is prohibited in Oregon due to the risk of introduction of diseases, and because all commercial bumble bees are exotic to Oregon. Leaf cutter bees, *Megachile rotundata*, are available commercially in Oregon and have been evaluated for their efficacy in crops such as alfalfa seed. There is, however, no information on their impact on pollination of red clover in Oregon.

In 2007 we conducted two studies to determine pollinator impact on red clover seed production in the Willamette Valley. In the first study, the efficacies of commercial and native bees were compared in cages. Our goals were to: 1) determine overall seed yield in cages pollinated by three different bee species, and 2) estimate seed yield per seed head in cages pollinated by three different bee species. In the second study, we estimated the abundance of naturally occurring native bees in red clover fields during the bloom period.

Methods

Pollination efficacies of commercial and native bees. The study was conducted in a red clover seed production field in Polk County. High quality cages (6 ft x 6 ft x 12 ft) from BioQuip® (Rancho Dominguez, CA) constructed with 32 x 32 sized mesh amber Luminite screen which allows penetration of sunlight but prevents the entry of insects, were set up over red clover plants in early July 2007 (Figure 1). The cages were secured firmly to the ground using 3-in nails. Each cage had two zippers 3 ft apart that formed a door for entry. The experiment was set up as a randomized block design with 3 replications. The following treatments were evaluated:

1. Honey bees as 3-super nuclei (i.e., 3 frames with brood), commercially obtained.
2. Bumble bee, *Bombus vosnesenskii*, obtained by collection of nests from residential properties in Linn and Benton counties in western Oregon.
3. Leaf cutter bee, *Megachile rotundata*, obtained commercially from Manitoba.
4. Control - all bees were excluded from the cage.
5. Open pollinated - 6' x 12' plots that were not caged.

Honey bee nuclei and bumble bee nests was introduced into the appropriate cages in the second week in July. Pupae of leaf cutter bees were maintained in an incubator at 28 ° C until the emergence of adults which were then transferred to the cages in the third week in July. The cages were monitored regularly to ensure that bees from the outside did not enter the cages. Despite frequent monitoring, two bumble bees were observed flying in the control cages. Towards the end of July, when the number of active bees were observed to be low, additional bees were introduced to each of the treatment cages, if necessary.

Estimation of seed yield in cages. In early September, when majority of the flowers had dried, the cages were removed and red clover seed was harvested using a small Carter flail harvester (Carter MGF Co. Inc., Brookston, IN). Only the central 3 ft of each cage was harvested. The same area was harvested from the open pollinated plots. The harvested material was transported to the Hyslop Crop Science Farm, and sun dried for one week. After threshing using laboratory hand harvesting devices so as to maximize seed removal, the weight of seeds from material collected from each cage and the open pollinated plots were recorded. A 10 g sample from

each test plot was sent to the Seed Testing Laboratory at Oregon State University for analysis of purity.

Estimation of seed yield per seed head. We collected 50 seed heads randomly from the unharvested material remaining in each caged area and from the three open pollinated plots. A random subsample of 10 seed heads was further selected. Each seed head was meticulously crushed and run through a sieve for collection of the seeds. Each of the 10 seed heads were examined closely and the number of flowers per seed head, the number of normal seeds, and the number of malformed or undeveloped seeds were recorded.

Abundance of naturally occurring native bees. We made visual counts of native bees while walking through the fields. Native bee estimates were made on a weekly basis by counting the number of bees observed on flowers during a 2 minute period. Towards the end of July the counts of bumble bees were so high that the counts were limited to 1 minute (the 2 m counts were divided by 2 for consistency). Each count consisted of slowly walking a straight line for 1 minute, while counting all of the bumble bees (by species) observed actually visiting clover racemes. Only bumble bees were counted as they are conspicuous because of their size and black and yellow color patterns. The area covered during each walk was approximately 75 ft x 3.3 ft.

Results and Discussion

By mid August the flowers in each cage progressively turned brown in all treatment cages. While flowers in the cages with bees had turned brown, the flowers in the control cages remained fresh. However at the time of harvest in early September, flowers in all cages were brown and dry.

Seed samples from all treatments were observed to be > 99 % pure after laboratory harvesting. The average (of three replications) seed weights from the honey bee cages (207.4g) and bumble bee cages (214.2g) were similar (Table 1). This indicates that, under caged conditions, the performance of both species is similar. In leaf cutter bee cages, the seed weight was observed to be about one third lower (136.4 g). This is probably due to the late introduction of bees into the cage. In the control, the average seed yield was 27.2g. We observed several insects such as the cucumber beetle in the control cages which could have been responsible for the seed yield observed. The average weight of seeds (365.1g) in the open pollinated plots was considerably higher than all cages. We speculate that this is because of the cage effect. The presence of the cages is likely to have resulted in reduced plant growth and in fewer flowers and hence fewer seeds.

Table 1. Weight of harvested seed from treatment cages and open pollinated plots.

Treatment	Mean weight (g) of cleaned seed
Cage with honey bees	207.4 (10.5)[1]
Cage with bumble bees	214.2 (6.2)
Cage with leaf cuter bees	136.4 (20.3)
Cage with no bees	27.2 (13.1)
Open Pollinated	365.1 (5.6)

[1]Standard error of the mean in parentheses.

For an in-depth analysis of the extent of successful pollination in each treatment, the numbers of seeds in individual seed heads were recorded. Overall, 10,164 flowers were examined from 150 seed heads (5 treatments, 3 replications and 10 seed heads per treatment). The number of flowers per seed head ranged from 73 to 183. We observed one seed per flower which is normal. Red clover has two ovules per flower but typically only one seed is produced. In 7% of the flowers we observed two seeds / flower (representing 'perfect pollination'). We recorded the presence of a pest, the seed feeding chalid, *Bruchophagus gibbus*, in 1% of the seed heads. Infestation levels ranged from 0 to 14% per seed head. We also observed that 3% of the seed heads had undeveloped / malformed seeds.

A comparison across the treatments indicated that on average, 79.6% of flowers produced seeds in the honey bee cages, 88.6% in the bumble bee cages, 61.7% in the leaf cutter bee cages (Table 2). We examined 351 flowers from the 3 control plots and observed only 5 seeds (1.7% seeds). Interestingly, an average of 73.5% of flowers produced seeds in the open-pollinated cages. This was marginally lower than what was observed in the bumble bee and honey cages. Hence, even though the overall seed yield was higher in the open pollinated plots compared with the bumble bee and honey bee cages, at the seed head level, pollination levels were similar.

Table 2. Comparison of seed yield per seed head in treatment and open pollinated plots.

Treatment	Mean number of seed (%)
Cage with honey bees	79.6 (2.2)[1]
Cage with bumble bees	88.6 (0.8)
Cage with leaf cuter bees[2]	61.7 (5.7)
Cage with no bees	1.7 (1.6)
Open Pollinated[3]	87.0 (2.2)

[1]Standard error of the mean in parentheses.
[2]Leaf cutter bees were introduced two weeks later than honey bees and bumble bees.
[3]Though seed yield was double compared with bee treatments, there was no difference at the level of the individual seed heads.

The results indicate that honey bees can pollinate red clover flowers under caged conditions in the Willamette Valley. In the past there have been conflicting reports on the efficacy of honey bees as pollinating agents of red clover. While earlier studies had indicating that the tongue of honey bees are not long enough to reach the nectar located at the base of the long corolla tube, studies by Wilsie and Gilbert (1940), Starling et al. (1950) documented that the nectar rises high enough for honey bees to be able to reach it. Our results confirm that honey bees can pollinate red clover effectively under no-choice situations.

