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Department of Crop and Soil Science Ext/CrS 136, 4/12

*** 30th anniversary issue ***

This is the 30th year of publishing the Seed Production Research report. The first report summarizing current research work of interest to the Oregon seed industry was printed in 1982. The goal then was to make public the results of research work in progress, or to summarize recently completed studies. That goal has guided this effort since the beginning.

The seed research capability at Oregon State University is not a discrete unit, but is integrated through several departments on campus, at branch experiment stations, county Extension staff, and scientists with the United States Department of Agriculture. The success of this force is rooted in the cooperative spirit among all who are engaged in the study of seed science.

In addition to state and federal research funds, grants from commodity commissions, the Oregon Seed Council, the Oregon Seed Trade Association and agri-business firms contribute support to specific projects. These extramural funds are greatly appreciated.

Special recognition is due to the OSC, the organization that for 30 years has supported this publication with a grant to cover printing costs and distribution of the report to seed growers throughout the state.

I would also remind readers that the more recent reports can be accessed online at the Oregon Seed Extension Program web site: http://cropandsoil.oregonstate.edu/seed-ext/publications/research-reports. An additional resource is the ScholarsArchive@OSU web site (http://ir.library.oregonstate.edu/xmlui/), where all previous reports back to 1982 can be accessed.

Lastly, given my recent retirement, this annual report will be assembled next year with "*new hands*." The format will likely change somewhat… and I'm confident that it will be for the better! I have had a *hand* in producing this publication since its beginning… having been an author in every issue we've published, and editing the report since 1989. It has been my privilege to have this responsibility.

Bill Young, Professor Emeritus

The following authors have contributed to this report.

Central Oregon Agricultural Research Center
M.D. Butler, Professor and Superintendent
R.B. Simmons, Senior Faculty Research Assistant
J.M. Weber, former student worker

Columbia Basin Agricultural and Research Center
D.A. Ball, Professor

Cooperative Extension Service – OSU
N.P. Anderson, North Valley Extension Field Crops Agent, Washington, Yamhill and Polk Counties
M.E. Mellbye, District Extension Agent, Linn, Benton and Lane Counties
T.B. Silberstein, Extension Agent, Marion and Clackamas Counties
D.L. Walenta, Extension Crops Specialist, Union County

Department of Crop and Soil Science – OSU
T.G. Chastain, Associate Professor, Seed Crop Physiology
A.R. Corkery, Student Technician, Entomology
D.W. Curtis, Faculty Research Assistant
G.C. Fisher, Professor Emeritus, Extension Entomologist
C.J. Garbacik, Senior Faculty Research Assistant
A.G. Hulting, Assistant Professor, Extension Weeds Specialist
C.A. Mallory-Smith, Professor of Weed Science
S. Rao, Professor, Entomology
K.C. Roerig, Faculty Research Assistant
W.C. Young III, Professor Emeritus, Extension Seed Production

Hermiston Agricultural Research and Extension Center
G.H. Clough, Associate Professor
P.B. Hamm, Professor and Superintendent

National Forage Seed Production Research Center - USDA-ARS
S.C. Alderman, Professor and Research Plant Pathologist
G.M. Banowetz, Research Microbiologist and Research Leader
S.M. Griffith, Professor and Research Plant Physiologist
G.W. Mueller-Warrant, Associate Professor and Research Agronomist
G.W. Whittaker, Research Hydrologist

Corvallis Plant Materials Center – USDA-NRCS
D.C. Darris, Conservation Agronomist
A. Young-Mathews, Conservation Agronomist

LONG-TERM EVALUATION OF ANNUAL RYEGRASS CROPPING SYSTEMS FOR SEED PRODUCTION – YEAR 6

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

A field trial was established to evaluate reduced tillage systems in annual ryegrass (*Lolium multiflorum*) seed production. This progress report summarizes the impact on seed yields and soil organic matter accumulation following 6 years of field testing at the OSU Hyslop Field Research Laboratory.

Introduction

Annual ryegrass seed production practices in Western Oregon have changed significantly from the time when open field burning and no-till planting was a common practice. Before 1990, more than 50% of the acreage was burned. Between 1990 and 2008, about 20% of the acreage was burned annually. Legislation in 2009 further restricted burning in Oregon and essentially eliminated open field burning for annual ryegrass seed production.

For the past 20 years, annual ryegrass seed production acreage was the most stable of Oregon's major grass seed crops with approximately 120,000 acres in production, primarily in the southern Willamette Valley. The stability of acreage is partially due to production on soils too poorly drained for small grains and vegetable crops, and on soils less productive than that required for higher value perennial grass and clover seed crops. This situation led to a system of continuous seed production of annual ryegrass. Some fields have been in continuous annual ryegrass seed production for over 40 years.

The majority of annual ryegrass seed production is managed with conventional tillage and planting systems. Although costs have increased, seed yields comparable to or greater than the traditional practice of open field burning have been achieved by the seed industry.

No-till and volunteer systems are being tested and used by farmers in an effort to reduce costs. In the volunteer system, a stand is established from seed shattered from the previous crop and no tillage or planting equipment is used. Grazing and row spraying with herbicides may be used to control stand density. When no-till planting is used, a sprout of volunteers and weed seeds are-sprayed with glyphosate herbicide before planting.

Both volunteer and no-till establishment systems offer reduced tillage and fuel expenses, as well as reduced concerns about dust and air quality. However, previous field work demonstrated that seed yields under volunteer and no-till systems decline significantly if these systems are used in consecutive years (Young et al., 1997). In the first year of production, no-till and volunteer methods have been comparable to conventional methods of planting, suggesting a system of alternate year tillage may be a feasible way to maintain seed yields. Some grass seed farmers report good results using a reduced tillage approach.

This study was designed to evaluate the multi-year economics of cropping systems in a continuous annual ryegrass monoculture. A secondary objective was to measure the impact on soil properties, especially soil organic matter and soil carbon levels in reduced tillage systems.

Material and Methods

The study was established at OSU's Hyslop Field Research Laboratory near Corvallis, Oregon in the fall of 2005. The diploid variety "Gulf" was used in the trial. The field had been planted to 'Gulf' annual ryegrass the previous two years under a conventional tillage system. Soil was a moderately well-drained silt loam with a pH of 5.4 and soil test levels of P, K, Ca, and Mg above those levels considered adequate for seed production. Six treatments were included in a Randomized Complete Block design, and replicated three times with plots 25 feet by 125 feet. The resulting treatments included:

1. Continuous conventional tillage and planting system
2. Continuous no-till planting system
3. No-till/conventional tillage rotation (alternate year tillage)
4. Volunteer/conventional tillage rotation (alternate year tillage)
5. Burn and no-till/conventional tillage rotation (alternate year tillage)
6. Volunteer/no-till/conventional tillage rotation (tillage every 3rd year)

In all except the burn treatment, residue from the previous year's crop was flail chopped and left on the field. Tillage included plowing to a depth of 8 to 10 inches, disking, and pulvi-mulching. A final seedbed was prepared by harrowing and rolling. All treatments except the volunteer included at least one preplant application of glyphosate to control volunteer seedlings. A preplant fertilizer of 200 lb/acre of 16-16-16 was applied to all treatments. A Great Plains no-till drill was used to seed all treatments except the volunteer at a planting rate of 12 lb/acre. The volunteer plots were established by allowing the seeds left on the surface the previous year to germinate and grow. Rows in the volunteer plots were established by spraying 7 inches out every 10 inches with glyphosate at 40 oz/acre. All herbicide use, pest control and spring fertilization (150 lb N/acre) were performed according to OSU recommendations and industry standards.

Plots were harvested by swathing in late June, using a modified John Deere 2280 swather. Yields were determined by cutting one 6-ft. swath lengthwise down the middle of each plot to assure a uniform harvest area. Plots were combined in mid-July with a Hege 180 plot harvester. Seed was cleaned using a Clipper M2B cleaner and clean seed yields, cleanout percentage and seed weight determined. Standard Central Analytical Laboratory procedures for soil carbon, organic matter and pH were used. Data were analyzed over the six years of the trial using a factorial design with years as an independent variable. The treatments in this study take more than one year's management into consideration; e.g., alternate year treatments were considered as two or three cycles of each rotation. Means were separated using on LSD (0.10).

Results and Discussion

Cropping systems produced significant differences in the six-year average clean seed yields (Table 1). No differences in percent clean-out or seed weight (g/1000 seeds) due to treatments were observed (data not shown). Among treatments, continuous no-till management had the lowest yield of the six different systems of stand establishment. The burn and no-till planting method alternated with conventional tillage had the greatest mean seed yield.

Table 1. Average seed yield of annual ryegrass and comparison of production costs after six years, 2006 - 2011.

Establishment system	Seed yield 6-year average		Total cost yearly average	Cost savings compared to con-ventional	Break-even price based on 2000 lb/acre and relative yields[2]	
	(lb/acre)	(% of con-ventional)	($/acre)	($/acre)	(lb/acre)	($/lb)
1. Continuous conventional tillage	1624 b[1]	100%	$612	$0	2000	$0.31
2. Continuous no-till	1423 c	88%	$517	$95	1760	$0.29
3. No-till/conventional tillage rotation	1570 b	97%	$565	$47	1940	$0.29
4. Volunteer/conventional tillage rotation	1549 b	95%	$526	$86	1900	$0.28
5. Burn and no-till/conventional tillage rotation	1760 a	108%	$561	$51	2160	$0.26
6. Volunteer/no-till/ conventional tillage rotation	1593 b	98%	$523	$89	1960	$0.27
LSD (0.10)	118					

[1]Means followed by the same letter do not differ significantly
[2]Yield expressed as a % of conventional x 2000 lb/acre

All systems of establishment that included alternate year tillage provided mean seed yields that were 95% to 98% of that achieved with the conventional annual tillage method of establishment. In year 6 (data not shown), the alternate year tillage treatments as a group out-yielded the no-till by 406 lb/acre and also out-yielded conventional tillage by 250 lb/acre. These results suggest that seed yields comparable to conventional tillage systems can be maintained with reduced tillage systems that include tillage once in every second or third year. Among the six systems of establishment, the continuous conventional tillage and planting approach had the highest cost of production, based on the Oregon State University enterprise budget for annual ryegrass (Eleveld et al., 2010). The conventional system was $51 to $89/acre more than methods of establishment that used tillage on an alternate year basis. Continuous no-till provided the lowest cost of production, but also experienced the most stand loss due to slugs. As a result no-till had the least uniform stand most years of the study, often with significant thin areas. Stand reduction due to slugs was probably a major reason for poorer yields in the continuous no-till treatment. Slug damage to seedling crops in the region is a common problem and a significant economic risk. Slug numbers in no-till annual ryegrass fields can be 14 to 29 times greater than in plowed and conventionally worked plots (Fisher et al., 1996). Systems that alternate no-till or volunteer methods with tillage have less risk of damage from this widespread and common pest. In addition, voles also seemed more of an issue in no-till plots, although there are no data to support this observation.

In this trial, the yearly mean seed yields when averaged across all treatments (the trial average for the year) ranged from a high of 2047 lb/acre in 2009 to a low of 1066 lb/acre in 2010. Seed yields in 2008 and 2010 were significantly affected by slug and vole damage. For this reason, composite yields for the treatments over years were below normal compared to commercial annual ryegrass seed fields in the Willamette Valley. While yields were low by industry standards, differences were statistically different. One way to compare treatments is to apply the relative yields (% of conventional) to the industry average seed yield of 2000 lb/acre. Based on this approach, and using the OSU enterprise budget for annual ryegrass, a break-even cost of production can be determined for each production system (Table 1). The break-even price for the conventional tillage method was $0.31/lb, and reduced tillage systems (excluding the open field burning method) had break-even prices that ranged from $0.27 to $0.29/lb of seed.

One of the reasons for using no-till or reduced tillage farming methods is to maintain soil organic matter levels and potentially increase carbon storage in the soil. Soil samples taken in this study showed that soil organic matter and soil carbon levels were similar under conventional or alternate year tillage systems in the 0-8 inch plow layer depth (Table 2). Soil organic matter and carbon were stratified under continuous no-till due to accumulation of soil organic matter in the surface 0-2 inch depth (Table 3). Below 2 inches (in the 2-8 inch samples) soil carbon in the continuous no-till was significantly less than that found in the soil samples taken from the other treatments, all of which included tillage during year 6 when samples were taken. Crop residues were incorporated by tillage to a greater depth than in no-till. And in spite of more tillage, which tends to promote the decomposition of soil organic matter through increased aeration and microbial activity, tillage in this trial has led to an increase in soil C deeper in the plow layer where it is slower to degrade. In contrast, crop residue in the no-till plots remained on the soil surface where it was subject to decomposition. Apparently the residue incorporation in this trial has been sufficient to balance that lost from tillage.

Table 2. The effect of planting methods and reduced tillage systems on chemical properties on soil collected from 0 to 8-inch depth. Year 6 of a long-term trial, Hyslop Experimental Farm, 2011.

Establishment System	Soil test			
	Carbon	Organic matter[1]	Total N	pH
	- - - - - - - - - - - - - (%) - - - - - - - - - - - -			
1. Continuous conventional tillage	1.64	3.98	0.123	6.03
2. Continuous no-till (6 years)	1.70	4.08	0.133	6.27
3. No-till/conventional tillage rotation	1.60	3.85	0.120	6.20
4. Volunteer/conventional rotation	1.63	3.90	0.133	6.13
5. Burn and no-till/conventional rotation	1.56	3.80	0.123	6.10
6. Volunteer/no-till/conventional rotation	1.57	3.78	0.120	6.17
LSD (0.05)	NS	NS	NS	0.137

[1] Determined by loss on ignition.

Table 3. The effect of no-till planting on the stratification of soil C, soil organic matter, and soil pH following six years of continuous no-till, Hyslop Experimental Farm, 2011.

Establishment System	Soil test (2011)				
	Soil depth	Carbon	Organic matter[2]	Total N	pH
	(inch)	- - - - - - - - - - (%) - - - - - - - - - - -			
Continuous no-till (6 years)[1]	0-2	2.05	4.04	0.147	6.07
	2-8	1.40	3.22	0.107	6.30
LSD (0.05)		0.06	NS	0.02	0.14

[1] All other treatments were tilled the year of sampling.
[2] Determined by loss on ignition.

Soil organic matter and nutrient stratification have been observed in previous no-till trials (Mellbye and Young, 1999). Despite differences in tillage and organic matter distribution, total accumulation of soil C among treatments was similar (assuming similar soil bulk density). Soil organic matter levels change slowly in a given cropping system in temperate climates (Johnston, 2011). The exception is when soil organic matter levels are low, and large additions of compost or manure are made, or when changes are made from annual to permanent grass cropping system. In a given climate and cropping system, soils tend to reach an equilibrium level of organic matter. Thus results from this trial may change over time, but the rate of C accumulation will probably be low compared to the total biomass of crop produced. A trend toward slightly higher soil organic matter and soil C levels can be observed in the continuous no-till treatments, but the changes are very small and not statistically different. More importantly, the results show that alternate year tillage or plowing in annual ryegrass cropping systems can maintain soil carbon at levels similar to those achieved with continuous no-till, at least over a short period of time.

Summary

To date, alternating conventional tillage with a no-till or volunteer method of establishment has provided seed yields close to conventional planting methods, but at a lower cost of production. Both alternate year and continuous tillage appear to maintain soil carbon levels comparable to continuous no-till for a period of up to 6 years. This trial is designed to last a minimum of 9 years, and a more thorough analysis of results will be presented in the future. The results to date demonstrate that alternatives to annual conventional tillage exist in annual ryegrass seed production that reduce costs while maintaining yields.

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The authors wish to thank OSU soil scientist Neil Christensen, OSU Extension Soil Specialist John Hart, and OSU crop physiologist Tom Chastain for advice and suggestions on analyzing data from this project.

ENERGY USE AND EFFICIENCY IN GRASS SEED CROP PRODUCTION

T.G. Chastain and C.J. Garbacik

Energy prices are an important consideration in managing the cost of producing grass seed crops. The cost of energy and the cost of farm inputs that are tied to energy have risen faster than the price of crops. Potential public policy changes, an improving economy, and the possibility of unforeseen international instability could individually and collectively, drive energy prices up even more sharply than anticipated by economists.

Since crops capture solar energy and convert that energy into harvested yield products, profitable crop production is aimed at making the best possible solar energy capture system at the lowest possible price. Direct and indirect energy costs in the form of diesel fuel, electricity, fertilizers, pesticides, and others can make economic crop production a challenge. To increase the efficiency of solar energy capture and partitioning to harvested products, grass seed growers use a wide variety of management inputs to optimize the size of the crop's biological solar energy collector. However, there is currently no information available on the energy use and efficiency of grass seed crops grown in the Willamette Valley.

Field trials were conducted in Evening Shade perennial ryegrass and Falcon IV tall fescue in order to measure the energy consumption of seed production management activities. Seed yield, straw, and other production characteristics were determined on the crops and a life-cycle energy budget was constructed for each species.

The field trials were designed to manipulate energy capture and partitioning within the crop and through the following management treatments:

1. Spring applied nitrogen (160 lbs/acre – perennial ryegrass, 120 lbs/acre – tall fescue)
2. Trinexapac-ethyl (Palisade) plant growth regulator (PGR)
3. Control (no spring N, no PGR)

Spring N was applied in March of each year by use of an Orbit Air spreader system and the PGR treatment [Palisade® (trinexapac-ethyl)] was applied in May to control lodging. Seed yield components were collected from each plot near peak anthesis of each seed crop in June. The seed crops were cut with a small-plot swather and threshed by a small-plot combine in July of each year.

The average seed yield harvested over the past two years of the study was increased by spring N in perennial ryegrass and yield was further increased by the use of PGR (Figure 1). However, only the combination of spring N and PGR consistently affected seed yield in tall fescue. Seed yields were not increased by PGR application in either grass seed crop in the absence of spring N.

The difference between straw yield with and without spring N was much greater in perennial ryegrass than in tall fescue over the two years (Figure 1). While the lower spring N rate in tall fescue (120 lbs N/acre) could be partly responsible for the difference between the species, the amount of straw produced by tall fescue without spring N was much larger than observed in perennial ryegrass. The PGR produced small but consistent reductions in straw yield.

Seed yield resulting from the treatments outlined above was used in calculating energy budgets for perennial ryegrass and tall fescue seed production. Energy consumption values were derived from the energy budgets for both crops and are reported in Table 1. The energy consumed in production of perennial ryegrass ranged from 4,080 to 8,760 MJ/acre, depending on the management inputs used. Production energy use values for tall fescue were slightly lower than for perennial ryegrass. The energy consumption for perennial ryegrass and tall fescue falls within the published range for other major field crops such as wheat, soybeans, and barley, and is less than what is required in production of sugar beets for sugar.

Seed energy outputs are tied to seed yield with lower energy output evident with low seed yield and higher energy output with high seed yield (Table 1). Energy efficiency is determined by the ratio of energy produced (output) to energy consumed (input). When energy efficiency ratios are greater than 1, the energy produced exceeds the energy used in producing the crop. The net gain in energy comes from the capture of solar energy and storage of that energy in the seed. The energy efficiency resulting from production of perennial ryegrass and tall fescue for seed is similar to other major grain crops, and is dependent on the production inputs used to grow the crop.

The energy embodied in the straw co-product further increases the amount of energy produced by grass seed production systems (Table 2). In perennial ryegrass and tall fescue, the straw is either harvested from the field for livestock feed or is chopped to decompose in place in the field, and energy is recovered as livestock products or plant nutrients released in the soil. But the straw might have potential value as a source of energy as a feedstock for biofuel or for the thermal generation of electricity. Energy efficiency of grass seed production is much greater with the addition of the straw co-product than was observed with harvested seed alone (Table 2). Efficiency ratios for the combined seed and straw harvest ranged from 4 to nearly 12 in perennial ryegrass and tall fescue seed crops.

The results from the first two years of field trials indicate that perennial ryegrass and tall fescue grown for seed are energy efficient crops, even when the straw co-product is not considered. But the work to date also identifies some potential areas of energy cost savings and opportunities for additional energy output. This will be further illustrated after the harvest of the 3rd crop from the experimental fields is completed next summer and a final report is produced.

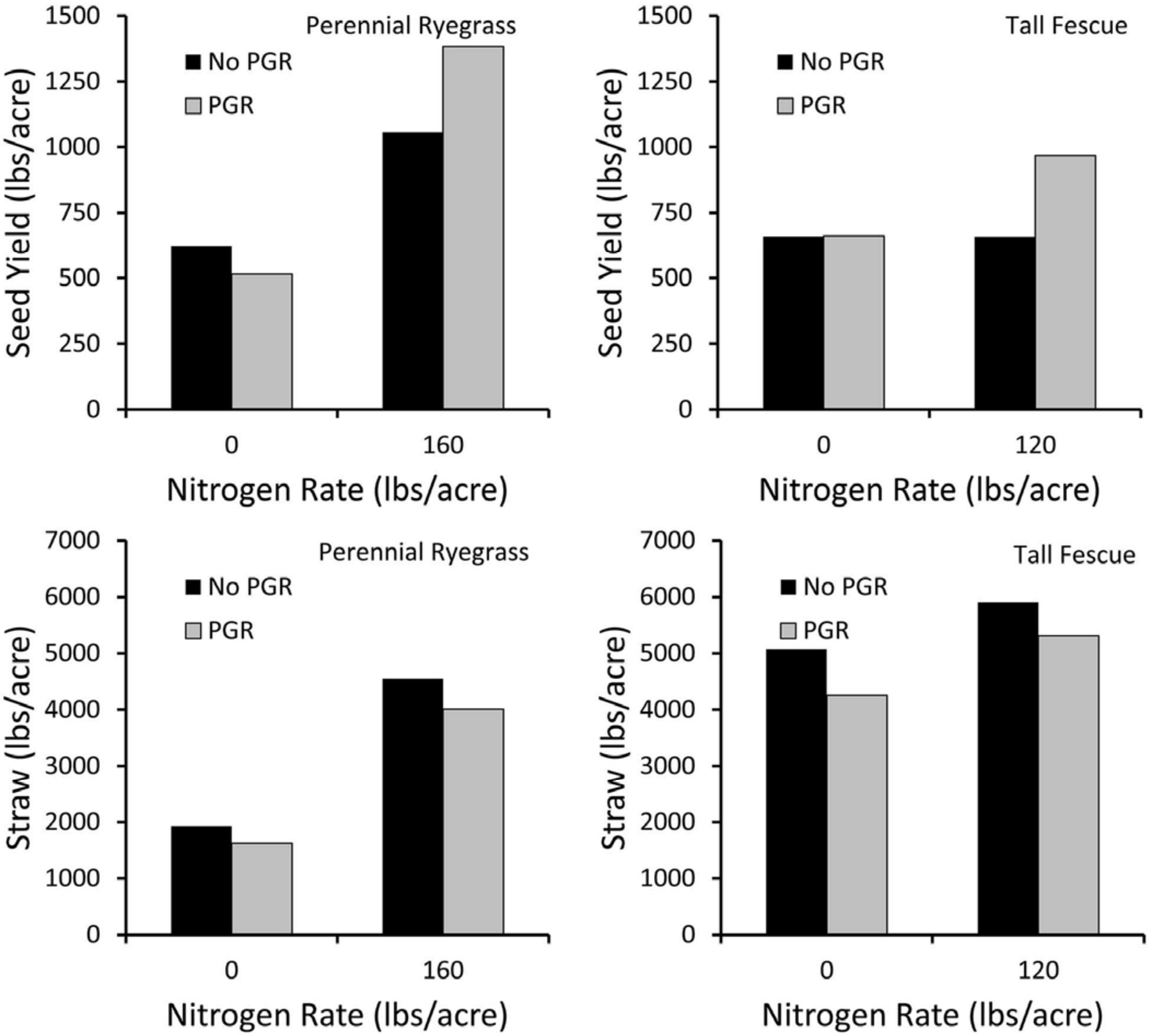

Figure 1. Effect of spring nitrogen and plant growth regulator (PGR) on seed and straw yield in perennial ryegrass and tall fescue.

Table 1. Effect of spring N and PGR on energy use and efficiency of grass seed crops in 2010 and 2011.

Treatment	Energy Consumed (EC)	Seed Energy Output (SEO)	Energy Efficiency
	(MJ/acre)	(MJ/acre)	(SEO/EC)
Perennial Ryegrass			
Spring N + PGR	8,760	11,659	1.33
Spring N	8,485	8,898	1.05
PGR	4,355	4,338	0.99
Control	4,080	5,252	1.29
Tall Fescue			
Spring N + PGR	7,589	8,151	1.07
Spring N	7,314	5,546	0.76
PGR	4,277	5,570	1.30
Control	4,001	5,567	1.39

Table 2. Effect of spring N and PGR on energy use and efficiency for seed and straw co-products produced by grass seed crops in 2010 and 2011.