However, honey bees are still not the best pollinators of red clover due to their foraging behavior in the open. When unrestricted by the presence of the cage, honey bees appear to disperse to collect pollen from other sources. A comparison of pollen collected from honey bee hives by placement of pollen traps in hives in red clover fields documented that honey bees were foraging on other flowers besides red clover. Earlier studies by Bohart (1957) and Peterson et al. (1960) documented that honey bees perform satisfactorily in red clover if they are sufficiently concentrated in the area and competing pollen and nectar sources are kept at a minimum.

These results suggest that the native bumble bee in the Willamette Valley, *B. vosnesenskii*, is an effective pollinator of red clover. However the abundance of *B. vosnesenskii* and that of other bumble bees was low during peak bloom in the field (Figure 2). Bumble bee abundance increased considerably in August but by then bloom had reduced to 50%. Hence to increase pollination in red clover, the number of bumble bees needs to be enhanced in early July. As commercial bumble bees are not available for release, local populations need to be enhanced. One option with potential is the addition of a border of flowering plants that bloom just prior to red clover bloom. A second option is to bring a portion of the red clover into flower without cutting, to provide forage for bumble bee pollinators during June. Currently, red clover is typically cut for hay so as to time a bloom onset in early July. The impact of retaining a border of uncut flowers needs to be evaluated in future studies.

References

Anderson, E.J. and Wood, M. 1944. Honey bee and red clover pollination American Bee Journal 84: 156-157.

Bohart, G.E. 1957. Pollination of alfalfa and red clover. Annual Review of Entomology. 2: 355-380.

Peterson, A.G., Furgala, B. and Holdaway, F.G. 1960. Pollination of red clover in Minnesota. Journal of Economic Entomology 53 (4): 546-550.

Rao, S. and Stephen, W.P. 2007. Native bee pollinators in clover seed production. *In* Young, W.C., Ed., Seed Production Research, Oregon State University Publication 126: 44-46.

Starling, T.M., Wilsie, C.P. and Gilbert, N.W. 1950. Corolla tube lengths studies in red clover. Agronomy Journal. 42: 1-8.

Wilsie, C.P. and Gilbert, N.W. 1940. Preliminary results on seed setting in red clover strains. Journal of the American Society of Agronomy. 32: 231-234.

Acknowledgments

We thank Steve Hamilton for permitting us to conduct the study in his red clover field. We also thank George Hoffman, Kathyrn Ackerman, Kimberly Skyrm and Daryl Ehrensing for assistance with harvest and seed cleaning.

Figure 1. Cages placed over red clover for comparison of pollination efficiencies of honey bees, bumble bees and leaf cutter bees.

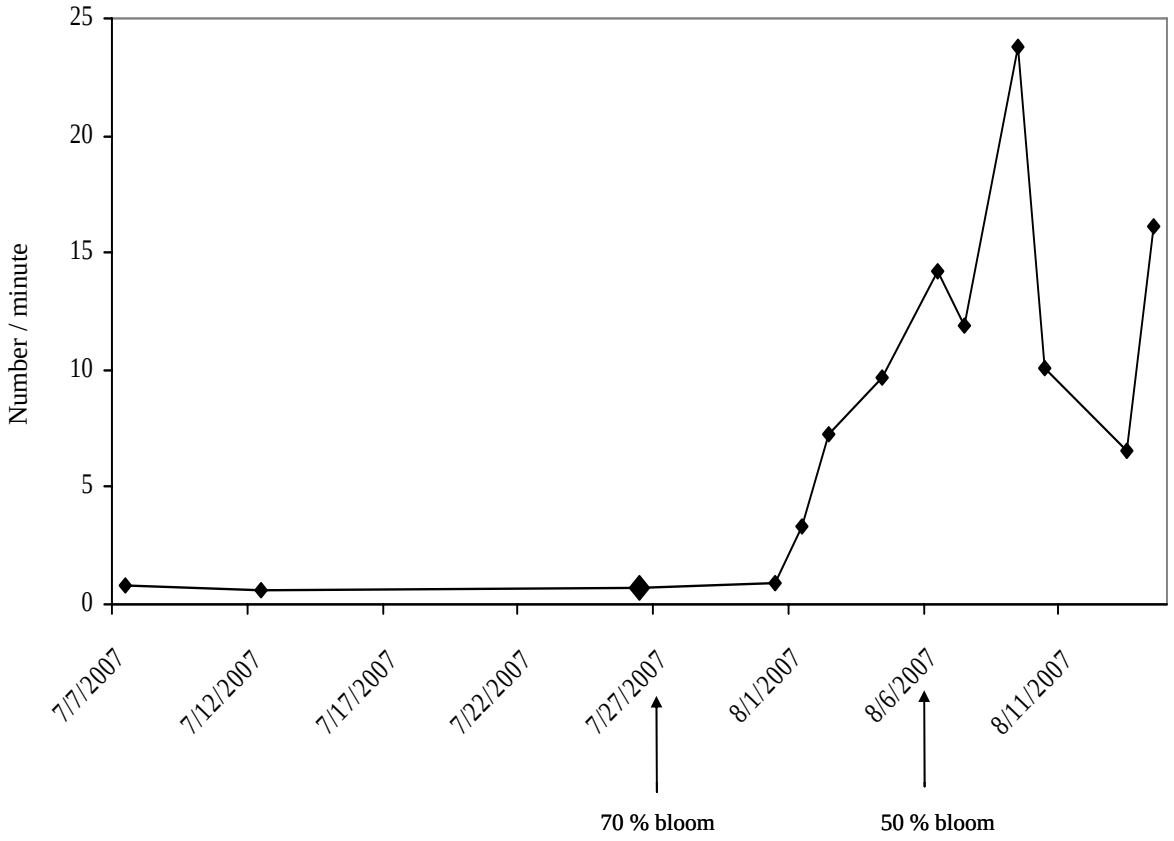


Figure 2. Abundance of bumble bees in a red clover seed production field in Polk County estimated through 2 minute counts of visual observations.

PROGRESS IN DEVELOPING A DNA SEQUENCE-BASED TEST FOR RAPID DIFFERENTIATION OF RYEGRASS GROWTH TYPES

R.E. Barker and L.D. Cooper

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 of 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 volunteer 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 positive 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 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. Results of the GOT 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 for 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.

The Test

We have developed a prototype test for implementation in commercial seed laboratories based on DNA sequence markers for two genes from ryegrass that are involved in the flowering or vernalization responses. We are currently integrating two of

these, *LpID1* and *LpVRN1* into a Multiplex-PCR test and we are continuing to develop additional markers to improve accuracy and decrease costs and time requirements of the test. We have designed a PCR test protocol that involves the following steps.

1. A seed sample (currently 400 seeds) is germinated and the seedling root fluorescence (SRF) assay is performed, which is normally run for 14 days, but can be shortened by transplanting seedlings as soon as fluorescence is expressed.

2. At the end of the SRF test (or at some point after the majority of the seeds have germinated), the individuals with fluorescing root traces are sampled for DNA extractions. The DNA extraction step is a routine laboratory procedure that can be performed in a number of ways depending upon the constraints of time, money and labor. Many commercial kits are available from various suppliers, which can save time and reduce labor costs, but kits cost more initially. Another factor to consider in choosing a DNA extraction method will be the number of samples that are being handled.

3. Once the DNA is extracted, quantified and quality checked, an allelic discrimination PCR (polymerase chain reaction machine) analysis is performed. This procedure involves taking a small amount of the extracted DNA sample, adding a DNA polymerase enzyme and a few other ingredients and running the reactions on a thermocycler or real-time PCR Machine that can separately detect the gene forms (alleles) of the markers we developed.

4. Data are analyzed using specialized software to generate reports showing the genetic status of each plant.

Marker Validation Panel

To validate the protocol, we ran the test on a panel of 20 ryegrass cultivars, which included nonfluorescent plants of each cultivar and a number of 'Gulf' plants as controls. This large panel of approximately 850+ individuals consisted of all the plants that showed Seedling Root Fluorescence (a variable number per cultivar) and also approximately 20 nonfluorescent plants per cultivar (Figure 1). After the SRF test, the plants were grown in continuous, high quality light for 12 weeks to evaluate the number of days required for reproductive tiller development (Figure 2).