Treatment	Seed and Straw Energy Output (SEO)	Energy Efficiency
	(MJ/acre)	(SEO/EC)
Perennial Ryegrass		
Spring N + PGR	44,138	5.04
Spring N	45,777	5.39
PGR	17,458	4.01
Control	20,867	5.11
Tall Fescue		
Spring N + PGR	51,198	6.75
Spring N	53,370	7.30
PGR	40,052	9.36
Control	46,700	11.67

EVALUATION OF FERROXX® SLUG BAIT FOR CONTROL OF GRAY FIELD SLUGS IN WESTERN OREGON

N.P. Anderson

Introduction

Slugs continue to be a pest of economic importance in western Oregon crop production. Several types of materials including metaldehyde and iron phosphate containing baits and sprays are currently used for control. However, damaging slug populations continue to be observed in many fields, especially in no-till seeding and high residue situations.

The new Ferroxx® (Neudorff North America) bait contains the active ingredient sodium ferric EDTA. Only recently did slug baits containing this compound become commercially available in the United States. However, EDTA baits have been used in other parts of the world since the mid 1990's. Like other iron materials, EDTA baits need to be consumed by the slug before death can occur, which usually takes place away from the bait or underground. The objective of this study was to evaluate a new commercially available bait for control of slugs in western Oregon.

Materials and Methods

The study was conducted in a Washington County red clover seed field during October and November, 2011. The field was in its second year of production and had not received tillage for 5 years. At this site, 50 ft. x 50 ft. plots were established in a randomized complete block design and replicated 3 times. Four molluscide treatments included: 1) untreated control; 2) Deadline MP® pellet bait applied at 10 lbs/acre; 3) Ferroxx pellet bait applied at 10 lbs/acre; and 4) Ferroxx pellet bait applied at 20 lbs/acre. Baits were applied with a rotary bait spreader. Treatments were established in an area of the field where heavy slug populations were documented prior to baiting. Baits were applied at dusk when temperatures were between 50-55°F, soil moisture was present, and wind speed was less than 10 MPH.

Slug populations were evaluated prior to and post-application of test materials. Three 18 in. x 18 in. slug blankets (designed by Liphatec Inc.) were soaked in water and randomly placed and secured in each plot. The study began on October 13. Number of slugs per blanket was recorded 2 days prior to application of all treatments, 2 days post-application, and at 7, 10 and 14 days after treatment application. At each evaluation, slugs were removed and blankets were re-wetted and set out in a new location within the plot.

Data were statistically analyzed using ANOVA and LSD. Slug days were calculated by averaging the number of slugs counted per plot on a given evaluation day by the number of slugs counted in the same plot on the previous evaluation day. This average was then multiplied by the number of days between the two evaluation days.

Results

Pre-bait evaluations revealed high numbers of gray field slugs (*Deroceras reticulatum*) present at the site. All treated plots significantly reduced slug numbers compared to the control plots *($P \leq 0.10$)*. There was no significant difference between plots treated with Deadline MP and Ferrox. Additionally, there was no significant difference between 10 lbs/acre and 20 lbs/acre Ferroxx treatments (Table 1). A sharp increase in slug numbers occurred in the untreated control plots (Figure 1). Weather events, including warm temperatures at night during that period, most likely influenced higher numbers of slugs found at the surface in the untreated plots.

Table 1. Slug days[1] per blanket in a 2 year old no-till red clover field in Washington County, OR.

Treatment	Rate	Slug Days / Blanket[2,3]
Control	0	183.7 a
Deadline MP	10 lbs/acre	96.6 b
Ferroxx	10 lbs/acre	120.7 b
Ferroxx	20 lbs/acre	121.1 b

[1] Slug days were calculated by averaging the number of slugs counted per plot on a given evaluation day by the number of slugs counted in the same plot on the previous evaluation day. This average was then multiplied by the number of days between the two evaluation days.
[2] Each plot contained 3 blankets per plot, totaling 9 blankets.
[3] Means were separated using LSD (0.10) test. Means followed by different letters are significantly different.

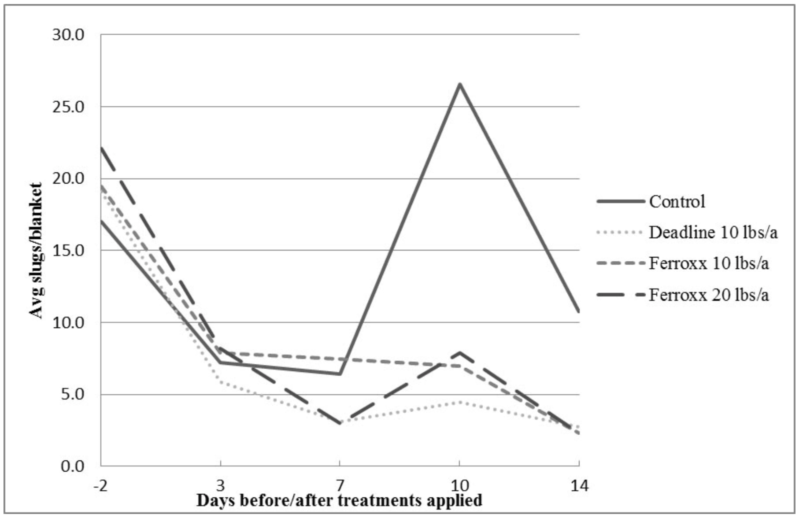

Figure 1. Slug counts (means) from monitoring blankets in Washington County, OR.

This study indicates that economic control of large slug populations continues to be a challenge in western Oregon. Results of this study indicate that Ferroxx, in addition to older metaldehyde and iron phosphate baits, can effectively reduce slug populations. The efficacy of each of these materials is likely to vary between fields, years, population age, and environmental conditions. No attempt was made to quantify differences between mixtures versus single product treatments.

Acknowledgements

This work was funded by the Oregon Seed Council/Oregon Department of Agriculture and Neudorff North America. I also extend my appreciation to Paul Coussens for the use of his field in the conduct of this study.

EFFECT OF FOLIAR APPLICATIONS OF TRINEXAPAC-ETHYL PLANT GROWTH REGULATOR ON RED CLOVER SEED CROPS

N.P. Anderson, T.G. Chastain, C.J. Garbacik, and T.B. Silberstein

Introduction

The use of foliar applied plant growth regulators (PGRs) has become commonplace on temperate grass crops grown for seed in Oregon and other parts of the world in the last decade. This practice has been adopted due to well documented seed yield increases and reduction in lodging (Chastain et al., 2003; Rolston et al., 2004). Little research has been conducted on the use of PGRs on legumes in Oregon, though some work conducted on red clover during the late 1980s showed reduced stem length and lodging and improved seed yields with soil applications of uniconazal and paclobutrazol (Silberstein et al., 1996). The soil applied products are not currently available for commercial application in seed crops due to issues with longevity in the soil and residual activity on subsequent crops.

Excessive growth of red clover interferes with maximum seed production and harvest. Lodging can also result in increased problems from disease and can reduce the number of inflorescences available for pollination. Stem elongation and flowering of red clover are long-day responses mediated by the plant hormone gibberellic acid (Lunnan, 1989). Trinexapac-ethyl (TE), commercially known as Palisade® EC or Moddus®, is a plant growth regulator that inhibits gibberellic acid biosynthesis which has resulted in a positive effect in controlling plant height and improved yield in grass and other seed crops.

Data from a study conducted in Norway reports a 21% seed yield increase in red clover crops when trinexapac-ethyl was applied at stem elongation (Øverland and Aamlid, 2007). In 2004, Moddus was registered for use on red clover seed crops in Norway. In this article we summarize the results from six on-farm trials designed to measure the effect of TE in western Oregon.

Materials and Methods

Large scale, on-farm trials were established on six commercial red clover seed fields in Washington and Clackamas counties in 2010 and 2011. The experimental design for the on-farm trials was a split-plot with treatments arranged in randomized complete blocks. Main-plots were farm research sites and sub-plots were PGR rate and timing treatments and an untreated control. Individual plots were 20 to 25 ft. wide by 300 ft. long. Treatments were applied with an ATV mounted boom sprayer equipped with TeeJet 11002 VS nozzles at 30 psi applying a spray volume of 14 gpa. No surfactant was used. Early applications were made when the crop was initiating stem elongation (BBCH scale 32), late applications were made when the crop in the bud emergence stage (BBCH scale 50), and split applications were made at these timings at a 1.7 pt/acre rate.

Plots were sampled at peak bloom for fertile head counts, stem counts, canopy height measurements, lodging scores, and above ground biomass dry weights. Plots were swathed and combined using grower equipment. A weigh wagon was used to determine seed yields harvested from each plot. Sub-samples of the harvested seed were collected to determine thousand seed weight, percent cleanout, and calculate total clean seed weight.

Results

No interactions of farm research site and TE treatments were evident in 2010; however, interactions were observed in seed yield, heads per square foot, canopy height and lodging score in 2011 (Table 1). Examination of the interaction effects suggested that the TE was more effective in seed yield modification and other aspects of plant performance at some farm sites than at others in 2011 (from analyzed data, but not presented here). Significant differences were observed in seed yield among farms in 2010, and for seed yield and several other characteristics in 2011. Seed yield and seed weight were affected by TE treatments in both years (Table 1). Heads per square foot and canopy height were also influenced by the application of TE in 2011. Trinexapac-ethyl did not affect lodging score, the above-ground dry weight or the number of primary stems in the red clover seed crop.

In 2010, TE treatments increased red clover seed yields by 15 to 34 percent above the untreated control (Table 2). Seed yield was significantly increased by TE when applied late at 1.7 pt/acre or when 3.4 pt/acre was split between early and late timings.

Table 1. Analysis of variance for TE treatment in on-farm trials with red clover seed crops in 2010 and 2011. On-farm trials were conducted at 2 farms in 2010 and 4 farms in 2011.

Source of variation	Clean seed yield	Seed weight	Head number	Canopy height	Lodging score	Dry weight	Primary stems
2010							
Farm (A)	***	NS†	--	--	--	--	--
TE (B)	*	*	--	--	--	--	--
A X B	NS	NS	--	--	--	--	--
2011							
Farm (A)	***	***	***	NS	**	NS	*
TE (B)	***	***	***	*	NS	NS	NS
A X B	*	NS	*	*	***	NS	NS

*$P \leq 0.05$.
**$P \leq 0.01$.
***$P \leq 0.001$.
†Not significant.

Table 2. Effect of TE timing and application rates on red clover clean seed yield and thousand seed weight in 2010.

TE timing and rate	Clean seed yield	Seed weight
(pts/acre)	(lbs/acre)	(mg/1000)
Control	308 a†	1.61 ab
Early 1.7	353 ab	1.70 b
Early 3.4	374 ab	1.63 ab
Late 1.7	414 b	1.59 ab
Split 1.7	414 b	1.53 a

† Means followed by the same letter are not different. $P \leq 0.05$.

In 2011, TE increased seed yield by 5 to 13 percent above the untreated control (Table 3). Three of the four TE treatments significantly increased red clover seed yield. In both years, the split 1.7 pt/acre treatment ranked among the best for increasing seed yield. Thousand seed weight was inversely related to seed yield; treatments producing highest seed yield had the lowest seed weight. Heads per square foot were increased by all TE treatments. The early 3.4 pt/acre treatment reduced canopy height, and that tendency was evident but not significant in other TE treatments.

Table 3. Effect of TE timing and application rate treatments on red clover clean seed yield, thousand seed weight, heads/ft^2, and canopy height in 2011.

TE timing and rate	Clean seed yield	Seed weight	Heads^2	Canopy height
(pts/acre)	(lbs/acre)	(mg/1000)	(no./sq ft)	(cm)
Control	991 a†	1.88 c	90 a	54.0 b
Early 1.7	1059 b	1.85 bc	114 b	51.2 ab
Early 3.4	1080 bc	1.81 ab	133 b	48.1 a
Late 1.7	1036 ab	1.82 ab	114 b	49.3 ab
Split 1.7	1117 c	1.79 a	121 b	48.5 ab

† Means followed by the same letter are not different. $P \leq 0.05$.

Discussion

In both years of this study, red clover grown for seed was responsive to TE applications. The cause of the seed yield increase seems to come from several factors including increased production of seed heads and reduction of canopy height. Field observations over the two years of on-farm trials indicate that in addition to increasing seed yield, TE treatments also promoted earlier maturation of the crop thereby allowing more timely harvest operations.

An important part of using this compound will be identifying the optimum rate and stage of crop development to apply TE for maximum effect. Additional studies are needed to determine such information. However, it appears that TE shows considerable promise for beneficial modification of the canopy of the red clover seed crop and for increasing seed yield under Oregon conditions.

Acknowledgements

Appreciation is extended to the Agricultural Research Foundation and Syngenta Crop Protection, Inc. for their financial assistance with the project. Appreciation is also expressed to the growers who provided land, time and use of equipment for the conduct of these trials.

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EVALUATION OF INSECTICIDES FOR MANAGEMENT OF CLOVER CROWN BORER IN RED CLOVER SEED PRODUCTION IN THE WILLAMETTE VALLEY

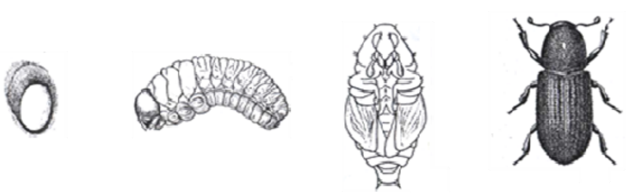
S. Rao, A.R. Corkery, N.P. Anderson and G.C. Fisher

Red clover is raised for seed in the Willamette valley on over 15,000 acres. Due to its nitrogen fixing abilities it is an important rotation crop for grass seed and wheat. The Willamette Valley not only produces very high red clover seed yields, but is also ranked first for total production in the United States (NASS, 2009).

Red clover is a perennial but in the Willamette Valley, by the end of the second year, the crop stand is very poor due to infestation by the clover crown borer. This insect pest, also known as the clover root borer, is a minute bark beetle, native to Europe. It has infested red clover fields in the Willamette Valley for over 100 years. It is one of the principal factors limiting the longevity of red clover stands after the second year crop, and frequently causes substantial yield losses due to severe infestation, even in first year crops.

The clover crown borer has been observed to attack a range of leguminous crops including peas, vetch, alfalfa, alsike, mammoth and red clover. However, it appears to prefer red clover and mammoth clover (Rockwood, 1926).

All life stages of the clover crown borer pest (Figure 1) develop underground. Due to its minute size and subterranean life cycle, the pest is difficult to detect in the field. Adult beetles, 0.1 inch long and dark brown, are present briefly above ground in the spring when they emerge, mate and then migrate from old clover fields to young clover fields. The remainder of the life cycle occurs below ground where they feed on red clover roots. Beginning in late April and May, females lay eggs in niches in the walls of burrows made in clover roots. Each female lays approximately 20 eggs over her life span. Eggs hatch in 17-30 days. Larvae are creamy white and burrow within the roots of red clover. The larvae develop slowly over the summer, and pupate in pupal chambers at the end of the larval mines inside the clover root. The pupal period lasts 8-13 days. Adults are fully formed by late summer but remain below ground.



Egg Larva Pupa Adult

Figure 1. Life stages of clover crown borer.

The pest overwinters primarily in the adult stage, although a few larvae are also present in the soil in winter and transform to adults the following spring. The total development period from egg to adult is 90 days or more while the total life span of an individual may last a year or longer. As the egg laying period extends over a considerable length of time, there is great diversity in stages of development of the pest within a clover root at any given time from late spring to fall. The pest undergoes one generation a year (Rockwood, 1926).

The earliest injury to new clover (first crop, seeded the previous fall), is observed in the spring, one to two weeks after the first adult migratory flight (Rockwood, 1926). Both males and females feed on the roots and crowns of the red clover plant. Simultaneous attacks by 5-6 root borers on one small root often causes the root to girdle which results in wilting and early death of the plant. This occurs in April and May. However, greater damage occurs in the summer and fall due to feeding by larvae and young adults. As many as 45 larvae have been observed in a single root, at varying stages of development. Feeding by larvae and adults hinders nutrient and moisture transport inside of the plant. As a result, infested plants turn brown, wilt, and die (Rockwood, 1926). Thus, damage by CCB results in a decrease in both forage yield and seed production in the subsequent year. Mining caused by the pest often becomes a site for infection by root rot fungus and other pathogens that also contribute to a decline of clover stands (Rockwood, 1926). A third year of seed production is generally not economical.

Since the clover crown borer undergoes most of its life cycle below ground, confined to the interior of host roots, control with insecticides is a challenge. Nonetheless, organochlorine pesticides similar to DDT proved to be effective in the past (Gyrisco and Marshall, 1950; Gyrisco et al., 1954). However, organochlorine insecticides are no longer available due to their persistence and toxic impacts on the environment. Currently, no labeled insecticides exist for controlling this pest. With the current economic downturn, there is renewed interest in clover crown borer management as red clover producers are seeking to reduce costs associated with reseeding or with crop removal and field preparation for a different crop. Hence, the objective of this study was to determine whether currently registered insecticides labeled for use in red clover seed production are effective in controlling the pest.

Material and Methods

The experiment was conducted in a red clover seed production field in Albany, Oregon, in 2011. The experiment was set up in a randomized block design with four replications. The following insecticides were applied in July using labeled rates: 1) Brigade® 2EC; 2) Carbaryl® 4L; 3) Lorsban ® Advanced; 4) Seduce® Spinosyn A and D; and 5) Control (no insecticide). In November, after the rains commenced and it was possible to dig plants, 10 plants were removed from each plot and placed in Berlese funnels at OSU to estimate the numbers of adult crown borers per plot.

Results

The results indicated that there were no statistical differences in the numbers of adults across the various treatments (P=0.29). However, the plots sprayed with Brigade and Lorsban had fewer adults compared to the other treatments and the control (Figure 2). Hence, further studies are warranted for a closer look at the impacts of these insecticides on clover crown borer adults.

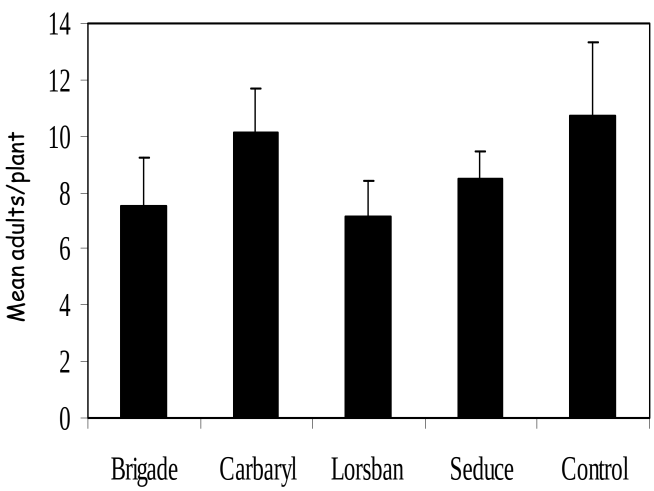


Figure 2. Comparison of the average number of clover crown borer adults in plots treated with insecticides in a red clover seed production field in 2011.

Discussion

The clover crown borer is a challenge to manage with insecticides currently labeled for use in red clover seed production. These are safer to the environment but less persistent as compared to the organochlorines which were effective in the past. However, it is possible that precise timing of the application of insecticides such as Lorsban and Brigade to coincide with the brief period when the adults emerge and disperse to infest new plants may provide an effective management tactic. Further research to determine if this is indeed possible, is planned at OSU.

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EVALUATION OF CHEMICAL AND MECHANICAL METHODS FOR MAINTAINING STAND PRODUCTIVITY IN FINE FESCUE SEED CROP PRODUCTIONS SYSTEMS IN THE ABSENCE OF OPEN FIELD BURNING, 2011

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

There are no effective non-thermal post-harvest residue management practices available that maintain an economic yield over the life of the stand (5 years +) in fine fescue seed production for Western Oregon. Seed yields typically decline following the first harvest in the absence of field burning. Yield declines of 10 to >50% were measured in research trials (Young et al., 1998; Zapiola et al., 2006) where non-thermal treatments such as baling and flail chopping the stubble were used. More aggressive stubble management improved yields over just baling, but it was still lower yielding and not an economic substitute for field burning given the added cost of baling and flail chopping.

The primary obstacle in fine fescues (and Kentucky bluegrass) is the need to expose the lower crown area at the soil surface (Meints et al., 2001; Chastain et al., 1997) and to minimize the amount of crop residue remaining. Research has been conducted on both fine fescues and Kentucky bluegrass in an effort to determine a way to substitute field burning with a non-thermal mechanical method. Vigorous fall tillers that are the major contributor to seed yield originate from the crowns of established plants (Canode and Law, 1979). In addition to the need for crown tillers to predominate, the creeping habit of red fescues also can cause excessive crowding in the stand and limit the size and capability of the new tillers. If stand conditions are too crowded in the fall, tillers will not respond to the vernalization process that occurs during the winter resulting in reduced seed production.

With these two factors in mind, residue management and stand crowding, this research will determine if there is a lower cost way of encouraging strong tiller development in the fall using two different strategies:

1) Use row spraying technology (Young et al., 1996) to reduce overcrowded stands and strengthen growth of rows.
2) Rather than flailing the whole stand to expose plant crowns for regrowth, no-till row cleaners will be used to expose row strips on regular intervals. Improved light penetration should increase growth in the exposed rows and shade all areas between the rows to act as a cover mulch.

Procedures and Results

Trials were established in cooperating grower fields. Table 1 lists the different fields and stand ages that were used in these trials. Treatments in fields varied depending on the primary residue removal that was used following harvest. Additional treatments in non-burned fields/field sections include rowspray treatments (using a 2% glyphosate solution) and/or mechanical row cleaner (thatching) treatments. All sites were either baled + flail chopped (BFC) or had the full straw load flail chopped back on the stand in unburned treatments. Rowspray (RS) and rowcleaner (RC) treatments were applied in the late fall or spring using equipment purchased with the grant for this project. A tractor from one of the farms was used to operate the equipment. Plots were large ~25-50 ft. wide and ~300 ft. long to facilitate grower harvest.

In addition to harvesting for seed yield, foot-row samples were taken at maturity to determine fertile tiller number, height, and specific dry weight (dry weight per tiller).

<u>**Site 1**</u>. This site is a long term trial that was started in fall 2008 following the first seed crop harvest. The 34 acre field was divided into four equal quarters (Figure 1) to examine different residue management practices over the life of the stand. Table 2 lists the sequence of post-harvest residue treatments imposed for the second through fourth seed crops. One quarter of the field (SE) was open burned (OB) every year as a reference treatment and one quarter of the field (NW) had a BFC residue treatment each year and was not open burned for the life of this study. The other two quarters alternated between BFC and OB on either odd or even crop years to determine if yields can be maintained with alternating annual open burns. The rowspray trial was imposed only within the continuous BFC section of the field. Rowspray treatments were applied in fall 2009, spring 2010 and spring 2011 to determine if the timing/stand age is important in maintaining or renovating stands. The rowspray trial is designed as a five treatment randomized complete block with three replications.

Table 1. Creeping red fescue fields with non-burn residue treatments, 2009-2011.

Site	Farm	Variety	Stand age (yrs)	2009	2010	2011
1	Doerfler Farms	Wendy Jean	2-4	X	X	X
2	Ioka Farms	Lustrous	3,4	X	X	
3	Ioka Farms	Lustrous	6,7		X	X
4	Victor Point Farms	Foxfire	5,6		X	X
5	Smith Farms	Garnet	3			X

Field Study

In the larger quartered field study, yields for 2009 (2nd crop) were about the same for either the BFC or the OB treatments (only two treatments for 2009). However, in 2010 (3rd crop), the two field sections that received the fall 2009 BFC treatment yielded about 300-400 pounds per acre less than the OB treatments. For field sections in 2009 or 2010, the effect on seed yield from treatment in 2008 or 2009, respectively, did not seem to carry into the second crop year. Both 2009 and 2010 open burned sections yielded similarly even though the previous year one of the quarters had the BFC treatment. In contrast, the two sections with the BFC treatment in 2009 had lower yields in 2010.

Seed yields from the third year treatments (2011 crop) depended on the three year sequence of treatments. The continuous BFC treatments yielded 350-450 pounds per acre less in 2011 than treatments that had at least one OB year. The other three treatments were within 100 pounds per acre yield with the continuous OB yielding the highest, the BFC/OB/BFC intermediate and the OB/BFC/OB a little less. Averaging the seed yield over the three crop years, the BFC/OB/BFC sequence produced yield that was similar to the continuous OB sequence. The OB/BFC/OB sequence and the continuous BFC treatment averaged about 150 and 300 pounds per acre, respectively, less than the continuous OB sequence. At $0.70/lb for seed, this equates to about $210 per acre reduced revenue and $630 per acre reduction over the three years with the FBC management. In this field, the even year rotation (one OB in the third crop year) yield was similar to the continuous three year OB sequence.

Rowspray trial

Yield data from the replicated trial within the continuous BFC section are also reported in Table 2. Seed yields in 2010 for the fall 2009 RS and the untreated BFC were very similar and very close to the field yields that were measured for the NW quarter of the field. Even though at least 50% of the stand was sprayed out, the plants were able to compensate and yield a little higher than the untreated BFC treatments. Seed yields in the second year following the rowspraying were significantly increased over the untreated BFC plots in both the fall and spring RS treatments. Row cleaner treatments were not very effective and the main impact on yield and growth was a result of the RS treatments; also, difficulties in plot harvesting prevented measuring data from RC treatments. The spring RS was very effective at stand thinning and removed over 75% of the stand resulting in a reduction of fertile tillers at harvest the first year of treatment. The spring RS plots in both years (2010, 11) were unable to compensate for this initial loss of fertile tillers causing seed yield to drop dramatically to about half of the other treatments. However, in the subsequent year, spring RS resulted in the highest overall yield. Biomass and fertile tiller densities parallel seed yield impact for both years (Tables 3 and 4), and the measured improvement in seed yield in the second crop year following the spring RS as shown with the spring RS 2010 data in Table 4. Overall, the fall 2009 rowspray gave the highest average seed yield and was intermediate between treatments that had any type of OB treatment and the continuous BFC. This treatment averaged about 100 pounds per acre more than BFC, so was effective in increasing yield but not as effective as OB treatments.

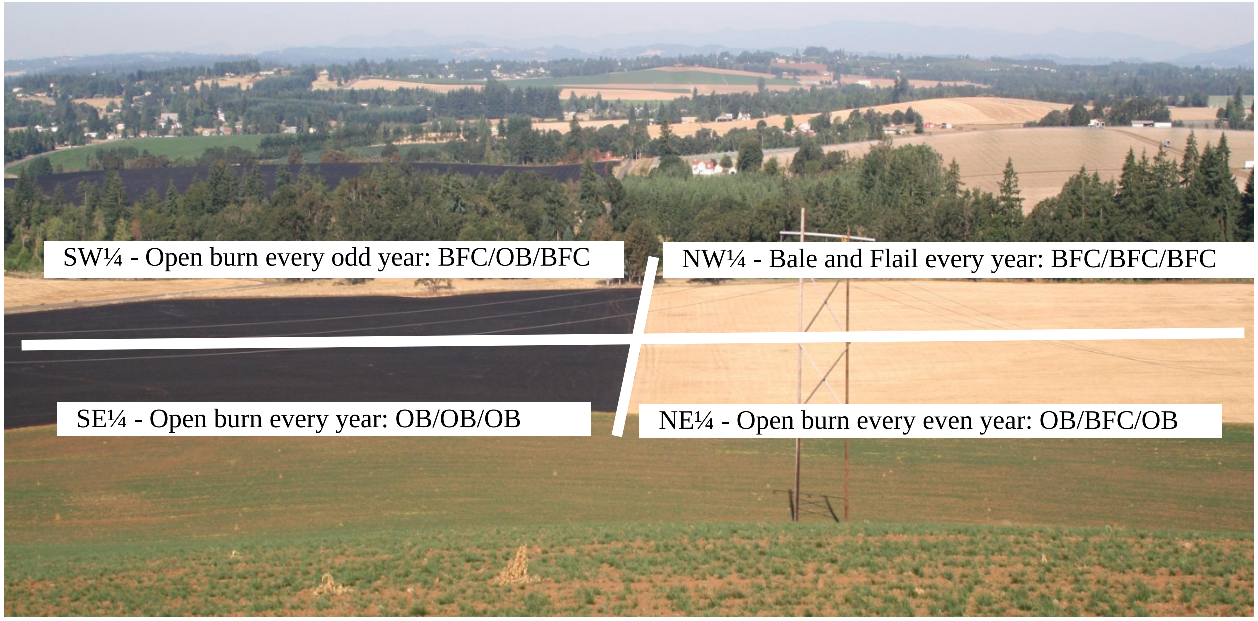

Figure 1. Doerfler field following OB on second sequence year, fall 2009.

Table 2. Site 1 - Doerfler Farms yield summary 2009-2011, Wendy Jean creeping red fescue.

Field quarter	**Post harvest residue treatments** Fall 2008/2009/2010	seed yield (lb/a)[1] 2009	2010	2011	3 yr avg.
NW	BFC / BFC / BFC[2]	1710	1822	1346	1626
SW	BFC / OB / BFC		2254	1746	1903
NE	OB / BFC / OB	1690	1909	1708	1769
SE	OB / OB / OB		2275	1803	1923

[1] Numbers followed by the same letter are not significantly different by Fishers protected LSD 0.05 (0.10)
[2] BFC = Bale + Flail, OB = Full straw open field burn

Replicated Trial within BFC only section	2010		2011		3 yr avg.[3]
Untreated	1884	a	1314	b	1636
Fall RS 2009	1940	a	1529	a	1726
Fall RS + RC 2009			1572	a	
Spring RS 2010	740	b	1648	a	1366
Spring RS 2011			892	c	1495

[3] 3 yr average uses untreated yield for years without treatments (1710 lb/a for 2009, 1884 lb/a for 2010)

Table 3. Tiller data, 2010

Farm	Treatment	Total dry wt	Fertile tillers	Dry wt	Plant height
		per ft-row 10" spacing			
		(g)	(no.)	(mg/tiller)	(cm)
Site 1 - Doerfler Farms (bale+flail)					
	Untreated check	75.8	246	248	74.6
	Fall 2009 RS	73.8	257	228	76.6
	Fall 2009 row cleaner + RS	74.1	266	297	77.8
	Spring RS 2010	56.0	129	257	74.3
	Untreated check	90.3	347	211	77.6
Site 3 - Ioka Farms Strips (full straw load flailed)					
	Disk/regrow	50.8	173	261	64.9
	Untreated	87.8	326	235	74.3
	Thatch	76.6	315	231	71.6
	Fall RS	75.0	280	229	74.7
	Spring RS	41.8	133	253	61.3
Site 4 - Victor Point Farms					
	Residue main factor				
	Full straw load flail chop 1X	53.8	184	220	70.1
	Bale + Flail chop 1X	60.1	233	210	69.9
	Rowspray main factor				
	Untreated	58.1	237 a	194	70.2
	Fall row cleaner + RS	46.6	150 b	236	68.2
	Fall RS	66.2	238 a	215	71.6

[1] Numbers followed by the same letter are not significantly different by Fishers protected LSD 0.05 (0.10)

Table 4. Tiller data, 2011

Farm	Treatment	Total dry wt (g) per ft-row 10" spacing		Fertile tillers (no.) per ft-row 10" spacing		Dry wt (mg/tiller)	Plant height (cm)	
Site 1 - Doerfler Farms (bale+flail)								
	Untreated check	74.1	c[1]	174	b	202	69.2	a
	Fall 2009 RS	85.6	b	257	a	229	67.1	a
	Fall 2009 row cleaner + RS	89.1	b	250	a	225	69.5	a
	Spring RS 2010	103.7	a	292	a	251	69.2	a
	Spring RS 2011	52.4	d	116	c	216	59.6	b
Site 3 - Ioka Farms Strips (full straw load flailed)								
	Disk/regrow	73.4		194		266	63.4	
	Untreated	67.6		191		230	66.3	
	Thatch	53.1		157		216	62.9	
	Fall RS	67.1		189		238	69.9	
	Spring RS	145.9		188		243	68.1	
Site 4 - Victor Point Farms								
	<u>Residue main factor</u>							
	Full straw load flail chop 1X	44.5	(b)	210		175	58.8	(b)
	Bale + Flail chop 1X	54.0	(a)	228		197	61.0	(a)
	<u>Rowspray main factor</u>							
	Untreated	45.7		213		175	59.1	
	Fall row cleaner + RS	50.9		214		198	61.7	
	Fall RS	51.1		229		185	58.9	
Site 5 - Smith Farms (bale+flail)								
	Untreated check	67.2		160		196	64.6	
	Spring RS 2011	30.5		40		177	46.3	
	Fall RS 2011	73.3		141		227	62.5	

[1] Numbers followed by the same letter are not significantly different by Fishers protected LSD 0.05 (0.10)

Figure 2. Untreated plot at Doerfler site, Fall, 2010.

Figure 3. Fall 2009 RS plot at Doerfler site, Fall, 2010.

Figure 4. Spring 2010 RS plot at Doerfler Site, Fall, 2010.

Site 2 – This site is a stand of creeping red fescue in its fourth crop harvest. The area for the row-spray treatments was baled and flail chopped. The design of this site was a randomized complete block with treated (row-sprayed) and untreated plots. Treatments were applied as in the previous trial. Row-spray treatments were not very effective in taking out much of the stand and thus, there was very little difference in the seed yields between row-spray treatment and untreated plots (Table 5). Seed yield from open burned areas adjacent to the non-burned area was about 250 pounds per acre greater. The previous year (2009), an area with a BFC treatment was compared to the open burn in the rest of the field. One year without burning decreased seed yield from 1537 lb/a to 1008 lb/a, a 1/3 drop in yield.

Site 3 – This site is an older stand (6th and 7th crop) of creeping red fescue that was declining in yield. The treated areas all had a full straw load flail chopped and left in the field. Treatments were applied in single strips approximately 50 ft. wide and 350 ft. long. The disk/re-grow treatment was done by the grower to renovate the stand. This strip was disked after harvest several times and left to re-grow. The untreated portion had the full straw load left on the field. The thatch treatment was applied by going over the area 4-5 times with the row cleaner in an attempt to cut out portions of the stand. The fall row spray was applied in November with nozzles set to spray a band width of about 6 inches spaced on 12 inch centers in an attempt to take out about 1/2 - 2/3 of the stand. The spring row spray was applied in mid March at the onset of rapid regrowth.

Seed yields were dramatically lower in the spring row-spray in 2010 (Table 5). There were also a lot fewer and shorter fertile tillers in this treatment (Table 3), which may have caused the lower yields. The spray out removed about 75% of the stand and it was unable to recover. All other treatments were comparable in yield. Regrowth on the spring row-spray was very good after harvest and the stand looked healthy with strong rows formed. For the 2011 harvest, the spring 2010 RS yielded the highest, at 937 lb/a compared to the untreated plots at 725 lb/a. The grower treatment of disking was the second highest treatment yield. From this data, any of the treatments improved yield in the second year of production following the treatments.

Site 4 – This site is an older stand (5th and 6th crop) of creeping red fescue that was declining in yield. A three acre section of the field was cordoned off to apply treatments. One-half of the area had the full straw load flail chopped in place and the other half was baled before flail chopping. The rest of the field was open burned. Row-spray (RS) treatments were applied across both residue regimes in November, 2009. Plots were 25 ft. x ~300 ft. and the trial was arranged in a split-block design with main treatments as either full straw load or baled + flail, and subplot treatments using row-spray (RS) /row-cleaner (RC) treatments replicated three times. Treat-ment combinations are listed in Table 6. The fall row-spray was applied in November 2010 with nozzles set to spay a band width of about 6 inches on 12 inch centers in an attempt to take out about 1/2 - 2/3 of the stand. The row-cleaner was operated in unison with the row-sprayer to thatch the strips between the nozzles that were not receiving the row-spray.

Table 5. Seed yield responses to row spraying and residue management in additional trial fields, 2009-2011.

Location	Seed yield (lb/a)	
Site 2. Ioka Farms, Lustrous creeping red fescue.		
	2009	2010
Open burn (field tmt)	1537	1481
Bale + FC (untreated)	1008	1255
Fall 2009 RS		1183
Site 3. Ioka Farms, Lustrous creeping red fescue.		
	2010	2011
Disk 2009/regrow	1018	875
Untreated	1047	725
Thatch fall 2009	1017	807
Fall 2009 RS	931	836
Spring 2010 RS	529	937
Site 5. Smith farms- Garnet creeping red fescue.		
		2011
RS spring 2011		322
Untreated		616
Untreated		670

The full straw main plot treatment reduced seed yields compared to the BFC treatments by about 200 pound per acre. There was also higher cleanout with the full straw load residue treatment as well as fewer fertile tillers (Table 3). Yields were somewhat lower in the RS+RC treatment. The two RS treatments were applied on sequential days and the effect of the row-spraying was much greater in the second day due to better spray conditions when the RS+RC treatments were applied. This may explain some of the differences in yield. Enough of the stand was taken out that the remaining stand was unable to compensate for the difference. Fertile tiller counts were significantly lower in the RS+RC treatment (Table 3) and were probably the main cause for differences in yield. Seed yields for the rest of the field were measured from windrows combined in the adjacent open burn area to assess a reference open burn field yield. The open burn strips were ~300 pounds per acre greater than the non-burn residue regime. The plot areas were open burned along with the rest of the field in 2011. Seed yields measured in 2011 were not affected by any of the treatments, nor by the residue main factor the previous year. There were some minor differences in dry matter production in the plots (Table 4) but none affecting yield.

Site 5 – This site was established in the winter of 2010-11 to test spring RS and fall RS the following year. The first set of treatments were sprayed in the spring 2010. The effect of this spring RS was similar to the other spring RS treatments at sites 1 and 3. Total dry weight and fertile tiller densities were impacted by the spring RS (Table 4), and seed yield (Table 5) was reduced by about half from 670 pounds per acre to 322 pounds per acre.

Benefits and Impacts

These trials were established to determine what would be the best, low cost post-harvest management method in the absence of burning, so open-burn treatments were not incorporated into the primary treatment areas. Row-spraying is effective at reducing the stand and taking out excessive growth. The thatch treatments that were applied did not do much to the stand and essentially any effect disappeared by mid-winter. This type of treatment needs to be much more aggressive and must remove a larger portion of the stand than was observed in this trial. A major finding in these trials was that in most cases, spraying out at least half of the stand in the fall did not reduce yields the year of treatment (except the RS+RC treatment at site 2). The plants were able to compensate for this loss in stand at harvest. Spring rowspraying generally had a negative effect on the current year crop, but the same

Table 6. Victor Point Farms (Site 4) seed yield summary 2010-2011. Foxfire creeping red fescue.

	Seed Yield (lb/a)		
Field strips	**2010**		**2011**
(open burn):	1499		863
Main factor comparisons			
Residue main factor			
Full straw flail 1X	1043	b[1]	843
Bale + Flail 1X	1258	a	825
Rowspray main factor			
Untreated	1181	(ab)	800
RS+RC	1012	(b)	874
RS only	1259	(a)	828
Two way table: sub-factor comparisons			
Full straw load Flail chop 1X 2009 only - open burn fall 2010			
Untreated	1102		790
RS+RC	910		920
RS only	1119		818
Bale + Flail chop 1X 2009 only - open burned fall 2010			
Untreated	1260		811
RS+RC	1115		827
RS only	1399		838

[1] Numbers followed by the same letter are not significantly different by Fishers protected LSD 0.05 (0.10)

treatments also had vigorous growth in the subsequent fall and demonstrated increased yields in the second year compared to the other rowspray treatments. Additionally, at all sites where the crop was followed for a second year after the rowspray treatments, all of the treatments improved yields over the untreated standard (bale + flail) treatment. This response seems to be intermediate to a full open field burn but can be an effective tool in extending the productivity under non-burn management.

This suggests that if a grower would want to reduce the number of fields that will be open burned, it may be best to allocate the open burns to older stands and/or try alternative treatments in the second or third year to keep the stand productive. This will permit the grower some flexibility in managing fields earlier in the season when burning is limited. The effect on long-term results of alternative residue management such as Site 1 will need to be tested on other varieties and locations to determine if this is a viable option.

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EFFECTS OF POST-HARVEST RESIDUE MANAGEMENT ON SEED PRODUCTION OF ROEMER'S FESCUE (*FESTUCA ROEMERI*)

D.C. Darris and A. Young-Mathews

Introduction

Roemer's fescue (*Festuca roemeri* [Pavlick] Alexeev) is a native bunchgrass that is recommended for revegetation of upland prairies and oak savannas in the Pacific Northwest. Although it is a useful restoration species, there is little information available on seed production practices. Members of the fine fescue complex (Chewings, creeping red, and slender red fescues) and closely related sheep fescue complex (hard, sheep, Idaho and Roemer's fescues) are commonly grown for turf seed in the Willamette Valley of Oregon. According to research conducted at Oregon State University, seed yield and quality were maintained in Chewings fescue (*Festuca rubra* L. ssp. *commutata* Gaudin) seed crops without burning when most of the post-harvest straw and stubble were removed by baling and then vacuuming or raking up remaining residue (Chastain et al., 1999; Young et al., 1998). In the same study, however, there were no nonthermal management practices that produced acceptable seed yields in creeping red fescue (*Festuca rubra* L. ssp. *rubra*) fields. More recent work has shown mixed results dependent on age of stand and a newer red fescue classification: Chewings (*Festuca rubra* L. ssp. *fallax* (Thuill.) Nyman) vs. slender creeping red (*Festuca rubra* L. var. *littoralis* Vasey) vs. strong creeping red (*Festuca rubra* L. ssp. *rubra*) (Chastain et al., 2011). The objective of this study was to determine the effects of different post-harvest residue management practices (low, medium and high mowing heights with residue removal versus open field burning) on the following year's seed production of Roemer's fescue.

Materials and Methods

Plant material used: The experiment was conducted on a field of Northwest Maritime Germplasm Roemer's fescue (accession 9079484, PVGOR 101) at the Corvallis Plant Materials Center (PMC) Schmidt Farm that was sown in October 2006 (medium mow reps 2 and 3) and October 2007 (all other treatments). The field was fertilized annually in March with 50 lb N/acre (150 lb/acre 33-0-0-12), and treated annually in October with Outlook® (dimethylamid-p) herbicide and Banvel® (dicamba) in the spring as needed.

Experimental design: The experimental design was completely randomized with three replicates per treatment. Plots were 4 x 100 ft consisting of four-row beds on 12-inch spacing. Four treatments were examined: control (no mowing or residue removal), low mow (1.5- to 2.5-inch mowing height with residue and stubble mostly removed), high mow (5- to 6-inch mowing height with residue and stubble partly removed), and burn (3- to 4.5-inch mowing height but residue and stubble left and then burned). The burn treatment was analogous to "residue and stubble open-burned with full straw load" used in similar research. There was also a fifth observational treatment of medium mow (3- to 4.5-inch mowing height with residue and stubble partly removed), but it was not included in statistical analyses as that part of the field was planted a year earlier than the rest (2006). Age of stand can affect seed yields and the medium mow plots were not randomized.

Treatment implementation: Seed was harvested from all plots with a seed stripper on July 10, 2010. Post-harvest residue was mowed and removed from low, medium and high mow treatments with a flail forage harvester on August 25, 2010. Burn plots were also mowed on this date, but residue was left on the surface to simulate a windrow or swath; these plots were burned on September 8, 2010. One of the control plots was incorrectly mowed and subsequently burned, resulting in four burn plots and two controls. Therefore, one of the control plots was sampled twice.

Data collection and analysis: All plots were scored for insect damage, injury, vigor/recovery, and culm (fertile tiller) abundance on a scale from 1 to 9 (9 as highest or most) on April 27, 2011. Plots were windrowed on July 12, 2011 and combined on July 28, 2011. Seed yield data were collected from 30-ft strips (120 ft^2) of uniform plant density in each plot. Effects of treatments on seed yield, insect damage, injury, vigor, and culm abundance were tested using ANOVA and Tukey HSD means comparisons in Statistix 8.1.

Results and Discussion

Results of seed yields and plot scoring for all four treatments, plus the observational fifth treatment, are given in Table 1. All mowed and burned treatments had higher seed yields than the un-mowed control (F=13.9, P=0.0015). Although the treatments did not differ

Table 1. Results of 2011 study on post-harvest residue management of Roemer's fescue at the Corvallis PMC.

Treatment	Seed yield	Insect damage	Injury	Vigor/ Recovery	Culm abundance
	(lb/a)	----- (scored on 1-9 scale, with 9 high/most) -----			
control	42.9 b*	2.7 ab	1.0 a	7.3 a	1.3 c
low mow	152.6 a	5.0 a	1.7 a	8.0 a	8.7 a
high mow	102.0 a	3.7 ab	1.0 a	7.7 a	5.3 b
burn	133.1 a	2.3 b	2.0 a	7.0 a	7.0 ab
med. mow	78.7	3.7	1.0	7.3	5.7

*Means in columns followed by the same letter are not significantly different in Tukey HSD tests (P = 0.05).

significantly among mowing height and burning, the low mow and burned plots tended to have the highest seed yields. Residue treatments also affected culm (fertile tiller) abundance scores (F=29.6, P=0.0001); the low mow had the most culms, followed by the burn and high mow, with the control having the least. In fact, there was a direct positive correlation between culm abundance score and seed yield (P=0.0001; Figure 1), so the higher yields in the low mow and burned plots in large part appear to be due to the greater abundance of culms on those plants. Other variables affecting seed yield such as percent seed set, seed weight, the number of spikelets per panicle, and the number of florets per spikelet could also have played a role, but were not measured.

Residue treatments also affected insect damage scores (F=4.31, P=0.04); low mow plots had the most insect damage while burned plots had the least (Table 1). Most of the observed damage was suspected to be from feeding grass sawfly larvae, as the stems appeared to have been clipped off near the base (often at an angle), although armyworm damage is also similar (Hollingsworth, 2011). Damage may have been greater in the low mow plots simply because they had a greater abundance of young foliage and more culms to attract insects to those rows. Therefore, yields may have been disproportionately reduced by insects under this treatment. In contrast, burn plots had the least amount of damage but a high abundance of culms (and recovery of foliage was not significantly less). Despite the small size of the plots and close proximity of treatments, burning may have reduced insect numbers or the desirability of such plots as habitat. The direct effect of insect damage on yield was not quantitatively assessed.

Residue management treatments did not significantly affect crop injury or vigor/recovery scores (P > 0.05, Table 1), so presumably observed differences in seed yield were not due to any direct damage to the plants from the residue management treatments.

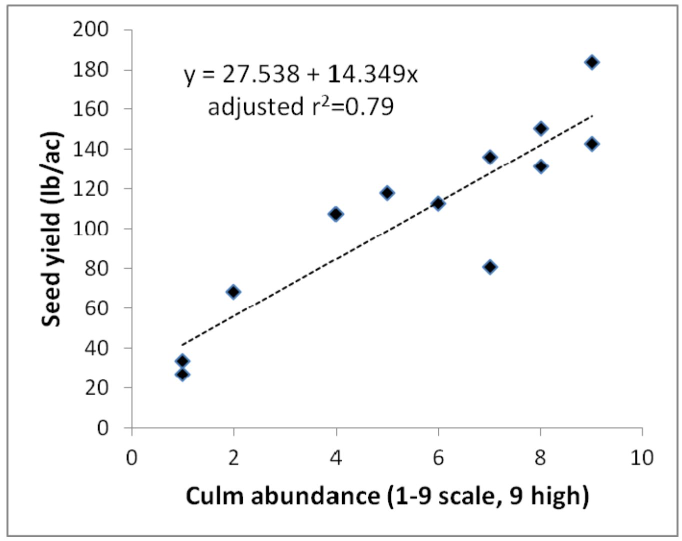

Figure 1. Relationship between Roemer's fescue seed yield and culm abundance scores in 2011 post-harvest residue management study at the Corvallis PMC.

Although it is only one year of data, results were similar to those of Chewings fescue, where mechanical removal of residue and stubble achieved seed yields similar to open field burning (Chastain et al., 1999; Young et al., 1998). Yields in this experiment are substantially lower than other fine fescues grown for seed in western Oregon, but Northwest Maritime Germplasm was not bred or hybridized, and yields of Roemer’s fescue typically decline on their own by age three. A repeat study is needed on a younger field and other germplasm.

Conclusions

If it is not possible to do open field burns on Roemer’s fescue seed production fields, comparable seed yields can still be obtained by mowing stubble low (1.5 to 2.5 inches tall) and removing all residue using a forage harvester or other method.

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EFFECTS OF NITROGEN FERTILIZER TIMING AND RATES ON SEED PRODUCTION OF ROEMER'S FESCUE (*FESTUCA ROEMERI*)

D.C. Darris and A. Young-Mathews

Introduction

Roemer's fescue (*Festuca roemeri* [Pavlick] Alexeev) is a native bunchgrass that belongs to the sheep fescue-Idaho fescue-hard fescue complex (Stace et al., 1992). Roemer's fescue is recommended for revegetation of upland prairies and oak savannas west of the Cascade Mountains from British Columbia to northwestern California (Darris et al., 2007). Although it is a useful restoration species, there is little information available on seed production practices.

Members of the red fescue complex (Chewings, creeping red, and slender red fescues) and closely related sheep fescue complex (hard, sheep, and Idaho fescues) are commonly grown for turf seed in the Willamette Valley of Oregon, and there is over 40 years of data available from research conducted by Oregon State University. According to this research, optimal fine fescue seed yields were obtained with spring (mid-February to late March) application of 30 to 70 lb N/acre (Gingrich et al., 2003). Fall (October) application of 15 to 30 lb N/acre to stimulate fall growth is optional, but the guide states that "nitrogen in the soil should be adequate for fall growth" (Gingrich et al., 2003). The purpose of this study was to determine the optimal timing and rates of nitrogen fertilization for seed production of Roemer's fescue.