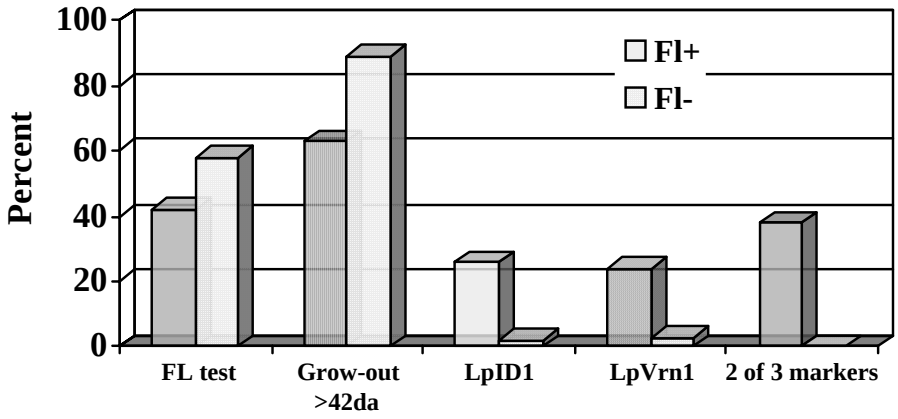


Figure 1. Individual marker characteristics of plants in the cultivar grow-out panel. The FL test bars represent the distribution of Fl+ and Fl-. Grow-out >42da is the percentage of plants not heading in 42da (6 wk), the end of a normal grow-out test. The other three sets of bars show the distribution of the molecular markers.

Counting Fl as a marker itself, the bars showing 2 of 3 markers is our target for a good test (Figure 1). Those plants with the annual type allele was less than for Fl alone, but confirmed by one of the two molecular markers. Using the same criteria of requiring two markers to confirm growth-type prediction, less than a half percent of the Fl- plants were confirmed as annual type.

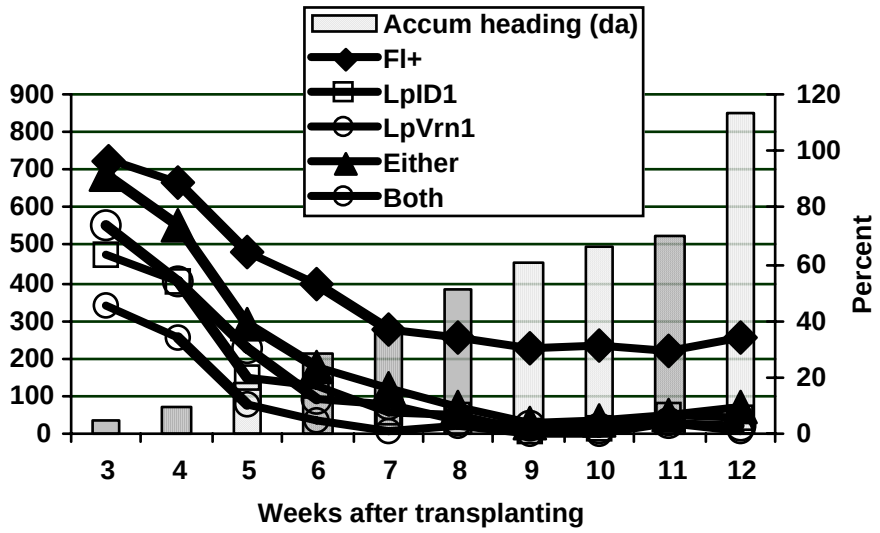


Figure 2. Accumulated heading (bars) of plants in the cultivar grow-out panel with Fl and the two molecular markers graphed as a percent of the group of plants that headed in that particular week segment.

Another way of looking at the data over the full 12wk grow-out period, heading continued to increase over time beyond 42da (6 wk) as shown in the bars of Figure 2. This points out why the grow-out test has had some difficulties; the regular test is just not conducted long enough in most cases. The graph of Fl+ containing plants (triangles) also demonstrates why SRF is a poor predictor of growth type. Fluorescence values level off at about 30% of the plants regardless of how long they take to flower. Either molecular marker (triangles) in Fl+ plants predicts growth type faster and better than a 10wk grow-out.

Molecular markers we found have the ability to detect the hybrids (of the alleles) as well as the two growth type extremes (Figure 3). Detecting hybrids is an important part of improving the ability to detect the contamination in high quality ryegrass seed production.

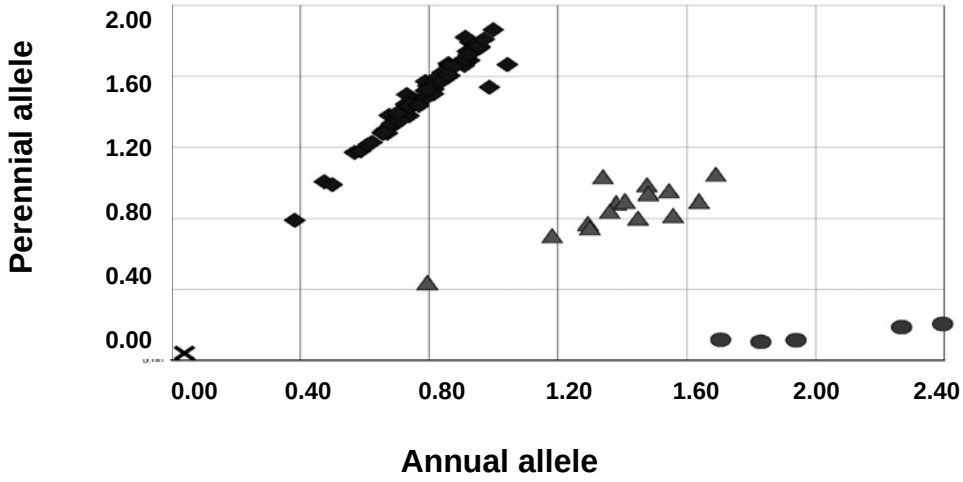


Figure 3. Ability of the LpID1 marker to predict plant growth types (allelic discrimination). Perennial alleles are diamonds, annual alleles are ovals and hybrids are triangles.

Steps to Implementation:

We have developed DNA sequence-based markers for two genes from ryegrass that are involved in the flowering or vernalization responses. We are currently integrating two of these, *LpID1* and *LpVrn1* into a Multiplex-PCR test and we are continuing to develop additional markers to improve accuracy and decrease costs and time requirements of the test. A decision support tool is being developed based upon these markers, initially as an excel spreadsheet or form and eventually as a web-based tool. This will be useful for the seed lab personnel to evaluate the samples as the PCR test is run.

In order for the Multiplexed DNA Sequence-Based Test to be used in a seed lab, it will have to be accepted as a rule by the Association of Official Seed Analysts (AOSA). The test protocol will be presented at the AOSA Annual Meeting, and then a Referee or Ring test will be developed to allow various seed testing labs an opportunity to evaluate our protocol.

References Cited:

Barker, R.E., S.K. Davidson, R.L. Cook, J.B. Burr, L.A. Brilman, M.J. McCarthy, A.E. Garay, and W.D. Brown. (2000). Hidden fluorescence in the seedling root fluorescence test of ryegrass. Seed Tech. 22:15-22.

EFFECT OF PRE-CHILLING TREATMENT ON THE GERMINATION AND FLUORESCENCE OF PERENNIAL RYEGRASS

S.G. Elias and A.E. Garay

Introduction

Perennial ryegrass (*Lolium perenne* L.), a cool-season grass, is widely used in northern regions for permanent turf and forage pastures and for overseeding of other grasses in the southern United States (Oregon Ryegrass Growers Seed Commission). Dormancy is a problem in freshly harvested seed of perennial ryegrass. It is a genetic characteristic that is influenced by environmental conditions such as temperature, moisture availability, and light quality (Weisner and Grabe, 1972; Dudeck and Peacock, 1986; Steadman, 2004). Priming treatment and after-ripening are used to overcome dormancy in ryegrass (Gallagher, et al., 2004). When testing for seed viability, dormancy in ryegrass is one of the obstacles that cause delay in delivering test results of standard germination and fluorescence tests to ryegrass growers.