Materials and Methods

An existing field of Roemer's fescue (Hyslop Research Farm, near Corvallis, OR) was used for this study. The field was 140 x 62.5 ft, with rows running north-south at 12-inch row spacing. The field was sown in October of 2007 for a carbon banded seeding trial with diuron herbicide applied immediately after sowing. Any residual carryover of diuron is expected to have dissipated by the start of this experiment in October 2009. The seed used to sow the field was harvested in 2004 from a mix of 47 accessions in a common garden study at the Corvallis Plant Materials Center; these accessions were originally collected throughout western Washington, western Oregon and northwestern California in 2001-2002. The field was fertilized once in March 2008 (the year prior to the study) at a rate of 50 lb N/acre. A standard regime of weed and disease control was used during this experiment. Outlook® herbicide (dimethenamid-p) was applied in the fall for volunteer and annual grass control and Banvel® (dicamba) was applied in the spring for broadleaf weed control. Residue was removed with a flail type forage harvester after each seed harvest. Rust was controlled with Quilt® fungicide (azoxystrobin and propiconazole) as needed. No irrigation water or other practices were applied.

Fertilizer was applied to plots according to 14 treatments (Table 1) as a granular mixture of urea and ammonium sulfate (33-0-0-12), marketed as "urea-sul," using an 8-ft wide Gandy type drop spreader. All rates are actual N/acre. Each plot was 8 ft wide and 16 ft long. In 2010, seed was harvested on July 8 from the middle of the plots with a 6-ft wide flail-vac seed stripper. Harvest occurred parallel to the seeded rows along the long axis of each plot. Plots with excessive lodging were hand-harvested in 1-m^2 subplots. In 2011, all seed was hand-harvested from 1-m^2 subplots on July 15 (mechanical harvest was not possible due to excessive lodging). Seed was cleaned and conditioned before recording plot yields. Lodging was scored prior to harvest on July 8, 2010 and July 15, 2011 on a scale from 1 to 10, with 1 being no lodging (plants completely upright) and 10 being the most lodging (plants flat). The experimental design was a randomized complete block with four replications. Data analysis consisted of ANOVA and Tukey HSD means comparisons performed in Statistix 8.1. An outlier (treatment 9, rep 2) was omitted from the 2010 data set in order to meet the assumptions of normality of variances for the ANOVA.

Results and Discussion

Mean seed yield of Roemer's fescue according to the 14 nitrogen fertilization treatments is given in Figure 1. Seed yield was significantly affected by treatments in both 2010 ($P < 0.001$) and 2011 ($P = 0.036$). In 2010, application of 50 lb N/a in February (Trt. 3) and split application of 25 lb N/a in October plus 75 lb N/a in February (Trt. 10) had higher seed yields than the control (Trt. 1) and many other treatments. Plots that received early spring fertilizer were noticeably greener and healthier looking. Nitrogen fertilization treatments also had a significant effect on lodging scores in 2010 ($P < 0.001$); plots that received the highest early spring (February and March) N rates (Trts. 6, 7, 10, 11, and 12) had higher lodging scores than the control (Trt. 1) and plots that only received fall (Trt. 2) or late spring (April) fertilization (Trts. 5, 8, 13, and 14) (data not shown). This may have been because fall fertilization rates were too low or fall-applied N was no longer available to the plant by the time fertile tiller formation began, and April application may have come too late after tillers had already formed, so tiller height and lodging were not affected.

Table 1. Nitrogen fertilization rates and timing for Roemer's fescue study at Hyslop Farm, Corvallis, 2010 and 2011.

Treatment	Year 1	Year 2
1	Control (no fertilizer)	Control (no fertilizer)
2	25 lb/a 28-Oct-09	25 lb/a 2-Nov-10
3	50 lb/a 24-Feb-10	50 lb/a 7-Mar-11
4	50 lb/a 22-Mar-10	50 lb/a 4-Apr-11
5	50 lb/a 28-Apr-10	50 lb/a 2-May-11
6	75 lb/a 24-Feb-10	75 lb/a 7-Mar-11
7	75 lb/a 22-Mar-10	75 lb/a 4-Apr-11
8	75 lb/a 28-Apr-10	75 lb/a 2-May-11
9	25 lb/a 28-Oct-09 + 50 lb/a 24-Feb-10	25 lb/a 2-Nov-10 + 50 lb/a 7-Mar-11
10	25 lb/a 28-Oct-09 + 75 lb/a 24-Feb-10	25 lb/a 2-Nov-10 + 75 lb/a 7-Mar-11
11	25 lb/a 28-Oct-09 + 50 lb/a 22-Mar-10	25 lb/a 2-Nov-10 + 50 lb/a 4-Apr-11
12	25 lb/a 28-Oct-09 + 75 lb/a 22-Mar-10	25 lb/a 2-Nov-10 + 75 lb/a 4-Apr-11
13	25 lb/a 28-Oct-09 + 50 lb/a 28-Apr-10	25 lb/a 2-Nov-10 + 50 lb/a 2-May-11
14	25 lb/a 28-Oct-09 + 75 lb/a 28-Apr-10	25 lb/a 2-Nov-10 + 75 lb/a 2-May-11

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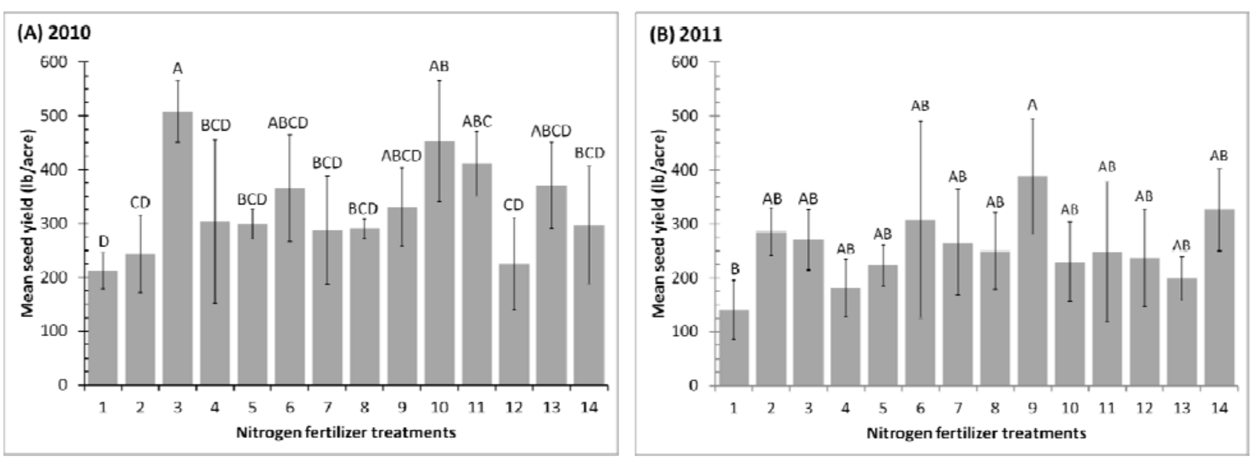

Figure 1. Seed production of Roemer's fescue at Hyslop Farm, Corvallis in 2010 (A) and 2011 (B) according to 14 nitrogen fertilization treatments. Mean ± 1 SD; within each year, means marked with the same letter indicate no significant difference at α = 0.05 level in Tukey HSD tests.

By 2011, the stands had begun to decline and overall mean seed yield was significantly lower than in 2010 (253±98 vs. 329±114 lb/ac, respectively; $P < 0.001$). There was also substantial plant and seed loss to predation by voles and mice. The only significant treatment effect in 2011 was that split application of 25 lb N/a in November plus 50 lb N/a in early March (Trt. 9) had higher seed yields than the control (Trt. 1). In 2011, fertilization treatments again significantly affected lodging scores ($P < 0.001$), with patterns similar to those seen in 2010 (data not shown). Interestingly, an ANOVA of the effects of total pounds nitrogen applied on lodging scores showed that application rates of 75 and 100 lb N/a had more lodging than 0 to 50 lb N/ac (mean lodging scores for applications rates of 100, 75, 50, 25 and 0 lb N/a were 4.6, 4.0, 2.2, 1.0 and 1.0, respectively; $P <$

0.001). Thus higher N application rates, especially in the early spring, appear to lead to increased lodging which makes direct harvest (i.e., straight combining or seed stripping) difficult and may reduce seed yields.

Conclusions

Our results suggest that optimum seed yields of Roemer's fescue can be obtained by applying 50 to 75 lb N/a in late February to early March, either alone or as a split application with 25 lb N/a in the fall (late October to early November). However, total application rates of 75 to 100 lb N/a are likely to increase lodging and make direct combining and seed stripping more difficult.

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EFFECTS OF NITROGEN FERTILIZER TIMING AND RATES ON SEED PRODUCTION OF JACKSON-FRAZIER GERMPLASM MEADOW BARLEY (*HORDEUM BRACHYANTHERUM*)

D.C. Darris and A. Young-Mathews

Introduction

Jackson-Frazier Germplasm meadow barley (*Hordeum brachyantherum* Nevski) is a source identified natural germplasm that was released in 2007 by the USDA-NRCS Corvallis Plant Materials Center. It is a native bunchgrass intended for quick cover in wetland restoration plantings, erosion control, and wildlife habitat along streambanks, waterways, shorelines, and ditch bottoms at low elevations in western Oregon, primarily in the Willamette Valley (Darris, 2007). There are currently no published data available on fertilizer recommendations for seed production of this species. The purpose of this study was to determine the optimal timing and rates of nitrogen fertilizer application for seed production of meadow barley.

Materials and Methods

An existing field of Jackson-Frazier Germplasm meadow barley, previously established at OSU's Hyslop Research Farm near Corvallis, OR (accession #9056373) was used for this study. The field was 132 x 62.5 ft, with rows running north-south at 12-inch row spacing. The field was sown in October of 2007 for a carbon banded seeding trial with diuron herbicide applied immediately after sowing. Any residual carryover of diuron is expected to have dissipated by the start of this study in October 2009. The field was fertilized once in March 2008 (the year prior to the study) at a rate of 50 lb N/acre. A standard regime of weed and disease control was used during this experiment. Outlook® herbicide (dimethenamid-p) was applied in the fall for volunteer and annual grass control and Banvel® (dicamba) was applied in the spring for broadleaf weed control. Residue was removed with a flail type forage harvester after seed harvest. Rust was controlled with Quilt® fungicide (azoxystrobin and propiconazole) as needed. No irrigation water or other practices were applied.

Fertilizer was applied to plots according 14 treatments (Table 1) as a granular mixture of urea and ammonium sulfate (33-0-0-12), marketed as "Urea-sul," using an 8-ft wide Gandy type drop spreader. All rates are actual N/acre. Each plot was 8 ft wide and 16 ft long. Seed was hand-harvested from 1-m^2 subplots on July 5-9, 2010 (excessive lodging prevented mechanical harvest). Seed was cleaned and conditioned before recording plot yields. Lodging was scored on July 5, 2010 on a scale from 1 to 10, with 1 being no lodging (plants completely upright) and 10 being the most lodging (plants flat). The experimental design was a randomized complete block with four replications. Data analysis consisted of ANOVA and Tukey HSD means comparisons performed in Statistix 8.1.

Table 1. Nitrogen fertilizer treatments for meadow barley seed production study, Hyslop Farm, Corvallis, 2010.

Treatment	N application rate & timing
1	Control (no fertilizer)
2	25 lb/a 28-Oct-09
3	50 lb/a 24-Feb-10
4	50 lb/a 22-Mar-10
5	50 lb/a 28-Apr-10
6	75 lb/a 24-Feb-10
7	75 lb/a 22-Mar-10
8	75 lb/a 28-Apr-10
9	25 lb/a 28-Oct-09 + 50 lb/a 24-Feb-10
10	25 lb/a 28-Oct-09 + 75 lb/a 24-Feb-10
11	25 lb/a 28-Oct-09 + 50 lb/a 22-Mar-10
12	25 lb/a 28-Oct-09 + 75 lb/a 22-Mar-10
13	25 lb/a 28-Oct-09 + 50 lb/a 28-Apr-10
14	25 lb/a 28-Oct-09 + 75 lb/a 28-Apr-10

Results and Discussion

Mean seed production for each treatment is summarized in Figure 1. ANOVA revealed no significant effect of nitrogen treatments on seed yield. Treatments 3 and 6, February application of 50 and 75 lb N/a, respectively, appeared to have the highest seed yields, but variation was too large to give significant differences. The unfertilized control (Trt. 1), the 25 lb/a October application (Trt. 2), and the 50 lb/a April application (Trt. 5) appeared to have the lowest yields.

Nitrogen treatments did, however, have a significant effect on lodging scores (Table 2). Plots that received no fertilizer, October only, and April fertilizer (Trts. 1, 2, 5, 8, 13, 14) had significantly less lodging than all other treatments, presumably because the N was applied too early (Oct) or too late (Apr) to affect tiller growth. Plots that received 75 lb/a N in March (Trts. 7 and 12) tended to have the highest lodging scores, so if direct mechanical harvest is planned (i.e., direct combining or seed stripping), high rates of nitrogen later in the spring should be avoided.

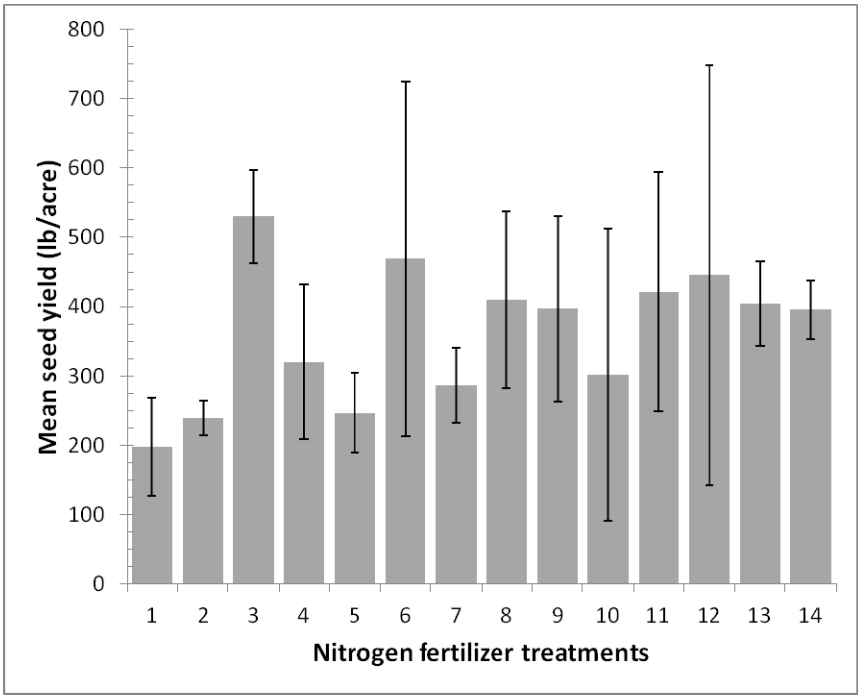

Figure 1. Seed production of Jackson-Frazier Germplasm meadow barley under 14 N fertilizer treatments. Bars represent mean ± 1 SD; ANOVA showed no significant differences among treatments.

Table 2. Tukey HSD comparison of meadow barley lodging scores (1-10 scale, with 10 high) by nitrogen fertilization treatment.

Treatment	Mean	Homogeneous Groups
7	9.50	A
12	9.25	A
10	8.75	AB
11	8.75	AB
6	8.50	AB
9	7.75	AB
4	7.50	AB
3	7.00	B
14	2.75	C
8	2.75	C
5	2.00	C
13	1.75	C
1	1.00	C
2	1.00	C
P < 0.001		

Conclusions

Although variation within and among treatments was too great to give conclusive results, there was a trend toward higher seed yields with February applications of 50-75 lb N/acre, so this is the recommended rate until further tests can be conducted. Split N application in the fall and spring appeared to have similar results to spring-only applications. High N rates (75 lb/a) are not recommended in March if seed is going to be harvested mechanically without swathing, as this can lead to higher rates of lodging and inaccessible seedheads.

References

Darris, D. 2007. Fact sheet: Jackson-Frazier Germplasm meadow barley. Available at http://plant-materials.nrcs.usda.gov/orpmc/publications.html (accessed 9 Mar 2012). USDA-NRCS Plant Materials Center, Corvallis, OR.

SAFLUFENACIL IN COOL SEASON GRASSES GROWN FOR SEED

D.W. Curtis, K.C. Roerig, A.G. Hulting and C.A. Mallory-Smith

Introduction

Saflufenacil is a new, low volatile, protoporphyinogen oxidase (PPO) inhibitor herbicide in group 14, a group which also includes the herbicides Goal® and Aim®. Field studies were conducted at Oregon State University from 2008-2011 to evaluate weed control potential and crop response to preemergence and post emergence applications of saflufenacil to perennial ryegrass and tall fescue being grown for seed production. PPO inhibitors including oxyfluorfen (Goal), are used in the grass seed production in combinations with other herbicides because they provide additional herbicide activity. Saflufenacil was tested to see what weed species it controls and to determine if synergy occurred when it was used in combination with other herbicides. Because it is a low volatile herbicide, saflufenacil could be less prone to off target movement than more volatile herbicides. Saflufenacil is not currently registered for use in grasses grown for seed at this time.

Methods

Two studies were conducted at Hyslop Research Farm near Corvallis, OR in the 2008-2009 growing season to evaluate saflufenacil applied either alone or in combination with other herbicides to quantify any synergistic effects for control of grass weeds in perennial ryegrass. The following two years, saflufenacil also was evaluated in two studies for broadleaf weed control with other low volatile herbicides in new plantings of perennial ryegrass. Saflufenacil was evaluated in the spring of 2011 for summer annual broadleaf weed control and crop tolerance in a commercial field of spring-planted tall fescue near Lebanon, Oregon. In all, five randomized complete block design studies, with four replications each, were conducted over four years. All studies were evaluated visually for percent weed control. Studies located at Hyslop Research Farm were harvested and evaluated for clean seed yield**.**

Results and Discussion

Study 1.

Saflufenacil applied to a new seeding of perennial ryegrass and was evaluated for control of diuron resistant annual bluegrass, Italian ryegrass and California brome. Saflufenacil was applied at 0.022 lb ai/A alone and in combination with either metribuzin (not currently registered for use on seedling perennial ryegrass), mesotrione (Callisto®), which previous research has shown to have activity on some grass species, and ethofumesate (Nortron®) to the ryegrass at the 1 tiller stage of growth (Table 1). Saflufenacil applications provided negligible control of the grass weed species in this study when applied alone. Mesotrione had limited activity on California brome but this activity was reduced by the combination with saflufenacil. In combination with metribuzin, saflufenacil applications resulted in a small additive effect for control of annual bluegrass and Italian ryegrass. In combination with ethofumesate, saflufenacil reduced control of California brome. Saflufenacil did not injure perennial ryegrass and had no effect on seed yield.

Table 1. Post emergence herbicide combinations for control of grass weed species in fall seeded perennial ryegrass grown for seed, Hyslop, 2008-2009.

Treatment[2]	Rate	Annual bluegrass[1]	California brome	Italian ryegrass	Seed yield[1]
	(lb ai/A)	--------------(% Control[3])--------------			(lb/A)
check		0	0	0	1847
metribuzin	0.14	18	10	30	1989
mesotrione	0.19	0	25	5	2091
ethofumesate	1.00	8	60	5	1955
saflufenacil	0.022	0	5	5	1984
saflufenacil +	0.022	25	23	48	2031
metribuzin	0.14				
saflufenacil +	0.022	0	3	10	2045
mesotrione	0.094				
saflufenacil +	0.022	15	43	8	1915
ethofumesate	1.00				
LSD (P = 0.05)					NS
CV					8.67

[1]Diuron resistant annual bluegrass, California brome, Italian ryegrass, perennial ryegrass seeded 9/24/2008

[2]Applied 11/18/2008 to 3 leaf - 2 tiller perennial ryegrass; NIS at 0.25% v/v + AMS at 8.5 lb/100gal added to mesotrione treatments; COC at 1 % v/v + AMS at 8.5 lb/100gal added to saflufenacil treatments

[3]Visual ratings 3/3/2009

Study 2.

Pyroxasulfone (Zidua®), glufosinate (Rely®), oxyfluorfen and saflufenacil were applied alone and in combination to an established stand of perennial ryegrass. The addition of these herbicides to pyroxasulfone contributed to a small increase in the control of diuron resistant annual bluegrass compared to when applied alone (Table 2). There were no differences in seed yields. Pyroxasulfone is not currently registered for use in grasses grown for seed.

Table 2. Annual bluegrass control in established perennial ryegrass grown for seed, Hyslop, 2009.

Treatment[3]	Rate	Annual bluegrass[1]	Crop injury[4]	Seed yield[2]
	(lb ai/A)	(% Control[4])	(%)	(lb/A)
check		0	0	1569
pyroxasulfone	0.09	90	3	1207
glufosinate	0.38	71	15	1144
oxyfluorfen	0.25	23	0	1403
saflufenacil	0.022	20	0	1500
pyroxasulfone +	0.09	98	15	1033
glufosinate	0.38			
pyroxasulfone +	0.09	98	8	1139
oxyfluorfen	0.25			
pyroxasulfone +	0.09	98	3	1273
saflufenacil	0.022			
LSD (P = 0.05)				NS
CV				19

[1]Diuron resistant annual bluegrass planted 10/15/2008

[2]Perennial ryegrass planted 9/25/2007

[3]Treatments applied 1/13/2009; NIS added to saflufenacil treatments at 0.25% v/v

[4]Visual ratings 4/24/2009

Studies 3 and 4.

Two studies initiated to evaluate broadleaf control with saflufenacil in newly seeded plantings of perennial ryegrass were conducted during the 2009-2010 and 2010-2011 growing seasons. In 2009, saflufenacil was applied at 0.022 lb ai/A to 1 tiller perennial ryegrass. In 2010, saflufenacil was applied at 0.089 lb ai/A preemergence and at 0.022 lb ai/A post emergence to 1 tiller perennial ryegrass. The post emergence applications provided 95-100% control of ivy-leaf speedwell, lesser-seeded bittercress and both common and sticky chickweed (Table 3). The post emergence weed control of saflufenacil was comparable to that from carfentrazone (Aim) and pyraflufen (Edict™). Saflufenacil did not provide effective control of the weed species when applied preemergence (Table 4). Yields were not affected by either pre or post emergence applications of saflufenacil.

Table 3. Broadleaf weed control in fall seeded perennial ryegrass grown for seed, Hyslop, 2009-2010.

Treatment[2]	Rate	Ivy-leaf speedwell	Lesser-seeded bittercress	Common chickweed	Sticky chickweed	Seed yield[1]
	(lb ai/A)	---------------------(% Control[3])----------------------				(lb/A)
check		0	0	0	0	1507
pyraflufen	0.0016	85	100	100	100	1629
carfentrazon	0.023	100	100	75	100	1717
saflufenacil	0.022	95	100	100	100	1711
LSD (P = 0.05)						NS
CV						11

[1]Perennial ryegrass planted 10/5/2009

[2]Applied 11/23/2009 to 1 tiller perennial ryegrass, NIS added at 0.25% v/v

[3]Visual ratings 1/26/2010

Table 4. Pre and post emergence broadleaf weed control in fall seeded perennial ryegrass grown for seed, Hyslop, 2010-2011.

Treatment	Rate	Appl.[2]	Lesser-seeded bittercress	Shepherd's purse	Sticky chickweed	Mayweed chamomile	Seed yield[1]
	(lb ai/A)	(timing)	------------------ (% Control[3])--------------------				(lb/A)
check			0	0	0	0	1198
saflufenacil	0.089	Pre	45	78	35	93	1320
saflufenacil	0.022	Post	100	100	100	100	1308
pyraflufen	0.0016	Post	88	78	78	95	1345
carfentrazone	0.023	Post	100	100	100	100	1220
LSD (P = 0.05)							NS
CV							8

[1]Perennial ryegrass planted 9/30/2010

[2]Pre applied on 10/2/2010; Post applied on 11/10/2010 to 1 tiller perennial ryegrass; NIS at .25 % v/v added to all post timing treatments

[3]Visual ratings 3/28/2011

Study 5.

A study conducted in the spring of 2011 included applications of saflufenacil at 0.022 lb ai/A alone and in combination with mesotrione to 2 leaf spring-planted tall fescue. Saflufenacil provided 90% control of the initial germination flush of sharppoint fluvellin, but did not control later emerging sharppoint fluvellin. The combination of mesotrione and saflufenacil provided 80% control of the later emerging sharppoint fluvellin. Neither saflufenacil nor mesotrione provided effective control of erect knotweed.

Table 5. Broadleaf weed control in spring-planted tall fescue grown for seed, Lebanon, OR, 2011.