To certify any ryegrass seed lot, a representative sample from that lot has to be tested and meet minimum quality standards for physical purity and viability (germination). In ryegrass, the results of the purity and fluorescence tests cannot be completed without finishing the standard germination test. The germination test results do not always reflect the actual viable seeds in a lot, especially in freshly harvested seeds where the dormancy level is high. Dormancy breaking procedures such as pre-chilling treatments (e.g., expose wet seeds to 5-10°C for 5-7 days in addition to a KNO_3 solution and light) have been shown to help in achieving better germination results. Under the pressure of time, the pre-chilling treatment may be terminated three or four months after harvest if it is thought that dormancy is broken; however, in some samples that possess high levels of dormancy pre-chilling beyond four months may be necessary.

In the current global seed industry, the value of a seed quality test such as purity and standard germination is based not only on accuracy and uniformity, but also on delivering test results in a timely manner. This allows seed producers and dealers to make quick decisions regarding marketing of their seed and protects them from losing sale opportunities.

This study was conducted to determine the effects of pre-chilling treatments on the speed of germination and the percentage of fluorescence in 142 samples of perennial ryegrass harvested in 2006 in Oregon.

Materials and Methods

One hundred and forty two perennial ryegrass samples representing seventeen varieties grown in Oregon were tested at the Oregon State University Seed Laboratory for standard germination and fluorescence tests. The tests were conducted on freshly harvested seeds in July and August 2006.

The standard germination test

Two sets of four 100-seed replicates from each of the 142 perennial ryegrass samples were randomly selected and prepared for the standard germination test. One set was planted without pre-chilling treatment at 15-25°C as described in the AOSA Rules for Testing Seeds (2007). The wet seeds of the second set were exposed to a pre-chilling treatment of 10°C for 7 days before moving them to 15-25°C. Normal seedlings of both sets were evaluated and counted after 7 and 14 days (excluding the pre-chilling period in the second test).

The fluorescence test

The normal seedlings of each of the 142 samples of both pre-chilled and non-pre-chilled tests were exposed to ultra-violet light in a dark room after 7 days (first count) and after 14 days (final count). The seedlings that showed fluorescent roots after 7 days from each test were counted, recorded and removed. All the germination boxes were placed back in the 15-25°C germinator until the fourteenth day where the normal seedlings from each test were exposed again to the ultra-violet light and seedlings that showed fluorescent roots were counted and recorded. All tests were terminated after 14 days according to the AOSA Rules.

The data were subjected to statistical analysis to determine the effect of pre-chilling treatment on the speed of germination and the fluorescence test results.

Results and Discussion

The effect of pre-chilling treatment on germination

The results showed that the germination percentage of 118 out of the 142 perennial ryegrass samples that received pre-chilling treatment did not change from the first count (7d) to the final count (14d) or increased by only 1% (Figure 1). Only 22 samples out of the 142 samples that did not receive pre-chilling treatment had similar germination in the first (7d) and the final count (14d) (Figure 1). The speed of germination and the uniformity in seedling size of the samples that received pre-chilling treatment were greater than the samples that were planted without pre-chilling treatment. The germinated seedlings of the non-pre-chilled samples were sporadic, which may explain the greater variation in the fluorescence results between the 7-day count and the 14-day count in the non-chilled samples compared to the chilled samples (Figure 2). At the first count (7d), 45 out of the 142 non-chilled samples (approximately 36%) had germination below 90%, whereas all the chilled samples achieved germination over 90%.

The endogenous abscisic acid (ABA) levels in seed that received pre-chilling treatment may be declined during the imbibition period of the cold treatment due to leaching (Debaene-Gill et al., 1994). The cold treatment may also shift the hormonal balance to enhance germination through the activity of gibberellic acid and cytokinin and/or the decline of the ABA (Copeland and McDonald, 2001). The pre-chilling treatment acted as priming treatment in providing enough moisture to activate the hydraulic enzymes that made the seeds ready to germinate once they were moved to the warm temperature.

These results suggested that many perennial ryegrass samples, even freshly harvested seeds, may reach maximum potential germination after only 7 days of warm germination (15-25°C) if they receive pre-chilling treatment of 7 days at 10°C. The results also indicated that 14 days of warm germination without cold treatment might not achieve maximum germination because the seeds need to be exposed to the cold temperature in order to break the dormancy. If seeds possess high levels of dormancy, 14 days of warm germination, in addition to the pre-chilling period would be needed (Figure 1).

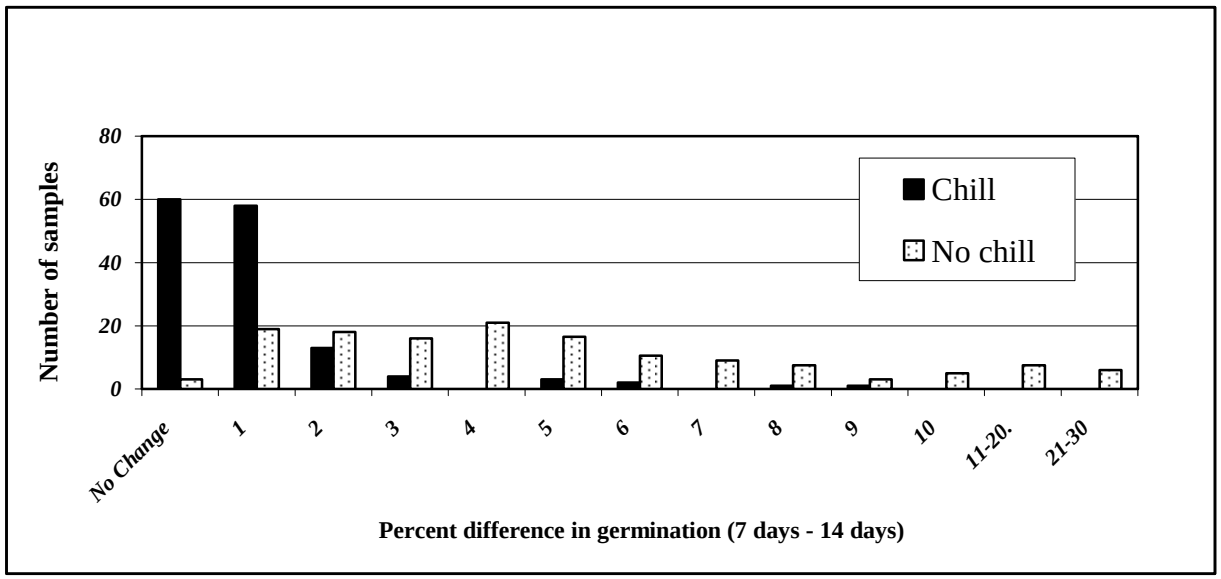


Figure 1. The difference in germination between the first count (7 days) and the final count (14 days) of 142 perennial ryegrass samples planted with and without pre-chilling treatment in standard germination tests.

The effect of pre-chilling treatment on fluorescence

The results of the study showed that the fluorescence percentage of 132 out of the 142 samples that received pre-chilling treatment did not change in the final count (14d) compared to the first count (7d). On the other hand, only 61 samples out of the 142 samples, which did not receive pre-chilling treatment, had similar fluorescence in the first (7d) and the final count (14d) (Figure 2).