		Percent Weed Control						
		Sharppoint fluvellin				Erect knotweed		
Treatment[1]	Rate	5/16	5/27	6/14	7/22	5/27	6/14	7/22
	(lb ai/A)	---------------------------------- (%) ----------------------------------						
check		0	0	0	0	0	0	0
mesotrione	0.094	0	88	83	80	56	28	43
saflufenacil	0.022	90	73	70	63	48	8	35
mesotrione +	0.094							
saflufenacil	0.022	90	93	85	80	58	28	40

[1]Applied 5/13/2011 to 1 to 2 leaf tall fescue and 4 leaf sharppoint fluvellin

Summary

Results of these studies suggest that saflufenacil will provide effective control of several broadleaf species. Future work will include evaluating tolerance in other grass seed crops including fine fescues and orchardgrass and optimizing uses in tall fescue.

ALTERNATIVE HERBICIDES TO DIURON IN CARBON SEEDED PERENNIAL RYEGRASS (*LOLIUM PERENNE*) GROWN FOR SEED

D.W. Curtis, K.C. Roerig, A.G. Hulting and C.A. Mallory-Smith

Introduction

Annual bluegrass (*Poa annua*) contamination in grass grown for seed is a major production challenge with significant economic ramifications. In the Willamette Valley, diuron applied preemergence over newly-planted seed rows protected with a narrow band of activated carbon has been the standard practice to control annual bluegrass for the past three decades. However, diuron resistant annual bluegrass is found in many grass seed fields in the Willamette Valley. Previous research by these authors has documented that indaziflam (Alion™) and pyroxasulfone (Zidua®) can provide excellent annual bluegrass control when applied preemergence to carbon seeded perennial ryegrass. In addition to evaluation of indaziflam and pyroxasulfone, rimsulfuron (Matrix®) was evaluated for annual bluegrass control in carbon seeded perennial ryegrass. None of these herbicides are registered for use in grasses grown for seed at this time.

Methods

In the fall of 2010, four studies were initiated to evaluate annual bluegrass and California brome control and perennial ryegrass injury from applications of indaziflam, pyroxasulfone and rimsulfuron. Herbicides were applied as preemergent broadcast treatments to perennial ryegrass seeded with a 1 inch wide band of activated carbon applied over the rows at 300 lb/A. Three studies were located at the Oregon State University Hyslop Research Farm near Corvallis, OR, and one study was located in a commercial field near Jefferson, OR. All studies utilized a randomized complete block design with four replications.

Visual evaluations of annul bluegrass and California brome control along with crop injury ratings were taken in the fall (data not shown) and in January. California brome was not present at the Jefferson, OR, site. Seed was harvested, cleaned and yields were quantified.

Results

Indaziflam treatments provided 90% or greater control of annual bluegrass at rates of 0.011 lb ai/A or greater at Hyslop Research Farm. Indaziflam did not provide acceptable control of California brome. Crop injury was acceptable at all rates and seed yields were equivalent to the standard treatments of diuron plus ethofumesate and pronamide plus ethofumesate (Table 1).

Table 1. Indaziflam in carbon seeded perennial ryegrass[1], Hyslop Farm, 2010-2011

Treatment	Rate	Appl. timing	Annual bluegrass[2]	California brome[2]	Crop injury[3]	Seed yield
	(lb ai/A)		----- (% Control[3])	-----	(%)	(lb/A)
check			0	0	0	1138
indaziflam	0.0054	pre	75	50	0	1176
indaziflam	0.0107	pre	92	70	11	1162
indaziflam	0.016	pre	90	68	4	1191
indaziflam	0.0214	pre	97	70	10	1190
indaziflam	0.0286	pre	92	73	10	1286
diuron +	1.0	pre	45	75	0	1290
ethofumesate	1.0	post				
pronamide +	0.25	pre	100	96	3	1177
ethofumesate	1.0	post				
LSD (P = 0.05)						NS
CV						8.8

[1]Perennial ryegrass carbon seeded 9/30/2010
[2]Diuron resistant annual bluegrass and California brome planted 10/1/2010
[3]Visual evaluations 1/5/2011

Pyroxasulfone applied at rates of 0.045 lb ai/A and above provided 90% or greater annual bluegrass control. California brome was not controlled adequately at any rate, although the 0.09 lb ai/A rate (highest rate evaluated) provided 80% control. Crop injury resulted in slightly reduced growth in the 0.09 lb ai/A treatment, but did not result in lower seed yields (Table 2).

Table 2. Pyroxasulfone in carbon seeded perennial ryegrass[1], Hyslop Farm, 2010-2011

Treatment	Rate	Appl. timing	Annual bluegrass[2]	California brome[2]	Crop injury[3]	Seed yield
	(lb ai/A)		----- (% Control[3]) -----		(%)	(lb/A)
check			0	0	0	1334
pyroxasulfone	0.023	pre	78	48	3	1271
pyroxasulfone	0.045	pre	93	58	10	1277
pyroxasulfone	0.09	pre	100	80	18	1333
diuron +	1.0	pre	38	68	0	1289
ethofumesate	1.0	post				
pronamide +	0.25	pre	98	93	5	1284
ethofumesate	1.0	post				
LSD (P = 0.05)						NS
CV						7.4

[1]Perennial ryegrass carbon seeded 9/30/2010
[2]Diuron resistant annual bluegrass and California brome planted 10/1/2010
[3]Visual evaluations 1/5/2011

Rimsulfuron did not provide adequate control of either the diuron resistant annual bluegrass or the California brome at Hyslop Research Farm. Crop injury resulted in slight growth reduction at the two higher rates but did not result in reduced seed yields (Table 3).

Table 3. Rimsulfuron in carbon seeded perennial ryegrass[1], Hyslop Farm, 2010-2011

Treatment	Rate	Appl. timing	Annual bluegrass[2]	California brome[2]	Crop injury[3]	Seed yield
	(lb ai/A)		----- (% Control[3]) -----		(%)	(lb/A)
check			0	0	0	1148
rimsulfuron	0.031	pre	35	30	0	1351
rimsulfuron	0.047	pre	55	35	9	1280
rimsulfuron	0.063	pre	68	33	11	1273
diuron +	1.0	pre	28	50	0	1217
ethofumesate	1.0	post				
pronamide +	0.25	pre	100	93	4	1210
ethofumesate	1.0	post				
LSD (P = 0.05)						NS
CV						6.7

[1]Perennial ryegrass carbon seeded 9/30/2010
[2]Diuron resistant annual bluegrass and California brome planted 10/1/2010
[3]Visual evaluations 1/5/2011

The study near Jefferson, OR, was located in a commercial field that had areas of poor drainage. The study area was impacted by high equipment traffic causing localized compaction which led to water ponding during the winter months. Initial perennial ryegrass injury was severe following the pyroxasulfone and indaziflam treatments (Table 4). We speculate that the application rates of these herbicides were too high for the poor drainage. However, at grass seed harvest, the only treatment that reduced seed yield was the highest rate of indaziflam. Initial annual bluegrass control was 90% or greater with the pyroxasulfone treatments. Rimsulfuron treatments provided better crop safety than the pyroxasulfone and indaziflam treatments. The two highest rates of rimsulfuron resulted in perennial ryegrass injury greater than the diuron standard, and provided less annual bluegrass control.

Table 4. Alternatives to diuron in carbon seeded perennial ryegrass[1], Jefferson, OR, 2010-2011.

Treatment[2]	Rate	Annual bluegrass control[3] 1/6/11	2/25/11	4/13/11	Crop injury[3] 1/6/11	2/25/11	4/13/11	Seed yield
	(lb ai/A)	-----------(%)-----------			------------(%)------------			(lb/A)
check		0	0	0	0	0	0	436
rimsulfuron	0.031	70	53	48	4	3	0	581
rimsulfuron	0.047	83	58	48	18	18	13	526
rimsulfuron	0.063	90	75	60	30	30	30	563
pyroxasulfone	0.09	97	96	78	30	30	33	658
pyroxasulfone +	0.09	100	99	73	38	48	43	631
ethofumesate	1.88							
pyroxasulfone	0.18	100	100	83	58	78	68	505
indaziflam	0.014	90	80	68	35	43	48	426
indaziflam	0.028	98	88	85	58	78	85	98
diuron +	2.4	98	89	79	10	13	8	585
ethofumesate	1.88							
pronamide +	0.25	46	45	48	3	3	0	527
diuron	1.6							
LSD (P = 0.05)								202
CV								28

[1]Perennial ryegrass planted 10/5/2010
[2]Applications made on 10/6/2010
[3]Visual evaluations

Summary
Indaziflam and pyroxasulfone have the potential to replace diuron in carbon seeding for the establishment of grasses grown for seed. Both indaziflam and pyroxasulfone provided good control of annual bluegrass at rates safe to the crop. Rimsulfuron has crop safety but will have to be combined with other herbicides to provide adequate annual bluegrass control. Further studies will be conducted to refine application rates to minimize the potential for crop injury and enhance annual bluegrass control with these three herbicides.

USING SWAT TO MODEL WATER QUALITY IN THE CALAPOOIA RIVER BASIN

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

Introduction

Soil erosion, off-site movement of nutrients, damage to wildlife habitat, and alteration of biochemistry on a global scale are well documented, albeit unintended, consequences of much human activity, including modern farming methods. Approaches to study these phenomena include monitoring of natural systems and modeling them using computer programs such as the Soil Water Assessment Tool (SWAT). A premiere example of efforts to better understand relationships among farming practices, conservation methods, and the broader environment is the USDA Conservation Effects Assessment Project (CEAP) whose 38 study sites include the Calapooia River Basin in western Oregon. Core elements of all CEAP projects include measurements of nutrient and sediment loads in streams draining study watersheds and modeling effects of landuse changes on water quality using SWAT.

Complex relationships exist amongst hydrology, landuse, and water quality in western Oregon. Our previous analysis of the impact of landuse and farming practices on water quality in the Calapooia River Basin identified a group of crops whose production was linked to higher concentrations of nitrate and total N during the winter in streams draining 40 subbasins. Because that analysis lacked a comprehensive hydrologic model, we were unable to say whether or not the subbasins with highest concentrations of N were truly the most significant exporters. Using time series analysis, we quantified a strong cyclical signal in N concentrations at 28 of the 40 subbasins, with primary peaks in December and secondary peaks near the usual time for application of spring N. Based on concentrations of N and clarity of temporal signals, we grouped the subbasins into four main types: those with low, medium, and high concentrations of total N (or nitrate) and a strong time series signal, and those with high levels of N and a weak (or nonexistent) time signal.

In addition to providing mass balance estimates for sources and sinks of nutrients and sediment, SWAT also offers the opportunity to explore the impact of landuse changes greater than the current range. However, before SWAT can be used to model scenarios for alternate futures, it must first be tested, and if necessary modified and recalibrated to match agricultural landuse, water quality, and hydrologic cycles in locales of interest. Although it has been generalized over the years of its development, the current version of SWAT still remains obviously focused on crops grown in mid-continental regions during the northern hemisphere summer, and many of SWAT's features insist on viewing the cropping year as a subset of the calendar year. In contrast, agriculture in the modified Mediterranean climate of western Oregon typically begins with tillage of the soil in late summer in preparation for an early fall planting of new grass seed stands, winter wheat, or other winter annuals. Even established perennial grasses go dormant in late summer/early fall as a consequence of limited rainfall, and behave like rapidly establishing winter annuals once rains return. In addition to crop choice and default management schemes, the hydrologic cycle in western Oregon is sufficiently foreign to the conditions used to develop SWAT that processes such as denitrification and overland versus groundwater flows may be poorly modeled.

Our specific objectives were to: (1) develop a hydrologic model whose streams and watershed boundaries aligned with locations of our water quality sampling points, (2) identify preexisting crops/landuses within SWAT whose modeled sediment and nitrate concentrations reasonably match observed data for subbasins dominated by single crops, (3) modify management practices within SWAT to improve the agreement between observed and modeled data for those crops, and (4) reexamine our previous conclusions on the role of current landuse practices on water quality from a perspective that included better hydrology.

Methods

Management inputs

Adjustment of default SWAT parameters to more closely model growth of grass seed crops in western Oregon began with changing fertilization from automatic to manual using recommended application rates and dates from OSU Extension Service guides. Dates for planting and harvest were chosen to provide reasonable matches to western Oregon agriculture. Other than copying crops and renaming them for use with manual fertilization and defined growing season dates, the only other change made to the SWAT crops database was switching ryegrass from a cool season annual to a perennial. For crops such as peppermint and meadowfoam that did not exist within the SWAT database, we copied and renamed other crops that possessed generally similar growth patterns.

Sampling procedures

Water quality samples were collected a total of 41 times from Oct. 5, 2003, through Jan. 22, 2007, generally within a single day, although collection from all sampling sites occasionally required a second or third day to complete. No samples could be collected from ephemeral streams that dried up during late summer through early fall. Rainfall data recorded at several nearby weather stations from 2000 through 2007 were interpolated to the 40 subbasins for which water quality data existed and were used in SWAT.

SWAT Model Simulation

The SWAT variable NYSKIP was set to a minimum of 3 years "burn-in" for all simulations, which included monthly printout for all multiple-year simulations and daily printout for single growing season simulations, which ran from Jan. 1 of one year through July 31 of the following year. SWAT output data files were imported into Excel to examine subbasin watersheds and stream reaches of interest, particularly output reaches of the entire Calapooia River Basin and the 40 water quality sampling points previously analyzed without use of SWAT.

Results

Observed precipitation and streamflow patterns

Rainfall in western Oregon typically peaks in December, with a long-term monthly average of 7.1 inches, and then slowly declines to a minimum of less than 0.4 inches in August. Over the sampling period from Oct. 2003 through Jan. 2007, precipitation averaged slightly above normal during late-fall through early winter but near-normal when viewed across the entire 40-month period. The 2004-05 cropping year was drier than the preceding year or the following years, all of which experienced slightly above normal precipitation, especially during winter.

Simulations using SWAT defaults for single landuse in the agricultural region

As a first step in evaluating how well "out of the box" SWAT would perform in the Calapooia River Basin, we modeled single landuses of range (RNGE), hay (HAY), generic agricultural row crops (AGRR), winter wheat (AGRC or WWHT), agricultural land generic (AGRL), winter tall fescue pasture (WPAS), corn (CORN), and red clover (CLVR) in the 57% of the basin for which we had detailed information on crops actually grown over multiple years, using National Land Cover Data (NLCD 2001) landuses for the remaining (mostly forested) 43% of the area (Table 1). Averaged over 5 years of simulations, water yield was the most stable variable, ranging from 22.1 inches for CORN to 27.5 inches for CLVR, or 56 to 70% of precipitation. Sediment loading was the least stable variable, ranging from 196 lb/a for CLVR to 24,103 lb/a for WPAS. Nitrate yield in surface runoff was intermediate, ranging from 0.53 lb/a for CLVR to 1.36 lb/a for AGRL. Sediment loss from AGRR and CORN was slightly less than half that from WPAS, indicating that SWAT defaults handled WPAS poorly as a western Oregon crop. When we examined the SWAT output tables at the locations of our water quality samples, none of these eight default crops generated values for nitrate or sediment that closely matched our raw data. In the case of nitrate, most of our raw data greatly exceeded the modeled results. Two likely causes for the wide discrepancies between modeled and observed data came to mind: (1) the SWAT defaults were not accurately modeling western Oregon conditions and farming methods, and (2) variability in sediment and nutrient fluxes among days within individual months prevented monthly averages in modeled results from matching up well with raw data collected on individual days.

Newly defined crops and modified management operations

Because the odd behavior in sediment loading of WPAS versus AGRR using SWAT defaults (heat unit scheduling and auto-fertilization) suggested that we didn't properly understand how non-cropping periods were being handled by SWAT, we created an explicit extreme fallow condition as crop number 1 by assigning August 1 for planting an eggplant crop (EGGP) followed by harvest on August 2 with no other activity during the year. Sediment loading from this extreme fallow condition averaged 31,747 lb/a (Table 2) or nearly three times that modeled for AGRR. To model growth of various new and established grass seed crops in western Oregon, we used operations that included some period of growth during the fall, a Jan. 1 restart required by SWAT, early summer harvest, and manual fertilization. Sequences of operations used to model establishment of new grass seed stands left the ground vulnerable to erosion at various times in the fall and/or spring. Crops modeled included established stands of perennial ryegrass (GSPR), tall fescue (GSTF), orchardgrass (GSOG), haycrop (TFHC), pasture (TFPA), and peppermint (MINT), new fall plantings of annual ryegrass (GSAR/GSLO), perennial ryegrass (FPPR), tall fescue (FPTF), clover (FPCL), winter wheat (WWHT), and meadowfoam (MDWF), and spring planted tall fescue (SPTF).

Table 1. Water, surface Q nitrate, and sediment yields averaged from 2003-2007 for the Calapooia River Basin with all agricultural land modeled as a single landuse using SWAT defaults.

Default SWAT landuse in agricultural area	NLCD[1] class number	Total water yield	Surface Q nitrate yield	Total sediment loading/loss
		(inch)	(lb/a)	(lb/a)
RNGE	71	25.6	0.64	205
HAY	81	24.6	0.78	313
AGRR	82	22.6	1.29	10,046
AGRC (or WWHT)	83	25.0	1.12	3,348
AGRL	85	22.4	1.36	7,323
WPAS	---	25.6	0.61	24,103
CORN	---	22.1	1.22	9,555
CLVR	8	27.5	0.53	196

[1]National Land Cover Data (NLCD 2001)

Table 2. Water, surface Q nitrate, and sediment yields averaged from 2003-2007 for the Calapooia River Basin with all agricultural land modeled as a single landuse using newly defined sequences of crop management operations.

Newly defined crop management in agricultural area	New crop code number	Total water yield	Surface Q nitrate yield	Total sediment loading/loss
		(inch)	(lb/a)	(lb/a)
Fallow	1	25.9	0.70	31,747
GSAR or GSLO	2 or 12	24.5	1.68	1,982
SPTF	3	22.1	0.47	4,965
GSPR	4	25.4	1.96	1,750
GSOG or GSTF	5 or 6	23.0	1.59	205
TFHC or TFPA	7 or 10	23.9	0.76	705
MINT	9	21.2	2.57	741
FPPR	13	24.5	1.86	1,974
FPTF	14	21.7	1.17	3,402
FPCL	15	21.7	0.56	3,920
WWHT	16	25.7	2.14	1,348
MDWF	17	25.4	1.14	5,965

Total water yield for the 15 new crops/management options was similar to that for the eight SWAT default crops, and ranged from 21.7 to 25.9 inches (Table 2). Total sediment loading in the new crops/management options ranged from 205 to 31,747 lb/a, with the increase over the eight default crops due to the addition of the extreme fallow case. Surface nitrate yield for six of the new crops/management options exceeded the largest value from the eight default crops, indicating that manual fertilization was now being modeled as leaking more N than default auto-fertilization. Since all of the default crops in Table 1 had under-predicted nitrate, the increased nitrate yield of many crops in Table 2 was a step in the right direction toward matching modeled and observed N losses.

Multiple-year modeling of observed crops/landuses

Scenarios run using observed crop distributions from the 2005, 2006, and 2007 harvest years starting a minimum of three years earlier showed the responsiveness of SWAT to variation in the weather (Table 3). The drier than normal crop year of 2004-05 not only had a total water yield of less than half that seen in other years, but also saw a 7 to 14-fold reduction in surface nitrate yield and a 4 to 6-fold reduction in total sediment loading. When the extremely wet harvest year of 1974 was modeled using the crop distribution of 2007, total water yield and sediment loading were double those seen on average in the three wetter recent years, while surface nitrate yield averaged nearly 3-times that present recently.

Next we extracted observations for individual dates from data files for subbasins aligned with our water quality sampling points (Figures 1 and 2). Because samples had only been collected on 12 to 15 discrete dates over each cropping year (and less than that at sites where the ephemeral streams dried up in late summer), we could not be certain our observations were truly unbiased. Perhaps nitrate and sediment concentrations and fluxes were higher or lower than average during the extreme flow events we tended to miss because sampling sites were inaccessible or the conditions judged too hazardous to attempt to sample. While several methods exist for weighting the observed concentrations of sediment or nutrients by factors that should reduce the sampling condition bias, the most straightforward was to use modeled water flow as the weighting factor, increasing the contribution of samples taken on higher flow days while decreasing the importance of samples taken on lower flow days.

Flow-weighted averages for observed sediment concentrations among our 40 sample sites ranged from a low of 5.8 ppm to a high of 40.3 ppm in the 2005 harvest year, with an average of 20.6 ppm. In the wetter 2006 harvest year, flow-weighted averages for observed sediment concentrations ranged from a low of 11.7 ppm to a high of 141.7 ppm, with an average of 66.5 ppm. Differences between years in sediment yield were even more dramatic, with an average of 45.2 lb/a in the 2005 harvest year compared to 406.4 lb/a in 2006. Modeled yearly sediment yield was substantially larger than observed sediment yield at most but not all sites (modeled was greater than twice observed sediment yield at 35 of 40 sites in 2005 and 31 of 40 sites in 2006). Even in the wetter year (2006), modeled soil loss in Calapooia River subbasins only exceeded the usual NRCS soil erosion tolerance “T value” of 1.5 tons/a at 9 of the 40 locations, with the flow-weighted observed erosion never exceeding that tolerance level. Plotting modeled versus observed sediment yield clearly shows the existence of many locations where SWAT greatly over-predicted sediment loss (Figure 1). Since SWAT even modeled too much sediment coming out from the densely forested upper end of the Calapooia River Basin, variables still needing to be better calibrated must include some that have no direct connection to agriculture.

Flow-weighted averages for observed total N concentrations among our 40 sample sites ranged from a low of 0.3 ppm to a high of 11.9 ppm in the 2005 harvest year, with an average of 3.6 ppm. In the wetter 2006 harvest year, flow-weighted averages for observed total N concentrations ranged from a low of 0.3 ppm to a high of 8.9 ppm, with an average of 2.6 ppm. Lowest concentrations in both years occurred at site #4 located at the upper end of the Calapooia River Basin in a densely forested region. Despite generally lower concentrations of N in the 2006 harvest year, average flow-weighted observed yearly total N yield increased from 7.4 lb/a in 2005 to 15.7 lb/a in 2006. Only 1 of the 40 sites had lower flow-weighted observed total N yield in 2006 than in 2005. Average modeled yearly nitrate yield exceeded flow-weighted observed total N yield by 79% (13.3 vs. 7.4 lb/a) in 2005 and by 98% (31.0 vs. 15.7 lb/a) in 2006. Modeled yearly nitrate yield was lower than observed total N yield at 11 of 40 sites in 2005, but only 1 of 40 sites in 2006. Plotting modeled nitrate versus observed total N yield showed a general tendency of SWAT to over-predict N at a majority of sites, along with under-prediction at some sites (Figure 2). Since inclusion of other dissolved forms of N along with nitrate would only serve to further increase the problem of over-prediction of N by SWAT at most sites, model parameters affecting factors such denitrification will need to be recalibrated before SWAT can provide truly reliable estimates of N fluxes in western Oregon.

Consistency of N-impact type groups

The four main subbasin groups previously identified in terms of their maximum total N concentrations and their temporal patterns were examined in terms of their performance in explaining variation in N transport among sample sites. In 2005, N-impact types 1 (low), 2 (medium), 3 (high), and 4 (high without strong temporal trends) had flow-weighted averages for total N of 0.6, 2.2, 5.4, and 4.9 ppm. In 2006, N-impact types 1, 2, 3, and 4 had flow-weighted averages for total N of 0.5, 1.6, 3.5, and 3.9 ppm. For observed yearly total N yield, N-impact types 1, 2, 3, and 4 averaged 1.5, 4.9, 10.7, and 10.0 lb/a in 2005 and 2.9, 9.6, 21.0, and 23.5 lb/a in 2006. For modeled yearly total N yield, N-impact types 1, 2, 3, and 4 averaged 2.6, 9.4, 12.9, and 24.0 lb/a in 2005 and 5.5, 22.0, 42.4 and 44.0 lb/a in 2006. It is clear that the N-impact type 1 subbasins exported the least N, with the type 2 subbasins exporting more N than the type 1 but less than the types 3 and 4. The type 3 and 4 subbasins differed relatively little in how much total N they lost over

Table 3. Water, surface Q nitrate, and sediment yields for the Calapooia River Basin with agricultural landuse modeled as known mixtures of 16 classes for the 2005, 2006, and 2007 harvest years.

Harvest year (previous Aug. 1 through current July 31)	Total water yield	Surface Q nitrate yield	Total sediment loading/loss
	(inch)	(lb/a)	(lb/a)
2005 crops (2004 weather)	25.0	1.37	1,697
2005 crops and weather	10.2	0.14	268
2006 crops and weather	26.3	0.98	1,063
2007 crops and weather	28.9	1.88	1,215
2007 crops (1974 weather)	55.4	4.09	3,242

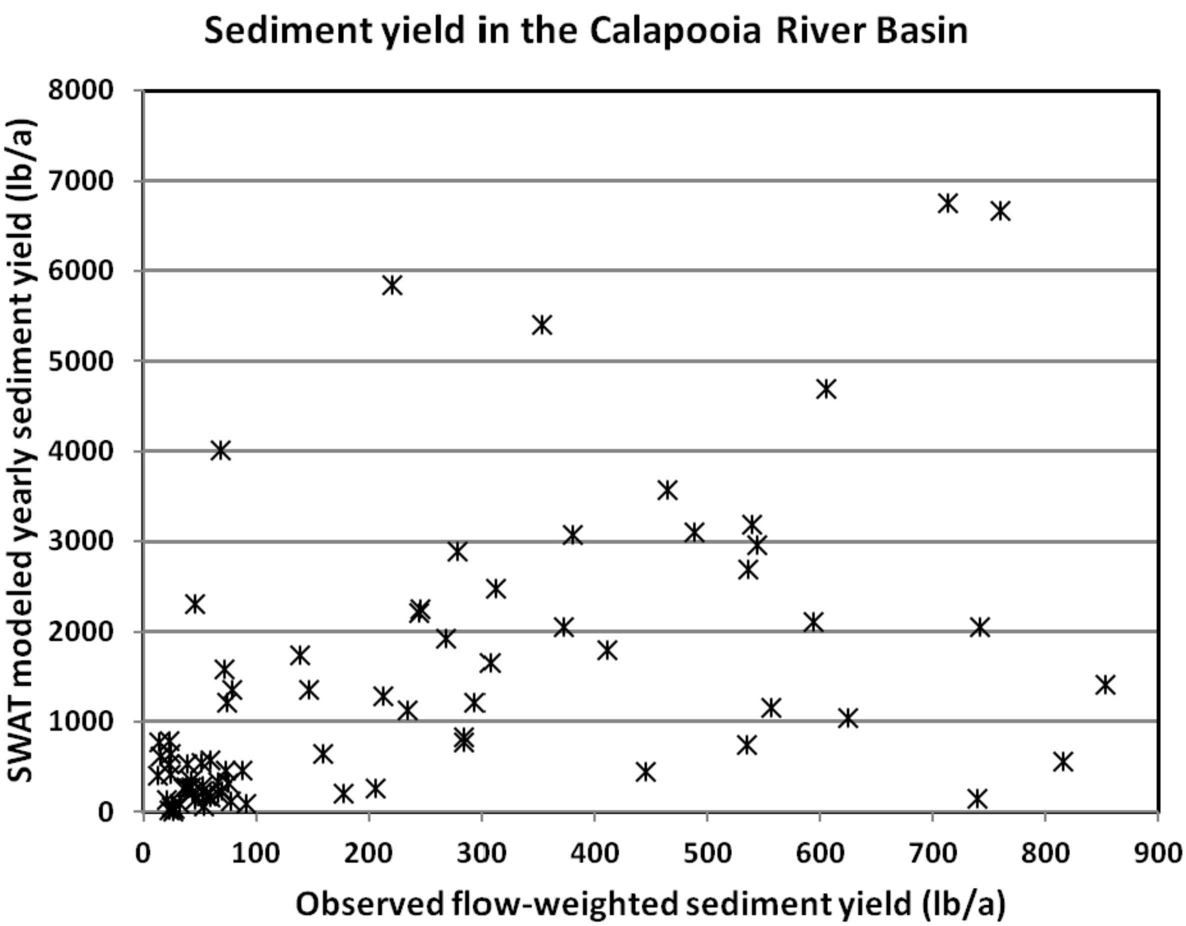

Figure 1. Yearly sediment yield in lb/a at 40 sample collection sites in the Calapooia River Basin for harvest years 2005 and 2006. X-axis values are the observed concentrations multiplied by modeled stream flows scaled to yearly totals. Y-axis values are modeled sediment yields from SWAT.

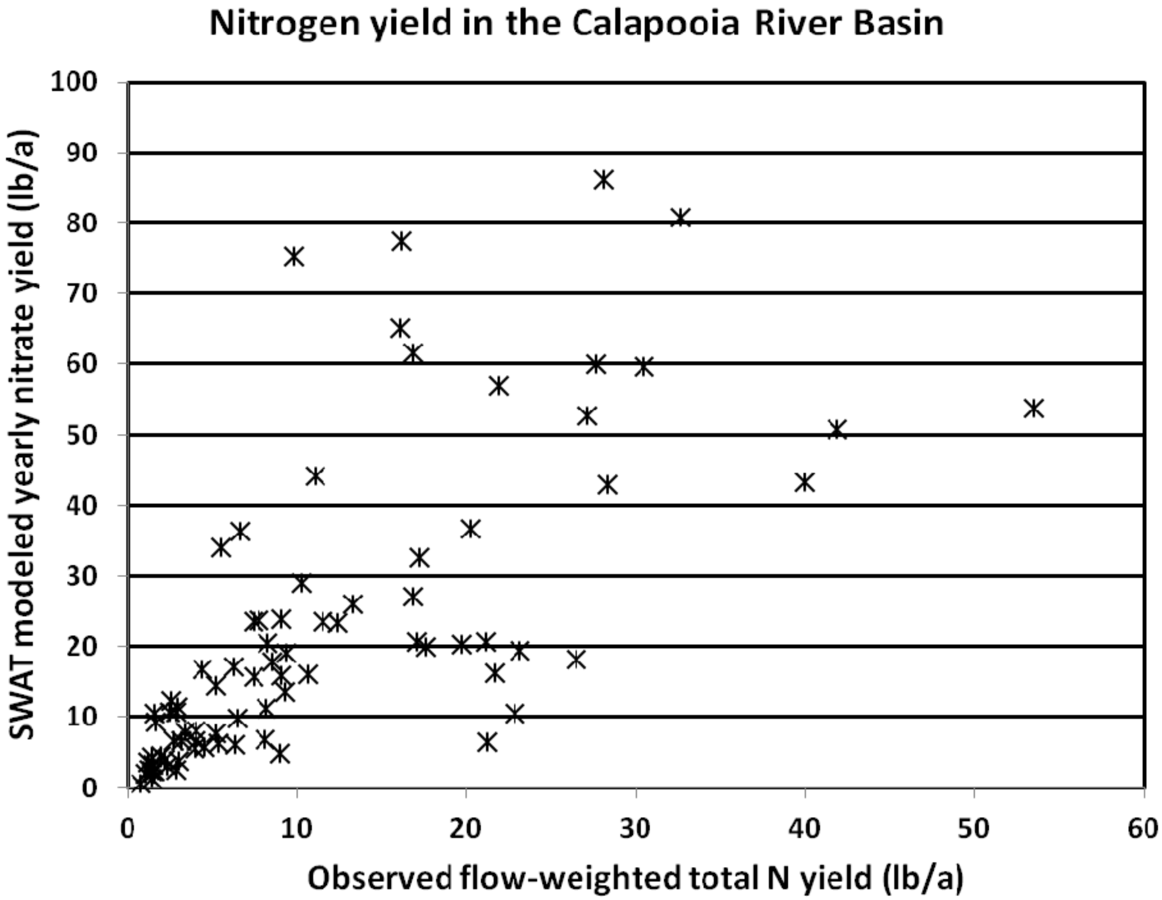

Figure 2. Yearly nitrogen yield in lb/a at 40 sample collection sites in the Calapooia River Basin for harvest years 2005 and 2006. X-axis values are the observed concentrations of total nitrogen multiplied by modeled stream flows scaled to yearly totals. Y-axis values are modeled nitrate yields from SWAT. The majority of nitrogen present in the samples and modeled by SWAT was in the form of nitrate.

the year. The primary difference between total N concentrations in the type 3 and 4 subbasins had been the presence or absence of peaks in December and minimums in the summer. Subbasin types 3 and 4 differed primarily in the size of the secondary peak in early spring, with the higher peak in the type 4 subbasins coinciding with the general timing of spring fertilizer application.

Discussion

Performance of SWAT

Before results of SWAT modeling can be used to describe alternate agricultural practice scenarios with the potential to reduce contamination of surface waters through changes in crops grown and management practices employed in their production, the issue of how well SWAT actually models the real world must be faced. For crops such as corn and soybeans in the Midwest, agreement between observed flows of N and sediment can be so close that conversion of Conservation Reserve Program grasslands to these row crops was both modeled and observed as an average increase in nitrate-N yield of 27 lb/a. Our current SWAT model for the Calapooia River Basin falls well short that level of precision. Water yield in SWAT simulations closely matched historical USGS gage data when averaged over months or years, but performs more poorly when measured on a daily basis.
Automatic calibration of SWAT using a Beowulf cluster and genetic algorithms has been shown to successfully recreate daily flow patterns in western Oregon, and will be used in future simulations once crop models and management operations have been adequately refined. Uncalibrated SWAT appears to direct unrealistically large fractions of precipitation into subsurface and deep ground water flows at the expense of surface flows, a phenomenon that should also be improved by better calibration of daily flows.
Our current group of management practices for 16 crops appears to seriously overestimate sediment flow

in western Oregon. It would be simple enough to adjust dates for planting/begin growth and harvest to alter predicted sediment flow by assuming that crops are in the ground and growing for longer fractions of the year. But since we created our new management sequences to match up with real planting and harvest dates, it would be rather unfair to fix sediment problems by simply pretending the crops are growing for more (or less) of the year than is the case.

Implications of landuse on water quality

Even though limitations in the precision of the current SWAT model for western Oregon grass seed crops restricts our ability to make quantitative predictions of the effects of changing crops and management practices, some general findings still hold. Grass seed crops export less nitrate in surface water than winter wheat or mint, but differences are probably less than 30%. Grass seed crops reduce sediment loading compared to most available alternatives, though no-till methods for winter wheat production might come close to approaching the efficiency of established grass seed crops in retaining soil on fields. Higher rainfall years will see greater total flux of N but lower concentrations in the water, with differences in nitrate yield among years easily spanning a factor of 10X. The low, medium, and high N concentration subbasin types identified without regard to total water yield retained their distinctiveness when water flow was factored in to provide estimates of nitrate or total N yield over time. The fourth N-impact type (the one lacking strong temporal signal in concentration) did not differ greatly from the third N-impact type in terms of N yield although more of the N was lost to runoff in early spring around the normal time for spring fertilizer application. Despite overestimating nitrate yield in general, our current SWAT model does not reproduce the N spikes seen in the spring-time at some but not all of the sampling locations. This strongly suggests that those spikes do indeed represent either direct application fertilizer to water flowing across the surface of fields or rainfall events shortly after application intense enough to transport N in surface water rather than moving it into the soil profile.

Conclusions

Our revised crops and management operations produced more realistic simulations of N and sediment dynamics in the Calapooia River Basin than the SWAT defaults. Both observed and modeled quantitative estimates for N yield confirmed the existence of the low, medium, and high N-impact types of subbasins we previously identified. Although our model is currently biased slightly upward for N yield, cases where the observed N concentrations in late winter and early spring substantially exceed the predicted values imply that urea-based fertilizers may have been applied too near in time to heavy rainfall or too close in space to running water. The primary flush of nitrate occurs in December, and represents inadequate growth in the fall by new seedlings and previously established perennial plants coming out of their late summer, moisture-stress induced dormancy to use up the available mineralized N. The hydrologic cycle simply overwhelms the cropping cycle, and nothing short of massive seasonal redistribution of water through expanded use of irrigation and water storage mechanisms could control this flush of nitrate. Discrepancies between observed and modeled losses of sediment and N indicate that SWAT must be thoroughly calibrated for western Oregon conditions before its results could be reliably used as the basis for defining impact of conservation programs and rewarding producers for adherence to standards.

ROTATIONAL CROP TOLERANCE TO SOIL RESIDUAL HERBICIDES PREVIOUSLY APPLIED TO SEEDLING KENTUCKY BLUEGRASS UNDER COLUMBIA BASIN PRODUCTION CONDITIONS

D.A. Ball and G.H. Clough

Introduction

A two year field study was established under Columbia Basin irrigated conditions to evaluate the soil persistence of three HPPD (p-hydroxphenypyruvate dioxygenase) inhibitor herbicides that may have potential use for weed control in grass seed production systems. These herbicides need to be evaluated for their potential to persist in soil under Columbia Basin irrigated growing conditions if they are to fit into local grass seed production systems. Excessive herbicide persistence in soil could cause injury to subsequent crops of onion, canola, winter and spring pea, dry bean, or alfalfa.

The results presented in this report summarize Kentucky bluegrass (KBG) crop response to various HPPD inhibitor herbicide treatments applied to newly seeded KBG, and on tolerance of the above mentioned crops grown in rotation with KBG under irrigated Columbia Basin conditions. Of the herbicides evaluated in this study, only Callisto® (mesotrione) is currently registered for use in KBG seed production. Other herbicide products evaluated are not registered for use in grass seed production, but were evaluated on an experimental basis. Mention of any herbicide product in this study is not meant to imply product endorsement or recommendation for commercial use. Read and follow all herbicide product labels prior to any use.

Methods and Materials

The experiment was located at the Hermiston Agricultural Research and Extension Center, Hermiston, OR. Kentucky bluegrass var. 'Barduke' was seeded on September 9, 2009. Preemergence (PRE) herbicide treatments were applied immediately after seeding on September 9, 2009. Postemergence (EPOST and MPOST) treatments were applied on October 6, 2009 and February 22, 2010, respectively. Conditions at time of applications are summarized in Table 1. All herbicides were applied at twice the typical field use rate to accentuate any potential carryover injury to the rotational crops (Table 2). All treatments were applied with a hand-held CO_2 plot sprayer delivering 17 gpa at 30 psi. Plots were 8 ft by 30 ft in size, in an RCB arrangement, with 4 replications. Soil at the site was a sandy loam (67.4% sand, 26.3% silt, 6.3% clay, 1.3% organic matter, 7.1 pH, and CEC of 9.5 meq/100g). Visual estimates of KBG crop injury were made at periodic intervals after application of herbicide treatments (Table 2). Plots were swathed in late June 2010 and harvested on July 7, 2010 with a Hege plot combine and further cleaned with a 'Clipper' seed cleaner. Final KBG clean seed yields were converted to lb/A (Table 2).

Table 1. Conditions at time of herbicide applications to seedling Kentucky bluegrass.

	Sept. 9, 2009	Oct. 6, 2009	Feb. 22, 2010
Timing	PRE	EPOST	MPOST
Kentucky bluegrass growth stage	Preemergence	2-3 leaf, no tillers	2 inch height, tillering
Air temp (F)	58	57	42
Relative humidity (%)	68	56	76
Wind velocity (mph)	W@ 1	NW@2	calm
Cloud cover (%)	100	0	0
Soil moisture conditions	Moist	Wet	Moist surface
Soil temp 1 inch (F)	69	66	59

Results and Discussion

When evaluated at 16 and 37 days after LPOST application, visible injury to seedling KBG (chlorosis) was evident in plots receiving a Laudis™ (tembotrione) application (Table 2). Other treatments exhibited slight to no visible crop injury when evaluated (Table 2). Note that all herbicides were applied at twice the typical field use rate to accentuate any potential carryover injury to the rotational crops. Visible KBG crop injury was not evident during any late-season observations (data not shown). All herbicide treatments provided complete control (100%) of henbit, prickly lettuce, and tumble mustard (data not shown). Differences in clean seed yield of KBG were evident (Table 2) and most likely due to differences in timing of weed control, and possibly due to moderate, mid-season crop injury from Laudis treatments.

Table 2. Herbicide treatment application details and seedling KBG visible crop injury and clean seed yields.

Treatment	Rate	Timing[1]	Crop injury March 10	Crop injury March 31	Clean seed yield July 7
	(fl oz/A)		(%)	(%)	(lb/A)
Untreated			0	0	386 bc
Callisto	12	PRE	0	0	502 a
Callisto	12	EPOST	0	0	420 bc
Callisto	12	LPOST	11	5	424 b
Laudis	6	EPOST	0	0	394 bc
Laudis	6	LPOST	30	16	361 c
Impact	1.5	EPOST	0	0	426 b
Impact	1.5	LPOST	1	0	382 bc
LSD (0.05)			1.9	1.3	59.4

[1] PRE – Preemergence treatment applied September 9, 2009. EPOST – Early postemergence treatments applied October 6, 2009. LPOST treatments applied February 22, 2010. All EPOST and LPOST treatments contained a crop oil concentrate (COC) at 1% v/v and a 32% liquid N solution at 2.5% v/v.

After seed harvest in July 2010, KBG straw was swathed, baled, and removed from plots. Plot areas were overhead sprinkler irrigated, disked, rototilled, and planted to an autumn seeded crop of canola, winter pea, winter onion, or alfalfa (Table 3). Plot areas designated for spring planted rotational crops were seeded to winter wheat as an overwintering cover crop. In spring of 2011, the winter wheat was killed with glyphosate and rototilled to prepare a final seedbed. Spring seeded pea, onion, dry beans, and carrot were seeded at typical planting dates for those crops. Rotational crop planting details are summarized in Table 3. Observations of any visible injury to rotational crops have been made approximately at bi-weekly intervals since rotational crop planting. There has been no evidence of any visible crop injury at any time since planting the rotational crops (data not shown). The time intervals between herbicide applications to KBG and planting of rotational crops are summarized in Table 4.

Crops replanted the following season after herbicide treated KBG included fall planted alfalfa, canola, onion, and winter pea, and spring planted pea, onion, carrot, and dry bean (see Table 4 for recropping intervals after herbicide applications to KBG). Observation of all crops evaluated throughout the growing season in this study failed to identify any visible growth inhibition from previous herbicide treatment at any time after application to seedling KBG (Tables 5-12). Similarly, final crop yield estimates did not reveal any yield reductions due to herbicide treatments applied to a previous crop of KBG grown for seed (Tables 5-11). From visual observations and yield estimates indicating a lack of any rotational crop response, we are preliminarily optimistic that the herbicides evaluated in this trial, even when applied at twice the recommended application rates may not pose a carryover threat to the tested rotational crops grown under irrigated Columbia Basin conditions. However, these results should be considered preliminary only, and cannot be used to make recropping decisions. The Callisto label specifies the legal rotational crop restrictions, and should be followed. The other herbicides evaluated in this trial, Laudis and Impact® (topramezone), are not registered for use in KBG. The results of this trial are not meant to be considered a recommendation for commercial use.

Table 3. Rotational crop planting details.

Crop	Variety	Planting date	Seeding rate	Seedbed preparation	Maintenance herbicides
Alfalfa	BarAlfa 32	Sept. 2, 2010	25 lb/A	Disk/rototill	Raptor/Select
Canola	DKW 13-69 (RR)	Sept. 2, 2010	6 lb/A	Disk/rototill	Roundup
Fall Onion	Highkeeper	Sept. 2, 2010		Disk/rototill	Dacthal/Select/ Goal + Buctril
Winter Pea	Austrian	Sept. 29, 2010		Disk/rototill	None
Spring Pea	Tonic	April 1, 2011	210 lb/A	Disk/rototill	MCPA + Basagran
Spring Onion	Renegade	April 7, 2011	-	Disk/rototill	Fusilade
Carrot	Red Core Chatenay	May 17, 2011	-	Disk/rototill	Lorox
Dry Bean	-	May 20, 2011	-	Disk/rototill	Raptor + Basagran

Table 4. Time intervals between herbicide applications to Kentucky bluegrass and rotational crop planting date.

Crop	PRE	EPOST	LPOST	PRE	EPOST	LPOST
	Days after herbicide application (DAA)			Months after herbicide application (MAA)[1]		
Alfalfa	358	331	192	11.8	10.9	6.3
Canola	358	331	192	11.8	10.9	6.3
Fall Onion	358	331	192	11.8	10.9	6.3
Winter Pea	385	358	219	12.7	11.8	7.2
Spring Pea	569	542	403	18.7	17.8	13.2
Spring Onion	575	548	409	18.9	18.0	13.4
Carrot	615	588	449	20.2	19.3	14.8
Dry Bean	618	591	452	20.3	19.4	14.9

[1] Months after herbicide application calculated by dividing DAA by 365 and multiplying by 12.

Table 5. Alfalfa crop response to herbicide treatments applied to Kentucky bluegrass and harvested dry weight (1st cutting). Harvested June 20, 2011.

Treatment	Rate	Timing[1]	Alfalfa crop injury November	Alfalfa crop injury May 4	Dry weight (1st cutting) June 20
	(fl oz/A)		----------- (%) ------------		(dry tons/A)
Untreated			0	0	2.6
Callisto	12	PRE	0	0	2.1
Callisto	12	EPOST	0	0	2.6
Callisto	12	LPOST	0	0	2.1
Laudis	6	EPOST	0	0	2.0
Laudis	6	LPOST	0	0	2.0
Impact	1.5	EPOST	0	0	2.0
Impact	1.5	LPOST	0	0	2.3
LSD (0.05)			NS	NS	NS

[1] PRE – Preemergence treatment applied September 9, 2009. EPOST – Early postemergence treatments applied October 6, 2009. LPOST treatments applied February 22, 2010. All EPOST and LPOST treatments contained a crop oil concentrate (COC) at 1% v/v and a 32% liquid N solution at 2.5% v/v.

Table 6. Winter canola crop response to herbicide treatments in Kentucky bluegrass and harvested dry seed yields.

Treatment	Rate	Timing[1]	Canola crop injury November	Canola crop injury May 4	Clean seed yield July 5, 2011
	(fl oz/A)		------------- (%) -------------		(lb/A)
Untreated			0	0	2908
Callisto	12	PRE	0	0	2979
Callisto	12	EPOST	0	0	2610
Callisto	12	LPOST	0	0	2677
Laudis	6	EPOST	0	0	2657
Laudis	6	LPOST	0	0	2627
Impact	1.5	EPOST	0	0	2773
Impact	1.5	LPOST	0	0	2695
LSD (0.05)			NS	NS	NS

[1] PRE – Preemergence treatment applied September 9, 2009. EPOST – Early postemergence treatments applied October 6, 2009. LPOST treatments applied February 22, 2010. All EPOST and LPOST treatments contained a crop oil concentrate (COC) at 1% v/v and a 32% liquid N solution at 2.5% v/v.

Table 7. Winter pea crop response to herbicide treatments in Kentucky bluegrass and harvested dry seed yields.

Treatment	Rate	Timing[1]	Winter pea crop injury November	Winter pea crop injury May 4	Clean seed yield July 20, 2011
	(fl oz/A)		------------- (%)	-------------	(lb/A)
Untreated			0	0	1496
Callisto	12	PRE	0	0	1453
Callisto	12	EPOST	0	0	1527
Callisto	12	LPOST	0	0	1547
Laudis	6	EPOST	0	0	1471
Laudis	6	LPOST	0	0	1304
Impact	1.5	EPOST	0	0	1480
Impact	1.5	LPOST	0	0	1752
LSD (0.05)			NS	NS	NS

[1] PRE – Preemergence treatment applied September 9, 2009. EPOST – Early postemergence treatments applied October 6, 2009. LPOST treatments applied February 22, 2010. All EPOST and LPOST treatments contained a crop oil concentrate (COC) at 1% v/v and a 32% liquid N solution at 2.5% v/v.

Table 8. Spring pea crop response to herbicide treatments in Kentucky bluegrass and harvested dry seed yields.

Treatment	Rate	Timing[1]	Spring pea crop injury May 4	Spring pea crop injury June	Clean seed yield July 20, 2011
	(fl oz/A)		------------- (%)	-------------	(lb/A)
Untreated			0	0	3083
Callisto	12	PRE	0	0	3640
Callisto	12	EPOST	0	0	3117
Callisto	12	LPOST	0	0	3250
Laudis	6	EPOST	0	0	3152
Laudis	6	LPOST	0	0	3397
Impact	1.5	EPOST	0	0	2960
Impact	1.5	LPOST	0	0	3406
LSD (0.05)			NS	NS	NS

[1] PRE – Preemergence treatment applied September 9, 2009. EPOST – Early postemergence treatments applied October 6, 2009. LPOST treatments applied February 22, 2010. All EPOST and LPOST treatments contained a crop oil concentrate (COC) at 1% v/v and a 32% liquid N solution at 2.5%.

Table 9. Fall-planted fresh onion bulb yield response to herbicide treatments in Kentucky bluegrass. Onions harvested July 5, 2011.

Treatment	Rate	Timing[1]	Onion bulb yield					
			Medium	Jumbo	Colossal	Under	Cull	Total
	(fl oz/A)		----------------------------------		(fresh tons/A)		------------------------------------	
Untreated			2.6	3.9	1.7	0.2	0.15	8.45
Callisto	12	PRE	2.2	3.6	4.0	0.1	0.29	10.21
Callisto	12	EPOST	4.1	2.9	1.9	0.2	0.06	9.24
Callisto	12	LPOST	2.7	2.4	1.5	0.3	0.12	6.94
Laudis	6	EPOST	2.4	2.4	2.2	0.1	0.23	7.31
Laudis	6	LPOST	3.7	3.3	1.7	0.2	0.10	9.00
Impact	1.5	EPOST	2.3	3.3	2.2	0.1	0.15	7.98
Impact	1.5	LPOST	2.2	2.2	1.2	0.3	0.05	5.91
LSD (0.05)			NS	NS	NS	NS	NS	NS

[1] PRE – Preemergence treatment applied September 9, 2009. EPOST – Early postemergence treatments applied October 6, 2009. LPOST treatments applied February 22, 2010. All EPOST and LPOST treatments contained a crop oil concentrate (COC) at 1% v/v and a 32% liquid N solution at 2.5% v/v.