Generally, seeds that have achieved maximum germination and have developed healthy root and shoot systems will have also expressed maximum fluorescence. Thus, if a sample has reached maximum germination in 7 or 10 days, waiting additional days is not likely to change either the germination or the fluorescence results significantly. Therefore, if an analyst is positive that maximum germination of a sample has been attained before the 14-day final count, he/she can terminate the test and report the results. This can save time in completing germination and/or a fluorescence test.

The results of this study suggested that many samples do achieve their maximum germination and express full fluorescence level several days before the currently prescribed 14 days; hence, there is a possibility of avoiding unnecessary delay in such cases. Samples that have not achieved their full germination potential should be given the full 14-day test period before final evaluation of germination and fluorescence.

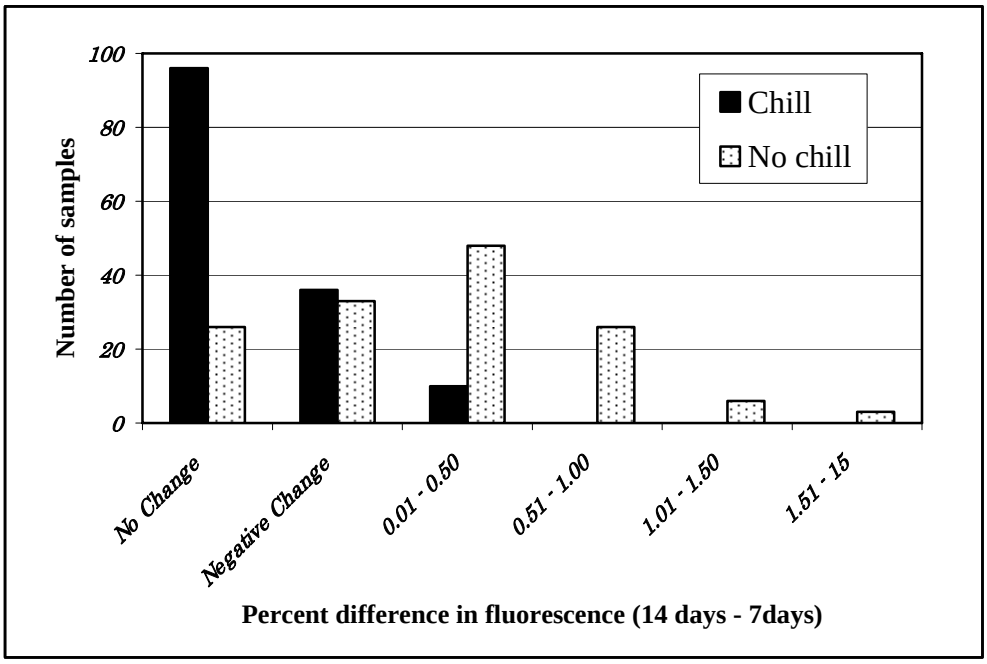


Figure 2. The difference in fluorescence between the first count (7 days) and the final count (14 days) of 142 perennial ryegrass samples planted with and without pre-chilling treatment in standard germination tests. Negative change means 7-day fluorescence percent is more than the 14- day percent y because more non-fluorescent seedlings germinated after the first count.

Conclusion

Perennial ryegrass samples that received pre-chilling treatments at 10°C for 7 days achieved faster and more uniform germination than non-chilled samples in the standard germination test. The pre-chilling treatment also speed up the fluorescence expression. The final germination (14d) of the samples that pre-chilled did not change from the first count (7d) in 42% of the total samples included in the study. The germination count after 14 days did not increase more than 3% compared to the germination after 7 days in 95% of the total samples tested. The fluorescence percentage after 14 days did not exceed the fluorescence after 7days in approximately 93% of the pre-chilled samples, whereas the fluorescence expression in non-chilled samples stretched over longer period of time.

References

AOSA. 2007. Rules for Testing Seeds. Association of Official Seed Analysts. Stillwater, OK, USA.

Copeland, L.O, and M. McDonald. 2001. Principles of seed science and Technology. Kluwer Academic Publisher, Norwell, MA, USA.

Debaene-Gill, Susan B., Phil S. Allen, and Donald B. White. 1994. Dehydration of germinating perennial ryegrass seeds can alter rate of subsequent radical emergence. J. Exp. Bot. 45: 1301-1307.

Dudeck, A.E., and C.H. Peacock. 1986. Pregermination of Italian ryegrass and tall fescue seed. Crop Sci. 26:177-179.

Gallagher, R.S., K.J. Steadman, and A.D. Crawford. 2004. Alleviation of dormancy in annual ryegrass (*Lolium rigidum*) seeds by hydration and after-ripening. Weed Sci. 52: 968-975.

Oregon Ryegrass Growers Seed Commission, Salem, Oregon. www.ryegrass.com.

Steadman, K.J. 2003. Dormancy release during hydrated storage in *Lolium rigidum* seeds is dependent on temperature, light quality, and hydration status. J. Exp. Bot. 55.929-937.

Weisner, L.E., and Grabe, D.F. 1972. Effect of temperature preconditioning and cultivar on ryegrass (*Lolium* sp.) seed dormancy. Crop Sci. 12: 760-764.

MINERAL CHARACTERIZATION OF TEMPERATE GRASSES FROM A HIGH RAINFALL ENVIRONMENT

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

Summary
Straw produced as a co-product of perennial ryegrass (*Lolium perenne* L.), orchardgrass (*Dactylis glomerata*), tall fescue [*Schedonorus phoenix* (Scop.) Holub] (formerly *Festuca arundinacea* Schreb.), and Kentucky bluegrass (*Poa pratensis* L.) seed production in the high rainfall area of western Oregon as well as clippings from urban and recreational turf developed from this seed have potential for use as biofuel feedstock. Previous efforts to convert this biomass to energy utilizing thermochemical approaches were plagued by the presence of "anti-quality" mineral constituents that impact the long-term durability of gasification reactors.

There is potential for genetic improvement of these grasses to enhance their suitability as feedstock for these reactors, but little is known about genotypic variability in mineral accumulation by these species. Mineral content of straw from selected cultivars of each species collected from multiple locations within the high rainfall production region were quantified and mineral distribution within the plant was determined.

Significant (P <0.01) variability in the amount of critical "anti-quality" minerals including calcium (Ca), chlorine (Cl), potassium (K), silicon (Si), and sulfur (S) were found, though differences in S were small (Tables 1 and 2). Minerals that represent soil nutrients removed with straw harvests also were quantified to aid evaluation of the sustainability of straw removal as bioenergy feedstock. Mineral accumulation varied between species and was dependent upon factors other than soil mineral content. Differences between cultivars and species collected from the same location suggest that genotypic variability in mineral accumulation may be exploited to develop germplasm with improved mineral uptake traits. Aside from N, soil K and P can be limited in some soils, removal of straw can affect long-term soil fertility if left unchecked by mining available soil K and P. Table 3 shows the amounts of K and P removed per ton of straw.

Material and Methods
Aboveground plant biomass of tall experimental line TFA4, perennial ryegrass, cv 'Manhattan', Kentucky bluegrass, and orchardgrass was collected from Oregon State University Hyslop Crop Science Farm. Aboveground biomass of selected cultivars of tall fescue and perennial ryegrass also were collected from a commercial farm near Lebanon, OR and cultivars of perennial ryegrass were collected from a commercial farm south of Corvallis, OR. All three sites were located in the high rainfall area of the Willamette Valley of western Oregon. Plants were cut 4 cm above the soil surface from four replicated 30 by 30 cm quadrats and separated into three tissue categories including leaves, stems, and whole plants. Minerals were extracted from plant tissue utilizing microwave-assisted acid digestion (EPA method 3052) with an Ethos D microwave station (Milestone, Monroe, CT) and analyzed for Al, Ca, K, P, S and Si by Inductive Coupled Plasma Optical Emission Spectroscopy (ICP-OES) (Perkin-Elmer Life and Analytical Sciences, Shelton, CT). Plant chlorine (Cl) content was quantified on tissue samples (25 g) that were extracted with 100 ml of deionized water, shaken for 30 min at 350 rpm and filtered through Whatman Qualitative No. 42 filters (Florham Park, NJ) that had been washed three times with 1% H_2SO_4 (v/v) and deionized water. The filtrate was analyzed colorimetrically for Cl (QuickChem method 10-117-07-1-C) on a Lachat flow injection autoanalyzer (Hach Co., Loveland, CO). Soil pH was determined on slurry consisting of 1:2 ddH_2O/soil. Soil organic matter was determined by loss on ignition at 500°C, after 4 h. Statistical analyses of mean differences between species and plant tissue were calculated by the analysis of variance general linear model (GLM) procedure, utilizing SAS (Statistical Analysis System Institute, Cary, NC). Mean differences between tissues within each species were also determined. All differences reported are significant at $P \leq 0.05$, unless otherwise stated. The Tukey's test was used for the multiple comparisons of observed means.