Table 10. Spring-planted fresh onion bulb yield response to herbicide treatments in Kentucky bluegrass.

Treatment	Rate	Timing[1]	Onion bulb yield					
			Medium	Jumbo	Colossal	Under	Cull	Total
	(fl oz/A)		(fresh tons/A)					
Untreated			2.2	32.0	7.3	1.2	0.5	43.2
Callisto	12	PRE	2.6	28.4	9.2	0.4	1.1	41.7
Callisto	12	EPOST	2.3	31.0	7.5	0.5	0.3	41.6
Callisto	12	LPOST	2.6	30.7	9.3	0.3	1.3	44.2
Laudis	6	EPOST	2.2	30.1	6.8	0.1	1.0	40.2
Laudis	6	LPOST	2.3	29.4	8.1	0.1	1.6	41.5
Impact	1.5	EPOST	2.3	31.3	8.2	1.1	0.6	43.6
Impact	1.5	LPOST	4.0	25.4	4.5	0.4	1.2	35.5
LSD (0.05)			NS	NS	NS	NS	NS	NS

[1] PRE – Preemergence treatment applied September 9, 2009. EPOST – Early postemergence treatments applied October 6, 2009. LPOST treatments applied February 22, 2010. All EPOST and LPOST treatments contained a crop oil concentrate (COC) at 1% v/v and a 32% liquid N solution at 2.5% v/v.

Table 11. Fresh market carrot response to herbicide treatments in Kentucky bluegrass and fresh carrot root yields.

Treatment	Rate	Timing[1]	Carrot crop injury June	Carrot crop injury July	Fresh carrot yield		
					Marketable	Cull	Total
	(fl oz/A)		(%)		(tons/A)		
Untreated			0	0	22	9.0	31.3
Callisto	12	PRE	0	0	25	8.5	33.9
Callisto	12	EPOST	0	0	23	9.2	32.7
Callisto	12	LPOST	0	0	24	9.8	33.8
Laudis	6	EPOST	0	0	26	8.0	34.0
Laudis	6	LPOST	0	0	25	8.7	33.7
Impact	1.5	EPOST	0	0	27	6.6	33.7
Impact	1.5	LPOST	0	0	25	10.4	35.3
LSD (0.05)			NS	NS	NS	NS	NS

[1] PRE – Preemergence treatment applied September 9, 2009. EPOST – Early postemergence treatments applied October 6, 2009. LPOST treatments applied February 22, 2010. All EPOST and LPOST treatments contained a crop oil concentrate (COC) at 1% v/v and a 32% liquid N solution at 2.5%.

Table 12. Dry pinto bean response to herbicide treatments in Kentucky bluegrass and dry bean seed yields.

Treatment	Rate	Timing[1]	Pinto bean crop injury June	Pinto bean crop injury July	Dry bean seed yield[2]
	(fl oz/A)		(%)		(lb/A)
Untreated			0	0	-
Callisto	12	PRE	0	0	-
Callisto	12	EPOST	0	0	-
Callisto	12	LPOST	0	0	-
Laudis	6	EPOST	0	0	-
Laudis	6	LPOST	0	0	-
Impact	1.5	EPOST	0	0	-
Impact	1.5	LPOST	0	0	-
LSD (0.05)			NS	NS	-

[1] PRE – Preemergence treatment applied September 9, 2009. EPOST – Early postemergence treatments applied October 6, 2009. LPOST treatments applied February 22, 2010. All EPOST and LPOST treatments contained a crop oil concentrate (COC) at 1% v/v and a 32% liquid N solution at 2.5%.

[2] Dry bean yield not calculated due to variable irrigation conditions.

EVALUATION OF PALISADE® ON FIFTEEN KENTUCKY BLUEGRASS VARIETIES GROWN FOR SEED IN CENTRAL OREGON UNDER NON-THERMAL RESIDUE MANAGEMENT

M.D. Butler and R.B. Simmons

Situation

Research to evaluate Palisade on Kentucky bluegrass was conducted in commercial seed fields of 'Merit' or 'Geronimo' from 1999 to 2003. Yields were increased by 31 to 36 percent 4 of the 5 years when Palisade was applied at 22 oz/acre from the second node (Feekes growth stage 7) to heads just becoming visible (Feekes 10.1). Late application, when the heads extended just above the flag leaf (Feekes 10.4), produced the greatest reduction in plant size, while plants tended to outgrow the effect of earlier Palisade applications. No differences between treatments in weight per 1,000 seeds were observed, and percent germination was not adversely affected.

Procedures

This research project was conducted at the Central Oregon Agricultural Research Center (COARC) near Madras. Varieties were replicated four times in main plots 10-ft by 60-ft, which were split into 10-ft by 20-ft subplots for comparing yields for plots treated with the growth regulator Palisade and plots left untreated. A split-plot analysis of variance was used to test treatment effects.

Palisade was applied at 24 oz/acre on May 11 when most varieties were at the second node to early boot stage. Applications were made with a CO_2-pressurized, hand-held boom sprayer at 40 psi and 20 gal/acre water using TeeJet 8002 nozzles. Plant height was measured June 20; percent lodging was estimated July 11 for the third-year field planted in 2008. A 6-ft by 17-ft section of each plot was swathed as varieties matured from July 11 to July 25. This was followed by combining of the plots at an appropriate timing. A plot-sized swather and Wintersteiger plot combine were used. Seed samples were transported to the Hyslop Farm near Corvallis, Oregon where they were debearded, run through a small-scale Clipper cleaner, and clean seed weight was determined.

Results

There were no significant interactions for seed yield and lodging between the 15 Kentucky bluegrass varieties and Palisade treatment (Table 1). Average seed yield (600 lb/acre) across varieties this season was lower than the previous two years (Table 2). Average seed yield did not increased following Palisade treatment this third season, unlike the 35 percent increase the first year and 19 percent increase the second. There was a significant interaction on plant height in year three of treatment (Table 2). Palisade reduced plant height an average of 1.9 inches, compared to 2.1 inches the first year and 3.1 inches the second. Percent lodging was decreased following Palisade treatment by10 percent, compared to 39 percent the first year and 57 percent the second.

Summary Discussion

The first planting was made in 2007, with a second planting in 2008. Nonthermal post-harvest residue management was employed across all plots during the study. Following harvest, straw was baled and remaining residue was removed mechanically using a Grass Vac to simulate field conditions following baling in the large plot variety evaluations off station. Harvest in 2008 was one first-year field, harvest in 2009 included a first-year and second-year field, harvest in 2010 was a second-year and third-year field, final harvest in 2011 of the final third-year field. With completion we have data for three ages of fields across two planting dates. This design also provides a comparison of results for the same age field across two different production years. There was stand deterioration for the 2007 planting following the first production year. This creates less confidence in the second- and third-year data from this field, and less weight should be given to these results.

Statistical analysis indicated significant interactions between the 15 Kentucky bluegrass varieties and Palisade treatments on first-year stands, with no statistical significance in the second and third years. Looking at trends associated with the 6 harvests across 3 production years to date, Palisade increased seed yield by an average of 19 percent (Table 2). The average for first-year fields was a 23 percent increase, second-year fields averaged 22 percent and third-year fields was a 13 percent increase. Reduction in plant height from Palisade averaged 2.7 inches with 6 harvests across 3 years, with a reduction of 1.7 inches for first-year fields, 3.8 inches across second-year fields, and 2.7 inches for the third-year fields. Palisade reduced lodging by an average of 35 percent across with 6 harvests across 3 years, with a reduction of 37 percent in first-year fields, 39 percent in second-year fields, and 29 percent for the third-year fields.

Evaluating the influence of Palisade by production year across stand age indicates an 11 percent increase in seed yield in 2008, 28 percent increase during 2009, 22 percent increase in 2010, and a decrease of 1 percent in 2011. Palisade reduced plant height by an average of 1.3 inches in 2008, and 3.3 inches for both 2009 and 2010, and 1.9 percent in 2011. Percent reduction in lodging with Palisade averaged 35 percent in 2008, 30 percent in 2009, 52 percent in 2010, and 10 percent in 2011.

Table 1. Effect of Palisade growth regulator on seed yield, lodging, and plant height on a 3rd year field of 15 Kentucky bluegrass varieties planted August, 2008, at COARC, Madras, OR.

	Clean seed yield (lb/acre)			Evaluation dates 6/20/11 Plant height (in)		Evaluation dates 8/2/11 Lodging (%)	
Variety[1]	Check	Palisade	% Check	Check	Palisade	Check	Palisade
Atlantis	588	624	106	22	19	18	18
Merit	656	493	75	24	18	33	3
Rhapsody	617	526	85	19	18	0	8
Valor	586	461	79	17	15	0	0
Bar-Iris	233	349	150	23	23	89	88
Crest	851	613	72	20	16	20	13
Monte Carlo	579	545	94	16	15	0	0
Shamrock	712	816	115	24	22	68	48
A00-891	709	669	94	21	17	40	11
A00-1400	460	407	88	22	18	39	5
Bandera	681	554	81	20	18	3	1
Bordeaux	582	782	134	22	21	36	21
Volt	589	837	142	23	24	63	43
Zinfandel	641	692	108	18	18	0	0
A01-299	524	526	100	18	19	0	0

[1] Paired t-test indicated no significant differences between Palisade treatments.

Table 2. Three-year averages of clean seed yield, lodging and plant height for 2007 & 2008 plantings of 15 Kentucky bluegrass varieties with and without Palisade at COARC, Madras, OR.

	Averages across 15 varieties: Seed yield (lb/acre)			Plant height (in)			Plant lodging (%)		
	Check	Palisade	% Check	Check	Palisade	Dif.	Check	Palisade	Dif.
2007 Planting									
1st Year	1266	1383	111	26.4	25.1	1.3	67	24	35
2nd Year	702	822	122	21.5	17.0	4.4	43	9	21
3rd Year	961	1093	125	21.7	18.3	3.4	40	19	48
2008 Planting									
1st Year	1025	1341	135	14.3	12.3	2.1	61	24	39
2nd Year	810	951	119	21.7	18.5	3.1	28	16	57
3rd Year	599	592	101	20.6	18.7	1.9	27	17	10

QUANTIFYING AMMONIA VOLATILIZATION FROM SURFACE-APPLIED FERTILIZERS IN CENTRAL OREGON KENTUCKY BLUEGRASS SEED PRODUCTION

*M.D. Butler and R.B. Simmon*s

Situation

Kentucky bluegrass seed fields in central Oregon, Hermiston, and in the dryland conditions of eastern Washington all use surface-applied nitrogen (N). The areas have diverse characteristics from high elevation of central Oregon, low elevation of the lower Columbia Basin, and rolling terrain of eastern Washington. Differences in winter temperatures and production practices create different risks for N loss. Soil characteristics and residue management vary between regions, as well as within regions. All three production areas receive their primary N application as topdress in mid- to late fall. When ammonium nitrate was available and N fertilizer cost low, volatile N loss was not a major concern. Recent observations by field representatives raise questions about the amount of N loss from volatilization of ammoniacal fertilizers such as urea.

Volatile N loss costs Kentucky bluegrass growers, wastes resources, and is an environmental concern. Ammonia in the air reacts with nitrous oxides and sulfur dioxide to form an aerosol product that produces smog and is a PM-2.5 particulate (U.S. Environmental Protection Agency designation). Quantitative measurement of volatile ammonia loss is necessary to define conditions where loss is minimal, and to put a cost to the loss and account for the N in fertilizer efficiency.

The objective of this second-year study was to quantify as pounds per acre ammonia volatilization from urea, Agrotain-coated urea and ammonium nitrate, applied to the soil surface in the fall under commercial field conditions to identify potential improvements in fertilizer management in grass seed production systems.

Procedures

Research in central Oregon was conducted on two Kentucky bluegrass (*Poa pratensis* L.) fields, one 50-acre field near Culver and the other a 75-acre field on the Agency Plains north of Madras. The last irrigation of the season had been completed just prior to fertilizer application at both locations. The Culver location was treated October 12, 2011 with four surface-applied N fertilizers, urea, Agrotain-coated urea at 1.5 lb/ton, Agrotain-coated urea at 3 lb/ton, and ammonium nitrate. The same four treatments were applied to the Agency plains location on October 18, 2011.

Fertilizers were applied to a 100-ft- diameter circle at a rate of 150 lb N/acre using a 3-ft Gandy turf spreader. Plots were arranged in a randomized complete block design with four replications. They were separated by a minimum of 300 ft to avoid possible ammonia cross-contamination between treatments.

Ammonia volatilization losses were measured with a modified passive flux method (Wood et al., 2000), which consists of a rotating 10-ft-tall mast placed at the center of each circular plot. Ammonia was sampled at five heights (1.5, 2.5, 4.8, 7.4, and 9.8 ft; Leuning et al., 1985). Each passive flux ammonia sampler consisted of a glass tube (0.28 inches diameter by 7.87 inches long). The end of the tube facing the wind was capped with a small opening to control airflow through the tube. The inside of the tube was coated with oxalic acid to trap ammonia from the air. The mast includes a wind vane that keeps the tubes facing into the wind. Two background masts were placed upwind of the predominant wind direction. Sampling tubes were placed on the mast immediately following fertilizer application, and changed daily during the first week, then every-other day thereafter. The duration of the project was 23 days at the Culver location and 21 days on the Agency Plains.

Sampling tubes were collected, capped at both ends to prevent any further collection of ammonia, and stored at 5ºC until processing at Hermiston. Processing began by shaking the tubes for 10 min with deionized water, then extracting and analyzing colorimetrically for ammonium (NH4 +) (Sims et al.,1995). Total ammonia volatilized from applied fertilizers was quantified by subtracting the background ammonia measurements. Vertical flux of ammonia was determined by summing horizontal flux at each measurement height (Wood et al., 2000).

Remotely operated weather stations (Campbell Scientific, Logan, UT) were placed on the edge of each field to collect data related to air temperature, soil temperature, humidity, rainfall, and wind speed and direction during the duration of the project at each location. Unfortunately, these onsite stations did not provide reliable data so the Agrimet weather station at the Central Oregon Agricultural Research Center on the Agency Plains was used for temperature, relative humidity, and wind speed.

Results

Comparison of nitrogen sources:

Following application of 150 lb N/acre, nitrogen loss due to ammonia volatilization across both locations was highest with urea, followed by Agrotain-coated urea at 1.5 lb/ton, Agrotain-coated urea at 3 lb/ton, and ammonium nitrate with the least volatilization. Ammonia volatilization across both locations averaged 36 lb N/acre for urea. Informally, it appears the amount of Agrotain applied to the urea is correlated to the amount of ammonia volatilization, with 22 lb N/acre for Agrotain-coated urea at 1.5 lb/ton, 16 lb N/acre for Agrotain-coated urea at 3 lb/ton, and data from the fall of 2010 indicated a loss of 9 lb N/acre for Agrotain-coated urea at 5 lb/ton. Losses with ammonium nitrate were 4 lb N/acre during the fall of 2011 and averaged 6 lb N/acre across the two years of the project.

Over a 23-day period at Culver, ammonia volatilization was 38 lb N/acre (25 percent) for urea compared to 18 lbs N/acre (12 percent) for Agrotain-coated urea at 1.5 lb/ton, 15 lb N/acre (10 percent) for Agrotain-coated urea at 3 lb/ton and 3 lb N/acre (2 percent) for ammonium nitrate. Over a 21-day period at Agency Plains, ammonia volatilization was 35 lb N/acre (23 percent) for urea compared to 27 lbs N/acre (18 percent) for Agrotain-coated urea at 1.5 lb/ton, 18 lb N/acre (12 percent) for Agrotain-coated urea at 3 lb/ton and 6 lb N/acre (4 percent) for ammonium nitrate.

Weather conditions:

During the initiation of the project at the Culver site, day time high temperatures were in the 60s, with night-time lows near 40°F. At 14 days after treatment (DAT) high temperatures had dropped from 70°F to 50°F, followed by a rise to near 70°F at 18 DAT. There is a corresponding drop in ammonia volatilization on 14 DAT (most notably on urea) that matches the drop in the daytime high temperature. The Agency Plains location was initiated six days after Culver. There is the corresponding flattening of the curve in ammonia volatilization for urea on 8 DAT and again on day 13. Temperature again dropped from near 70°F to 50°F at 13 DAT, followed by a rebound to the low 60s before dropping back down into the 40s. Informally, there appears to be a correlation between day time temperatures and level of volatilization at both locations. Any correlation with relative humidity and wind speed is more difficult to discern.

Summary of two-year project:

Heavy dew and higher temperatures appear to increase the amount of ammonia volatilization under central Oregon conditions. Unlike companion projects in the Columbia Basin where the volatilization curve is reported to flatten to near horizontal in two weeks, our curves often continue on an upward trajectory throughout the third week of monitoring this season. Perhaps overnight dew or frost, followed by warm days that create a daily freezing and thawing cycle promotes continued ammonia volatilization. The effect of relative humidity and wind speed on volatilization is less clear.

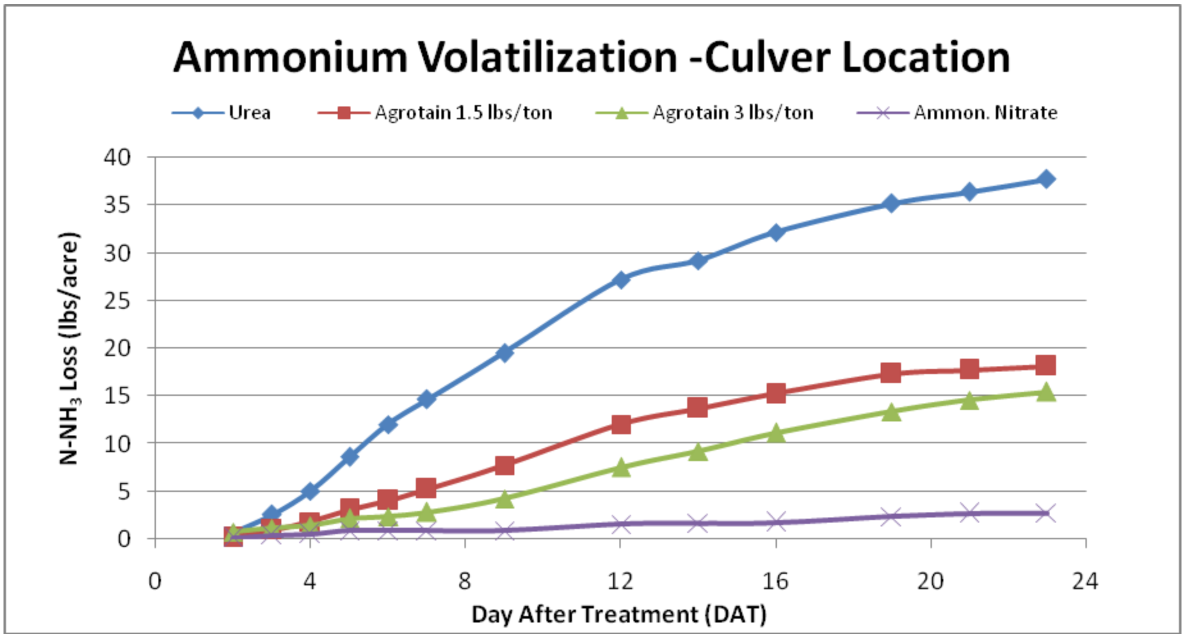

Figure 1. Ammonia volatilization loss from four nitrogen sources at Culver initiated October 12, 2011.

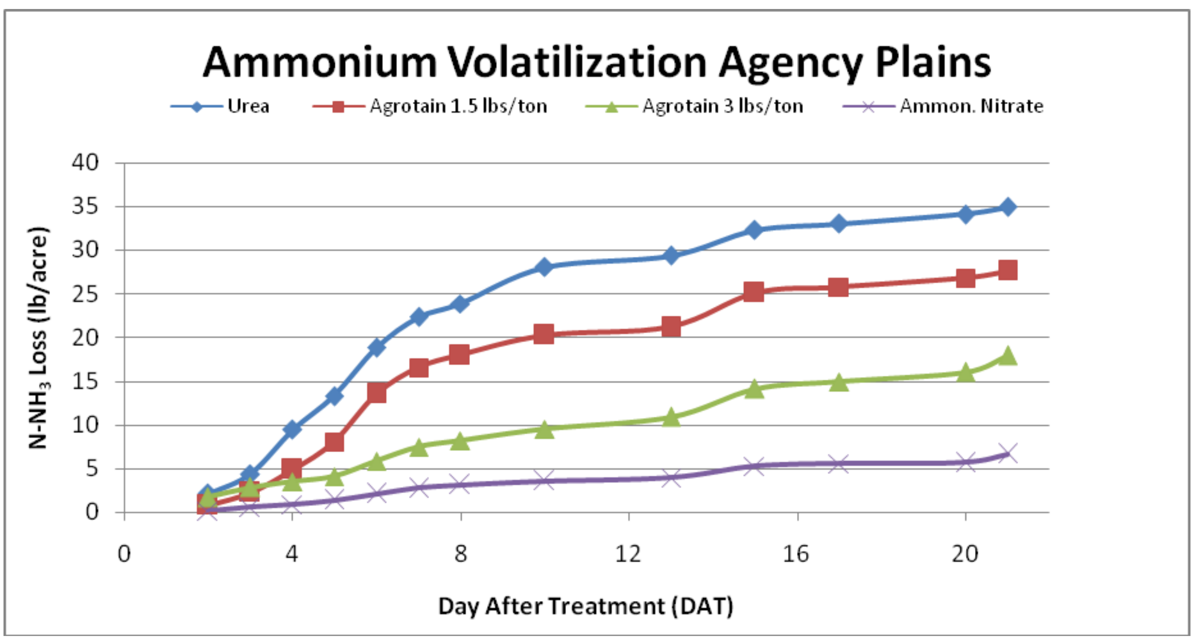

Figure 2. Ammonia volatilization loss from four nitrogen sources on Agency Plains initiated October 18, 2011.

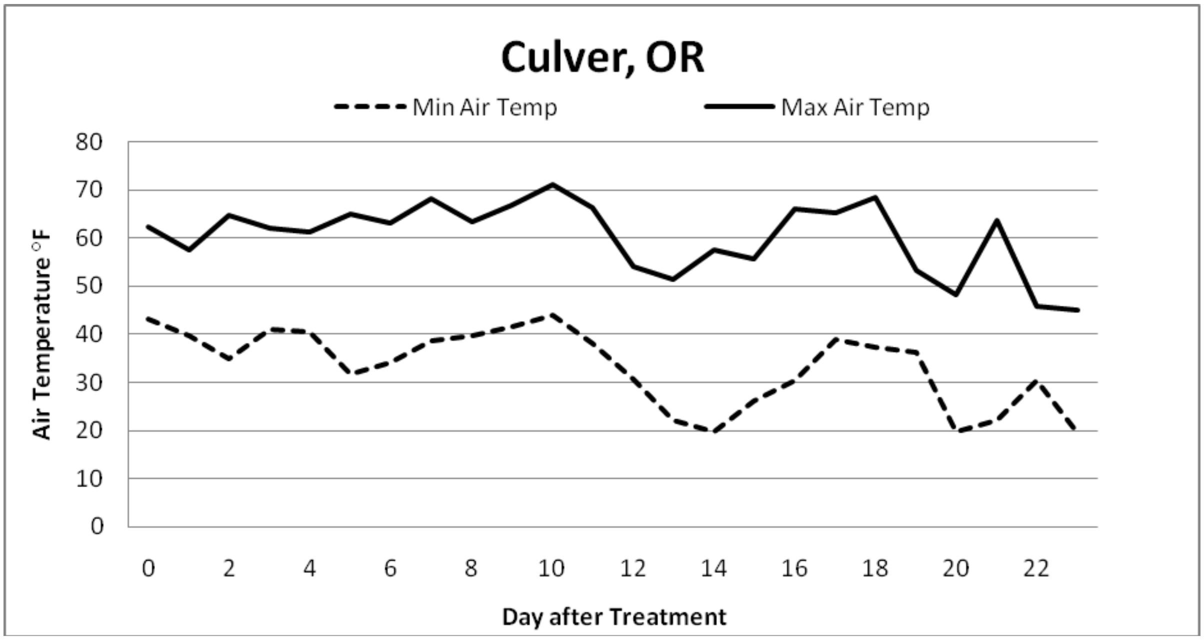

Figure 3. Air temperature maximums and minimums for 23 days of observations at Culver, OR.