Acknowledgments
The authors thank Machelle Nelson and Donald Streeter for excellent technical support.

Literature of Interest
Banowetz, G.M., A. Boatang, J.J. Steiner, V. Sethi, H.M. El-Nashaar. 2008. Assessment of straw biomass feedstock resources in the Pacific Northwest. Biomass and Bioenergy (in press).

Steiner, J.J., Griffith, S.M., Mueller-Warrant, G.W., Whittaker, G.W., Banowetz, G.M., Elliott, L.F. 2006. Conservation practices in western Oregon perennial grass seed systems I. Impacts of direct seeding and maximal residue management on production. Agron. J. 98, 177-186.

Table 1. Partitioning of materials within stems, leaves, and whole plant tissues of tall fescue [TF; *Schedonorus phoenix* (Scop.) Holub] (formerly *Festuca arundinacea*, Schreb.), experimental line TFA4, perennial ryegrass (PR; *Lolium perenne* L.) cv. 'Manhattan,' Kentucky bluegrass (KBG; *Poa pratensis* L.) and orchardgrass (OG; *Dactylis glomerata* L.) plants propagated at Hyslop Crop Science Farm near Corvallis, Oregon. Mean (n=4) values within a row of three values corresponding to each tissue followed by the same letter are not significantly different at P=0.05 using Fisher's LSD mean comparison test.

	Stem				Leaf				Whole plant			
Mineral	TF	PR	KBG	OG	TF	PR	KBG	OG	TF	PR	KBG	OG
	(mg/kg)											
A1	196ab	282a	187ab	56b	58a	63a	53a	60a	197a	118ab	94ab	70b
B	27.8b	58.8a	49.1a	25.5b	19.7ab	12.8b	24.9a	13.2b	23.0b	25.9b	36.3a	23.2b
Ca	4764c	9918a	5245c	7488b	1354b	1476b	1421b	2124a	4006bc	4743b	3003c	6482a
Cl	2620a	1950b	2540a	1560b	4380a	2810c	3510b	1690d	4000a	2250c	3120b	1490d
Co	149ab	188a	184a	110b	46.2ab	64.3a	36.8ab	25.3b	142a	85.8b	107ab	100ab
Fe	180a	213a	218a	114b	34.8b	70.2a	45.7ab	38.6b	172a	106b	130b	104b
K	18573b	17475b	17323b	26503a	47058a	14095a	20073a	19433a	20740b	17233b	18140b	28855a
Mg	1288b	1756a	1092b	1832a	846a	712b	530c	868a	1419b	1186b	801c	1756a
Mn	99.2a	60.7b	79.0ab	63.4b	41.4ab	51.4a	30.3b	39.5ab	87.7a	55.5b	50.2b	54.7b
P	415c	1065b	1284b	1754a	365b	831a	756a	711a	667d	1381b	938c	1661a
S	900b	980a	910b	840b	900b	910a	910a	910a	900ab	840b	760a	910ab
Si	9495a	7203a	8343a	9789a	1594b	1916ab	2113ab	2450a	6895a	3733b	4354b	7046a
Zn	49.1c	62.2bc	83.1a	71.8ab	41.5ab	37.3ab	48.5a	31.3b	38.9a	44.4a	46.4a	48.8a
	(g/kg)											
C	426b	434a	432ab	430ab	432a	435a	431a	435a	429a	401a	436a	432a
N	6.9c	11.3b	14.1ab	15.7a	5.2a	5.3a	4.7a	3.4a	7.2b	8.8b	10.1b	14.8a

Table 2. Mineral accumulation by cultivars of tall fescue [*Schedonorus phoenix* (Scop.) Holub] (formerly *Festuca arundinacea*, Schreb.), and perennial ryegrass (*Lolium perenne* L.) cultivars propagated at locations in Benton (Seed Research of Oregon farm; SR) and Linn (Blue Moon Farm; BMF) counties in western Oregon.

Mineral	Tall fescue (SR)			Perennial ryegrass (SR)			Perennial ryegrass (BMF)			
	Grand II	Harrier	Titan LTD	Linn	Manhattan	SR-4600	Linn	Manhattan	Palmer II	Pennfine
	(mg/kg)									
A1	326a	332b	248a	383a	363a	325a	1186a	1119a	399b	461b
B	6.0b	16.3a	7.9b	24.3a	14.4b	15.0b	23.2a	6.6b	10.0ab	2.2b
Ca	3833a	3567a	3847a	3990a	2699b	3920a	5254a	4880ab	3937bc	3000c
Cl	800a	700a	800a	713b	769a	717b	1079a	963a	929a	1000a
Co	227a	226a	180a	323a	309a	278a	776a	733a	263b	320b
Fe	284a	263a	234a	384a	417a	278a	887a	838a	327b	384b
K	16076a	13520b	16286a	13988b	16922a	14710a	19677ab	21973a	20500a	20487b
Mg	1653a	1338b	1673a	1591a	1032b	1608a	2018a	1769a	1628ab	1300b
Mn	44a	75b	38c	93.2a	60.4b	71.5b	59a	52ab	38b	40ab
P	600a	947a	586a	1100a	1100a	1200a	2117ab	2664a	2284a	1800b
S	970a	1100a	840a	1053a	1703b	1174a	2760a	2810a	5426a	5340a
Si	13891a	8813a	10730a	9356a	7018a	9922a	13157a	10500ab	9504b	8500b
Zn	2.5b	17.3a	4.7b	16.6b	10.2c	21.0a	23.4a	27.0a	22.9a	23.9a
	(g/kg)									
C	406a	397a	403a	385b	435a	363c	382a	386a	400a	371a
N	7.0a	8.7a	4.5b	7.1b	5.2c	8.0a	6.5b	5.1a	5.1a	5.2a

Table 3. Potassium and phosphorus content of tall fescue [*Schedonorus phoenix* (Scop.) Holub] (formerly *Festuca arundinacea,* Schreb.), and perennial ryegrass (*Lolium perenne* L.) straw expressed in units of pounds per ton.

Mineral	Benton County Oregon						Linn County Oregon		
	Tall fescue cultivar			Perennial ryegrass cultivar			Perennial ryegrass cultivar		
	Grand II	Harrier	Titan LTD	Linn	Manhattan	SR-4600	Linn	Manhattan	Pennfine
	(lb per ton of straw)								
P	1.20	1.89	1.17	2.20	2.20	2.40	4.24	5.33	3.60
K	32.2	27.1	32.6	28.0	33.9	29.4	39.4	44.0	41.0

GENOTYPIC VARIABILITY IN MINERAL ACCUMULATION BY GRASSES FROM LOW RAINFALL AREAS OF THE WESTERN U.S.

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

Summary
Straw produced as a coproduct of grass seed and cereal grain production represents a potential supply of biomass for energy production. The low-density distribution of this biomass in many locations suggests that distributed small-scaled thermochemical technologies may provide an economic conversion approach. The utility of straw as feedstock for thermochemical approaches is impacted by the presence of "anti-quality" mineral constituents that form slag at commonly used operating temperatures. Slag reduces the useful life of thermochemical reactors. Harvesting straw also removes mineral fertilizer components and soil carbon that impact the sustained production of subsequent crops.

The objective of this research was to characterize mineral accumulation by diverse grasses produced for seed at two contrasting locations in the low rainfall region of the Pacific Northwest to determine the following: 1) whether genotypic differences in mineral accumulation by these grasses provide opportunity for genetic improvement of feedstock characteristics and, 2) fertilizer and carbon values of straw as conservation residue.

Significant ($P < 0.01$) differences in the accumulation of most minerals that were analyzed occurred between genotypes of Kentucky bluegrass (*Poa pratensis* L.), perennial ryegrass (*Lolium perenne* L.) and tall fescue [*Schedonorus phoenix* (Scop.) Holub] (formerly *Festuca arundinacea*, Schreb.). Mineral accumulation varied between species and was dependent upon the location at which the plants were grown (Tables 2 and 3). On average, harvested straw contained 26 kg/Mg (52 lb/ton) of potassium, 0.85 kg/Mg (1.7 lb/ton) of phosphorus, and 340 kg/Mg (680 lb/ton) of carbon. Much of the potassium and phosphorus are recovered in ash produced by a small-scale gasification reactor. Aside from N, soil K and P can be limited in some soils, removal of straw can affect long-term soil fertility if left unchecked by mining available soil K and P. Table 3 shows the amounts of K and P removed per ton of straw.

Methods and Materials
Aboveground plant biomass was collected from Kentucky bluegrass cultivars after seed harvest in commercial production fields in Spokane Co., WA. Additional accessions of Kentucky bluegrass, along with perennial ryegrass and tall fescue accessions were collected at early vegetative stages during the month of April from at the USDA Agricultural Research Service Plant Germplasm Introduction farm in the low rainfall area of eastern Washington. The soil at the Spokane County site was a Freeman silt loam while that at Pullman was a Palouse silt loam. Plants were cut approximately 4 cm above the soil surface transferred to the laboratory, dried at 70°C for 24 h and ground and weighed. Three one-inch diameter soil cores were sampled to a depth of 30 cm from each location.

Minerals were extracted from plant tissue utilizing microwave-assisted acid digestion (EPA method 3052) with an Ethos D microwave station (Milestone, Monroe, CT) and analyzed by Inductive Coupled Plasma Optical Emission Spectroscopy (ICP-OES) (Perkin-Elmer Life and Analytical Sciences, Shelton, CT). Plant chlorine (Cl) content was quantified on tissue samples (25 g) that were extracted with 100 ml of deionized water, shaken for 30 min at 350 rpm and filtered through Whatman Qualitative No. 42 filters (Florham Park, NJ) that had been washed three times with 1% H_2SO_4 (v/v) and deionized water. The filtrate was analyzed colorimetrically for Cl (QuickChem method 10-117-07-1-C) on a Lachat flow injection autoanalyzer (Hach Co., Loveland, CO). Carbon (C), nitrogen (N), and sulfur (S) in tissue ground in a Tecator Cyclotec 1093 sample mill were quantified using a Perkin Elmer 2400 Series II CHNS/O analyzer (Shelton, CT). Soil pH was determined on slurry consisting of 1:2 ddH_2O/soil. Soil organic matter was determined by loss on ignition at 500°C, after 4 h. Kentucky bluegrass straw was gasified as described (Boateng et al., 2007) and mineral content of the ash resulting from gasification was quantified by Wyoming Analytical Laboratories, Inc. (Laramie, WY). The content of heavy metals, dioxins and furans in the ash was determined by GC-MS by Columbia Analytical Services (Kelso, WA).

Statistical analyses of mean differences between species and plant tissue were calculated by analysis of variance / general linear model (GLM) procedures, utilizing SAS (Statistical Analysis System Institute, Cary, NC). Mean differences between tissues within each species were also determined. All differences reported are significant at $P \leq 0.05$, unless otherwise stated. The Tukey's test was used for the multiple comparisons of the observed means.

Acknowledgments
The authors thank Machelle Nelson and Donald Streeter for excellent technical support. We also thank Gady Farms in Spokane County and Dr. Vicki Bradley and the USDA/ARS Plant Germplasm Introduction and Testing Unit, Pullman, WA for their cooperation in obtaining the grass and soil samples used in these studies. 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.

Literature of Interest

Banowetz, G.M., A. Boatang, J.J. Steiner, V. Sethi, H.M. El-Nashaar. 2008. Assessment of straw biomass feedstock resources in the Pacific Northwest. Biomass and Bioenergy (in press).

Steiner, J.J., Griffith, S.M., Mueller-Warrant, G.W., Whittaker, G.W., Banowetz, G.M., Elliott, L.F. 2006. Conservation practices in western Oregon perennial grass seed systems I. Impacts of direct seeding and maximal residue management on production. Agron. J. 98, 177-186.

Table 1. Mean concentration of selected minerals in aboveground biomass of Kentucky bluegrass (*Poa pratensis* L.) cultivars propagated in commercial production fields in Spokane County, WA. Mean (n=4) values within a column followed by the same letter are not significantly different at $P = 0.05$ using Fisher's LSD mean comparison test.

Mineral	Kentucky bluegrass cultivar								
	Casablanca	Cheetah	Gady	Ginger	Jefferson	Kenblue	Kenblue (no-till)	Parkland	Rampart
	(mg/kg)								
A1	145a	52d	38e	31fg	24h	29gh	35ef	101c	114b
B	64.2a	33.0b	26.5c	33.1b	28.4c	30.2c	28.3c	34.3b	60.6a
Ca	3790b	2210c	1720d	1780d	2120c	1700de	1530e	1860d	4290a
C1	3700b	3050e	4300a	3270d	3180de	2530f	2170g	2900ef	3490c
Co	228a	214c	156d	142de	105g	114fg	129ef	263ab	257b
Fe	657a	447b	296c	244cde	124f	170ef	194def	569a	451b
K	36900b	30500e	43000a	32700d	31800d	25300g	21700h	29000f	34900c
Mg	1890a	1090e	960f	1180d	1240c	1250c	970f	1090e	1570b
Mn	27.1a	19.7c	15.2d	6.7g	6.26g	12.53e	9.41f	21.2b	12.2e
P	980d	1160b	940d	1290a	930de	1060c	850f	870ef	1200ab
S	2030ab	980d	2450a	1530bc	1030cd	1090cd	1090cd	1010d	1030cd
Si	15900b	8300de	7600e	12500c	12600c	8700d	8300de	12000c	21600a
Zn	1.61ab	1.72a	0.80e	1.60ab	1.20cd	1.41bc	1.08de	1.73a	1.60ab
	(g/kg)								
C	343b	463a	363b	298c	461a	434a	462a	448a	432a
N	13.0a	10.8c	13.1a	13.4a	10.5c	12.7ab	10.9c	11.3bc	10.7c

Table 2. Mean concentration of selected minerals in aboveground biomass of accessions of tall fescue [*Schedonorus phoenix* (Scop.) Holub] (formerly *Festuca arundinecea*, Schreb.), perennial ryegrass (*Lolium perenne* L.) and Kentucky bluegrass (*Poa pratensis* L.) collected propagated at USDA field plot in Whitman County WA. Mean (n=4) values for respective species followed by the same letter are not significantly different at $P = 0.05$ using Fisher's LSD mean comparison test.

	Grass species and accession number												
	Tall fescue				Perennial ryegrass				Kentucky bluegrass				
Mineral	600689	600898	600899	600970	255175	403887	403891	403896	25715	25762	34918	371775	578847
	(mg/kg)												
A1	338a	245a	419a	502a	806a	495b	829a	646b	391a	786a	531a	564a	808a
B	30.8ab	22.2b	40.1a	38.9ab	64.6a	46.1bc	45.1c	59.4ab	38.9a	53.1a	35.2b	37.1b	38.0b
Ca	5130b	5270ab	6450a	5840ab	6400a	5690ab	5510ab	4980b	3880c	6050a	3700c	5050b	5120b
Cl	2580a	2830a	3380a	3010a	2150b	2690ab	3460a	3250a	2690ab	2170bc	1950c	2910a	2580ab
Co	406ab	304b	443ab	545a	855ab	534b	101a	666ab	432b	850ab	635ab	561ab	927a
Fe	470ab	355b	499ab	626a	933a	611c	900a	762b	500b	958ab	710ab	647ab	104a
K	31600a	32700a	30000a	28500a	31200a	30800a	28900a	28900a	25800a	25100a	24300a	24700a	25900a
Mg	2770a	2220a	3000a	2540a	1840a	1820a	1960a	1850a	1530c	2160a	1820b	2090a	1800b
Mn	116a	98a	129a	110a	121a	108ab	82b	91ab	157a	116b	115b	109b	158a
P	3140a	3690a	3100a	3360a	3380a	3420a	3120a	3000a	4400a	3900b	3510b	3740b	2970c
S	940a	910a	962a	905a	914a	888ab	928a	859b	953a	957a	897b	936a	928ab
Si	2850a	2610a	2610a	2510a	2000b	2000b	2440ab	2740a	2230b	2520a	2260b	2160b	2280b
Zn	27.2a	39.5a	25.1a	39.9a	54.7a	66.3a	69.3a	62.2a	54.9b	67.4ab	72.1ab	71.2ab	89.8a
	(g/kg)												
C	396b	394b	411a	395b	401a	399ab	395ab	393b	413a	406ab	400bc	403bc	399c
N	30.5ab	27.4b	30.8a	28.0ab	28.2a	24.6a	26.0a	23.0a	34.1ab	36.8a	26.1c	31.4b	25.2c

Table 3. Potassium and phosphorus content of tall fescue [*Schedonorus phoenix* (Scop.) Holub] (formerly *Festuca arundinacea*, Schreb.), perennial ryegrass (*Lolium perenne* L.) and Kentucky bluegrass (*Poa pratensis* L.) straw expressed in units of pounds per ton.

	Whitman County Washington												
	Tall fescue accession				Perennial ryegrass accession				Kentucky bluegrass accession				
Mineral	600689	600898	600899	600970	255175	403887	403891	403896	25715	25762	34918	371775	578847
	(lb per ton of straw)												
P	6.28	7.38	6.20	6.72	6.76	6.84	6.24	6.00	8.80	7.80	7.02	7.48	5.94
K	63.2	65.4	60.0	57.0	62.4	61.6	57.8	57.8	51.6	50.2	48.6	49.4	51.8

	Spokane County Washington								
	Kentucky bluegrass								
Mineral	Casablanca	Cheetah	Gady	Ginger	Jefferson	Ken blue	Ken blue no till	Parkland	Rampart
	(lb per ton of straw)								
P	1.96	2.32	1.88	2.58	1.86	2.12	1.70	1.74	2.40
K	73.8	61.0	86.0	65.4	63.6	50.6	43.4	58.0	69.8

ASSESSING TRADE-OFFS BETWEEN CROP PRODUCTION AND ECOLOGICAL SERVICES: THE CALAPOOIA BASIN

R.W. Colvin, G.R. Giannico, A.T. Herlihy, W.J. Gerth, R.B. Confessor, R.G. Fare, T.S. Garcia, S.M. Griffith, S.P. Grosskopf, B.C. McComb, G.W. Whittaker and G.W. Mueller-Warrant

Project Goals:

1. To quantify linkages between conservation practices in grass seed producing areas and biophysical responses including water quality and biological indicators; and,

2. To develop a model to assess tradeoffs between agricultural practices that maximize economic benefits and conservation actions that sustains or improve ecosystem services.

Specific Objectives:

1. Describe the extent, timing and placement of conservation practices currently in the study watershed;

2. Assess the effects of those conservation practices, their location and their interactions on water quality and quantity;

3. Evaluate the effects of conservation practices on key biological indicators that respond to cumulative alterations in land cover and resulting water quality and quantity.

4. Develop an objective-optimization model based on the information derived from objectives to assist farmers, NRCS (Natural Resource Conservation Service) staff, and local conservation districts in identifying cost effective conservation practice strategies;

Disseminate the findings of this research project to specific target audiences through adequate outreach activities and extension products.

Progress to Date:

In our attempt to quantify linkages between conservation practices and biophysical responses, including water quality and biological indicators, and to develop a model to assess tradeoffs between agricultural practices that maximize economic benefits and conservation actions that sustain or improve ecosystem services we completed the following steps during 2007.

- The SWAT (Soil and Water Assessment Tool) streamflow model was successfully calibrated and validated in the Calapooia watershed.

- A field season of new physical habitat, water quality, fish, amphibian, and bird data was collected.

- A new amphibian capture protocol was developed and implemented so that we could sample intermittent streams directly adjacent to grass seed fields.

- Fish and macroinvertebrate data collected in intermittent streams within the basin over the last six years were entered into composite databases.

    - For fish, five field seasons of winter-spring (November-May) data were combined into one database. Over this period, 54 different sites were sampled; some were sampled in more than one year. For each site, the number of species caught and catch per unit effort were determined.

    - The macroinvertebrate database included Spring samples collected in 2 years (2003 and 2004). Macroinvertebrate assemblage data were used to determine benthic invertebrate density, taxonomic richness, and proportional abundance, diversity, tolerance, and feeding group metrics.After elimination of six sites that were found to be flood impacted (dominated by outside macroinvertebrates being washed in) the final database had 30 different sample sites, some of which were sampled in more than one year.

- Relationships between fish and macroinvertebrate metrics and physical habitat, water quality, and GIS (Geographic Information System)-derived landscape metrics were investigated. Initial data analyses lead to the selection of four fish metrics and four macroinvertebrate metrics for detailed analyses. Most of these biological condition metrics were affected by distance to the nearest perennial water source. Species richness, diversity, and fish CPUE (Catch Per Unit Effort) decreased significantly as the distance to a perennial water source increases.

    - Comparing different metrics to distance to perennial water provide plots which are classic “envelope” relationships seen when multiple factors are involved. Adjusting these metrics with distance to perennial water requires looking at the changes near the stressor or controlling factor maxima, rather than the center of the distribution. These adjusted metrics may be a better estimate of the effect when that factor is the limiting constraint. Data analysis in second year of the project will focus on how these adjusted

metrics respond to the habitat, chemical and GIS stressor metrics.

Ongoing Efforts:

- Analyze water quality data and calibrate/validate SWAT for quality parameters (suspended sediments, NO_3^-, PO_4^{3-} etc.): per sub-basin and the whole watershed.

- Continue developing the link between SWAT, the economic model, and the biological indicators and implement them at different spatial scales.

Funding:
A grant from USDA-CEAP (Conservation Enhancement Assessment Project) supported the development of the 2007 Calapooia biological sampling as well as the initial analyses. This funding was also used characterize the accuracy of the SWAT watershed model for hydrologic simulation of flow patterns in the Calapooia watershed.

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

Appreciation is expressed to the Officers of the 2007-2008 Oregon Seed Council:

Mike Thomas, President
Rodney Hightower, FirstVice President
Matt Herb, Second Vice President
Jerry Marguth, Treasurer
David S. Nelson, Executive Secretary

Business Address

Oregon Seed Council
1193 Royvonne, S., Suite 11
Salem, OR 97302

Tel: (503) 585-1157
FAX: (503) 585-1292
E-mail: dlnassoc@aol.com

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.

Now available online at
http://cropandsoil.oregonstate.edu/seed-ext