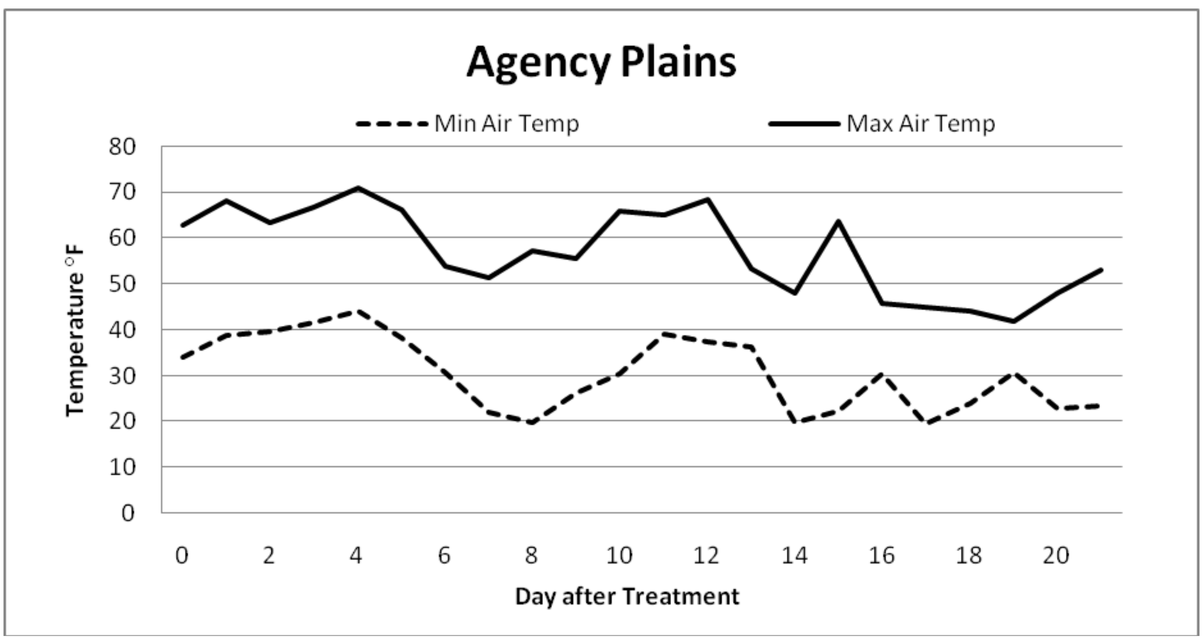

Figure 4. Air temperature maximums and minimums for 21 days of observations at Agency Plains.

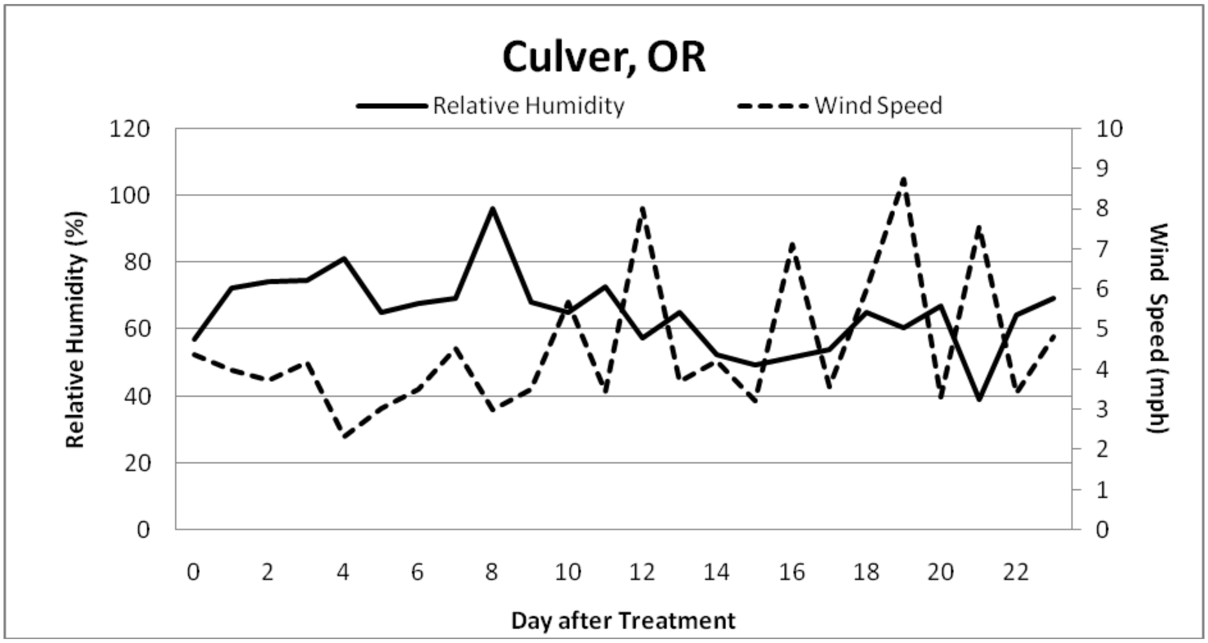

Figure 5. Percent relative humidity and wind speed for 23 days of observations at Culver, OR.

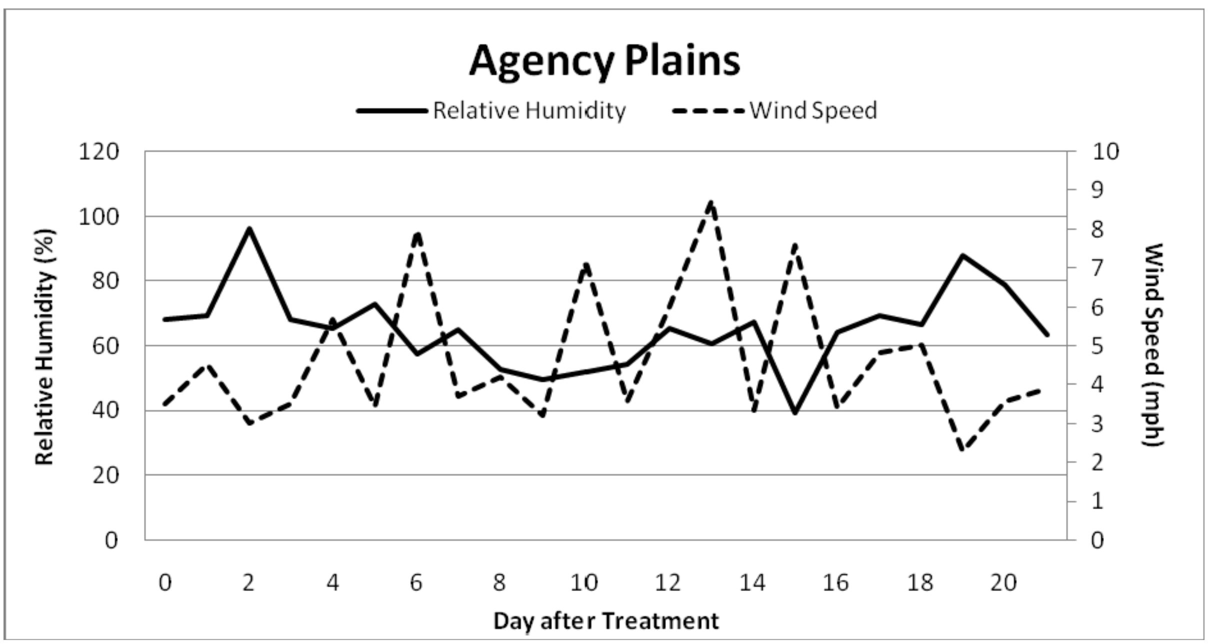

Figure 6. Percent relative humidity and wind speed for 21 days of observations at Agency Plains.

Table 1. Observations made while changing tubes at Culver location and Agency Plains, 2011.

Culver			Agency Plains		
DAT[1]	Date[2]	Notes	DAT[1]	Date[2]	Notes
0	12-Oct	Heavy Dew	0	18-Oct	Light Dew
2	14-Oct	Heavy Dew	2	20-Oct	Heavy Dew
3	15-Oct	Light Dew	3	21-Oct	Heavy Dew
4	16-Oct	Heavy Dew	4	22-Oct	Light Dew
5	17-Oct	Frost	5	23-Oct	Heavy Dew
6	18-Oct	Frost	6	24-Oct	Light Dew
7	19-Oct	Light Dew	7	25-Oct	Light Dew
9	21-Oct	Heavy Dew	8	26-Oct	Light Dew
12	24-Oct	Light Dew	10	28-Oct	Dry
14	25-Oct	Light Dew	13	31-Oct	Light Dew
16	28-Oct	Light Dew	15	2-Nov	Light Dew
19	31-Oct	Frost	17	4-Nov	Frost
21	2-Nov	Frost	20	7-Nov	Frost

[1] DAT=Day after treatment
[2] Date of tube placement

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SOD WEBWORM MANAGEMENT SYSTEM FOR KENTUCKY BLUEGRASS SEED PRODUCTION IN CENTRAL OREGON

M.D. Butler, J.M. Weber, and R.B. Simmons

Situation

Surveys of insect pests in Kentucky bluegrass fields were conducted in central Oregon and the Grande Ronde Valley during 2003-2005. Results indicated the presence of sod webworm (*Chrysoteuchia topiaria*) and cutworms (*Protagrotis obscura*) in central Oregon. At that time sod webworms were considered an emerging pest that could have a financial impact on Kentucky bluegrass fields in central Oregon. As a result this ongoing project has focused on sod webworm populations and distribution during the 2005 through 2009 seasons. The strategy has been to use pheromone traps that emit a scent to attract males in order to track the number of the sod webworm moths. This has been followed by sod sampling to determine the potential correlation between moth and larval populations. The original objective of this research was to determine whether pheromone traps can be used as an indicator of fields that will have high populations of larvae in the fall, when control measures are applicable. A strong correlation between moth flights and larval populations the following fall has not be found. The number of cutworms collected in pheromone traps has been tracked as well.

Procedures

Four pheromone traps were placed in each of the 4 quadrants of 11 commercial Kentucky bluegrass seed production fields on May 25, 2010. Fields with potential insect problems in the Madras and Culver, Oregon, areas were chosen for the project. Contents of the traps were collected weekly from June 1 to August 2, with the number of sod webworm and cutworm moths noted. Pheromones were replaced twice during the project to ensure adequate attractant was present.

Results

Sod webworm moth populations began to increase starting June 29, with peak flight from July 13 to July 26, and a significant decrease in overall numbers on August 2 (Table 1). During peak flight the average number of sod webworm moths collected per field per week from the 4 traps ranged from 200 to 300 for 4 fields. The total number of sod webworm moths collected per field varied from 98 to 1,014 over the trapping period.

Cutworm moths attracted to the traps were tracked as well (Table 2). Populations began to increase on June 8, peaked on July 6, and significantly declined on August 2. The total number of cutworms collected per field ranged from 59 to 219 during the trapping period. Cutworm populations in central Oregon are generally modest compared to Kentucky bluegrass production areas like the Grande Ronde Valley of northeastern Oregon. The cutworm life cycle in central Oregon appears to be similar to that of the sod webworm, but with an earlier peak flight.

Summary

Sod webworm numbers and flight timings in central Oregon Kentucky bluegrass fields have been similar over the last three seasons, 2008-2010. In general, sod webworm moths appear in late June and steadily increase in numbers until peak flight in mid- to late July, with a significant decline in population the first of August as fields dry down in preparation for open field burning. Cutworm moths peak a few weeks prior to the sod webworm peak, generally in early July.

There is an option for control of sod webworm by treating adults at peak flight prior to egg-laying, rather than targeting larvae in the fall as has been done historically. If this approach was used, pheromone traps would have a direct influence on the need for treatment rather than being an indicator of potential larvae populations in the fall. There has not been a strong correlation between adult populations in early summer and larval number in the fall. Control of adults is complicated by harvest operations, while application of insecticides in the fall is effective against multiple insect pests.

Table 1. Sod webworm moths collected per field of Kentucky bluegrass using pheromone traps from June 1 to August 2, 2010, near Madras, OR.

	Collection dates for sod webworm moths										
Field	June 1	June 8	June 15	June 22	June 29	July 6	July 13	July 19	July 26	August 2	Total
1	3	8	1	9	121	49	146	257	293	127	1014
2	3	0	0	2	112	72	140	219	41	95	684
3	0	0	0	24	85	32	109	271	194	130	845
4	3	0	0	0	15	31	90	278	163	7	587
5	4	3	1	7	29	10	113	91	121	26	405
6	6	2	0	0	14	5	31	5	24	11	98
7	0	0	4	9	15	14	65	44	15	5	171
8	2	0	0	0	130	23	80	85	16	1	337
9	0	0	0	3	108	13	162	131	98	49	564
10	1	0	0	12	212	176	48	196	72	13	730
11	1	2	0	0	36	44	28	10	4	2	127
Total	23	15	6	66	877	469	1012	1587	1041	466	5562

Table 2. Cutworm moths collected per field of Kentucky bluegrass using pheromone traps from June 1 to August 2, 2010, near Madras, OR.

	Collection dates for sod webworm moths										
Field	June 1	June 8	June 15	June 22	June 29	July 6	July 13	July 19	July 26	August 2	Total
1	1	3	10	20	11	6	2	17	3	0	73
2	0	5	6	7	15	54	10	20	19	9	145
3	0	0	6	6	16	53	5	9	35	8	138
4	1	8	23	47	23	61	20	7	21	5	216
5	4	16	24	12	16	41	15	7	11	7	153
6	0	14	8	9	23	65	31	40	24	5	219
7	2	3	0	0	0	14	20	34	13	3	89
8	0	2	1	8	11	75	43	19	6	1	166
9	1	5	8	6	3	48	31	10	20	7	139
10	6	10	6	8	5	28	23	12	15	0	113
11	1	0	0	4	22	17	5	4	6	0	59
Total	16	66	92	127	145	462	205	179	173	45	1510

DEVELOPMENT OF A PHENOLOGICAL MODEL FOR THE DENVER BILLBUG IN CENTRAL OREGON BLUEGRASS SEED PRODUCTION

M.D. Butler, J.M. Weber, S. Rao, and R.B. Simmons

Situation

The Denver billbug (*Sphenophorus cicatristriatus*) has occasionally been observed in central Oregon Kentucky bluegrass fields grown for seed. During insect sampling from 1996 through 2007 for sod webworm (*Chrysoteuchia topiaria*) and cutworms (*Protagrotis obscura*), the Denver billbug was collected at low levels in occasional fields, but has never been considered an important pest. During the fall of 2008 high levels of the billbug were found in one field, with moderate levels in two others. Sampling continued in 2009 to identify the timing of the four life stages: egg, larva, pupa, and adult. Billbugs do most of their damage while in the larval stage and can cause significant damage to grass seed fields. Left uncontrolled, populations tend to double annually. Pitfall traps and sod sampling were used for collection of the various life stages to develop a phenological model and control strategy for the Denver billbug in central Oregon.

Procedures

During the fall of the 2009 season three commercial bluegrass seed production fields showing billbug damage were selected for sampling. Eight pitfall traps were placed in each of the three fields on March 3, 2010 and checked on a weekly basis through July 6, when they were removed for harvest. Pitfall traps were not replaced in the fields following harvest.

Eight, 12-inch-diameter sod samples, 2 inches deep, were collected every 2 weeks from March 16 through June 22, 2010. These samples were taken within 3 to 5 ft from the pitfall traps and kept refrigerated while waiting for processing. Sod samples were processed for 4 days using Berlese funnels. Berlese funnels are used for extracting insects and other arthropods from soil and litter samples. Insects and other arthropods that live in soil will move away from a heat source that is drying out the soil. Therefore, a heat source above the soil samples is used to cause the insects to move downward, where they will fall through a screen holding the sod sample down a funnel and into a container for collection. Insects were collected, identified, and counted. In addition, samples were screened for any nonmobile adults or larvae.

Random samples of adult billbug and larvae were sent to Dr. Sujaya Rao at Oregon State University for DNA sampling. The objective of this portion of the study is to determine if molecular markers could be identified for separation of three billbug species, *Sphenophorus parvulus* (bluegrass billbug), *S. cicatristriatus* (Denver billbug) and *S. sayi* (currently no common name). The three species are indistinguishable as larvae and current species identification is based on adult characteristics.

Results

Adult billbugs were collected from pitfall traps weekly from March 3 through July 6, 2010. The first collection of adults began on May 17 and continued through July 6, 2010. The first two weeks of June saw the highest number of adults in pitfall traps, then steadily decreased through July 6 (Table 1).

Billbugs were collected from sod samples taken from March 16 to June 22, 2010, with adult numbers reaching a peak of 12 per field, and first appearing in significant number on May 6 (Table 2). Larvae were active during the entire collection period, with the highest numbers from May 17 to June 7. It appears from our sampling that the Denver billbug overwinters in both the adult and larval stages.

DNA analysis of adult billbugs by Sujaya Rao confirmed the presence of *S. cicatristriatus* (Denver billbug). Based on reports from other parts of the US, the bluegrass billbug and the Denver billbug have the potential to cause major economic damage to Oregon's grass seed industry. There are no reports of damage by the third species, *Sphenophorus sayi*. Presently, we are working to understand the life-cycle of these species in Oregon using molecular markers that allow identification at the larval stage. This process facilitates evaluation of the possible risks presented by each species to grass seed farmers in Oregon.

Summary
Numbers of adult Denver billbugs collected in pitfall traps peaked in late May and early June in 2009, and the first half of June in 2010. Adults collected from sod samples peaked from during June 9 to 22 in 2009 and from May 6 to June 7 in 2010. A second peak in adults was collected from pitfall traps from late September through October, 2009. Larval populations collected from sod samples peaked on June 22, 2009 and May 17 to June 7, 2010. A second peak occurred from September 22 through October 23, 2009. Many small larvae were observed during mid-June 2009, indicating a new hatch of larvae during late spring.

Two years of data collected from Kentucky bluegrass seed fields in central Oregon will be used to develop a phenological model to show life stages of the Denver billbug throughout the calendar year. This will provide the basis for recommendations for control of this pest.

Table 1. Number of adult billbugs collected in pitfall traps from fields located on the Agency Plains near Madras, OR, 2010.

	Collection dates											
Field	March 3-23	April 5	April 14	April 20	May 6	May 17	May 24	June 7	June 14	June 22	June 28	July 6
	(Adults per field)											
1	0	0	0	0	0	2	1	5	2	4	2	1
2	0	0	--[1]	0	0	1	0	2	3	0	2	0
3	0	0	0	0	0	3	2	8	5	6	7	3

[1] Traps not collected.

Table 2. Number of billbug adults and larvae collected from sod samples taken from fields located on the Agency Plains near Madras, OR, 2010.

	Collection Dates											
Field	March 16	April 5	May 6	May 17	June 7	June 22	March 16	April 5	May 6	May 17	June 7	June 22
	(Adults per field)						(Larvae per field)					
1	1	0	12	2	11	2	24	43	74	119	114	89
2	0	0	3	1	0	1	6	7	13	11	31	20
	0	1	1	1	1	0	0	0	0	4	0	6

CHAR CHARACTERIZATION OF THERMOCHEMICAL TREATED KENTUCKY BLUEGRASS SEED SCREENINGS

S.M. Griffith and G.M. Banowetz

The on-farm production of bioenergy from straw and seed screenings and the recycling of the char from the combustion process serve as an alternative effective and efficient means of making wise-use of readily available agriculturally produced on-farm byproducts while simultaneously improving farm net profit, conserving net energy consumption, and more importantly, directly contributing to greater agricultural sustainability. Energy and char produced from on-farm gasification systems, using crop residue aftermath from a crop not specifically grown for the sole purpose of energy use, has significant merit with regard to influencing farm sustainability, curbing escalating production costs, and facilitating distributed networks.

Char produced from the gasification of post-seed harvest Kentucky bluegrass residues could be recycled to a cropping system as a soil amendment if chemical characterization determined that the gasification process had not produced or concentrated deleterious chemical or physical factors that might harm the environment, crop growth or yield. Previous reports have shown that char derived from the pyrolysis of a variety of biomass feedstocks has potential to enhance soil quality by pH adjustment, mineral amendment, and improved soil porosity.

Successful application of char as a soil amendment will almost certainly require a chemical characterization as part of the permitting process required by most localities. In general, chemical characterization for permitting processes addresses the potential for negative impacts of land application due to the presence of possible heavy metals or organic contaminants in the char. Relatively few published studies have quantified the heavy metals along with the secondary organic contaminants in gasification char produced at temperatures less than 700°C, particularly in units like those designed for small-scale implementation (Boateng et al., 2007).

The objective of this research was to characterize char produced from Kentucky bluegrass (*Poa pratensis* L.) seed mill screenings (KBss) by a small-scale gasification unit operated at temperatures between 600 to 650°C with respect to polyaromatic hydrocarbons (PAHs) and selected heavy metals as well as other physical and chemical characteristics and determine its suitability for agricultural application as a soil amendment.

Our findings, shown in Tables 1 through 5, support the hypothesis that char produced by thermochemical treatment of Kentucky bluegrass seed screenings could be applied in a cropping system without toxic environmental consequences and possibly serve multiple purposes, such as: recycling critical plant macro- and micro-nutrients back to existing cropland, enhance soil carbon sequestration, raise soil pH of acid soils (pH 10-10.5), and improve water holding capacity (fine particle size, 85% of total between 125-500 µm). Crop field trails need to be implemented to further test these hypotheses.

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Table 1. Proximate and ultimate analyses of char produced by gasification of Kentucky bluegrass (*Poa pratensis* L.) seed screenings residue.[1] Char was generated in a farm-scale gasification unit operated at temperatures ranging from 600 to 650°C.

Analysis	Parameter	As received	Moisture free	Moisture & ash free
		---------------------------- (wt%)	----------------------------	
Proximate	Moisture	4.35		
	Ash	46.29	48.40	
	Volatile matter	20.01	20.92	40.54
	Fixed-C	29.35	30.68	59.46
Ultimate	H	0.99	1.04	2.01
	C	45.71	47.79	92.61
	N	1.44	1.51	2.92
	S	0.33	0.35	0.67
	O	0.89	0.93	1.80
Heating value (kJ)		7314	7646	14817

[1] Laboratory analysis performed by Wyoming Analytical Laboratories, Inc. (Laramie, WY).

Table 2. Proximate and ultimate analyses of Kentucky bluegrass (*Poa pratensis* L.) seed cleaning residues.[1]

Analysis	Parameter	As received	Moisture free	Moisture & ash free
		---------------------------- (wt%)	----------------------------	
Proximate	Moisture	7.24		
	Ash	8.92	9.62	
	Volatile matter	70.53	76.03	84.12
	Fixed-C	13.31	14.35	15.88
Ultimate	H	4.81	5.19	5.74
	C	43.11	46.47	51.42
	N	1.18	1.27	1.41
	S	0.49	0.53	0.58
	O	34.25	36.92	40.28
Heating value (kJ)		7766	8373	9263

[1] Laboratory analysis performed by Wyoming Analytical Laboratories, Inc. (Laramie, WY).

Table 3. Analysis of polynuclear aromatic hydrocarbon content of char produced by gasification of Kentucky bluegrass (*Poa pratensis* L.) seed cleanings in a farm-scale gasification unit operated at temperatures ranging from 600 to 650°C.[1] Toxicity characteristic leaching procedure (TCLP) and semi-volatile organic compounds by GC/MS.

Analyte	Concentration	MRL[2]
	------ (µg kg^{-1}dwt) ------	
Naphthalene	nd[3]	0.10
2-Methylnapthalene	nd	0.10
Acenaphthylene	nd	0.10
Acenaphthene	nd	0.10
Fluorene	nd	0.10
Debenzofuran	nd	0.10
Phenanthrene	nd	0.10
Anthracene	nd	0.10
Fluoranthene	nd	0.10
Pyrene	nd	0.10
Benz(a)anthracene	nd	0.10
Chrysene	nd	0.10
Benzo(b)fluoranthene	nd	0.10
Benzo(k)fluoranthene	nd	0.10
Benzo(a)pyrene	nd	0.10
Indeno(1,2,3-cd)pyrene	nd	0.10
Dibenz(a,h)anthracene	nd	0.10
Benzo(g,h,i)perylene	nd	0.10

[1] The TCLP for semi-volatile organic compounds was performed using GC/MS following EPA methods 1311, 3501C, and 8270C by Columbia Analytical Services, Inc., Kelso, WA.
[2] Method reporting limit
[3] Not detected

Table 4. Quantification of polychlorinated dibenzodioxins and polychlorinated dibenzofurans in char produced by gasification of Kentucky bluegrass (*Poa pratensis* L.) seed cleanings in a farm-scale gasification unit operated at temperatures ranging from 600 to 650°C.[1]

Analyte	Concentration	MRL[2]	TEF[3]
	------------- ($\mu g\ kg^{-1}$dwt) -------------		
2,3,7,8-TCDD	nd[4]	0.301	1.0
1,2,3,7,8-PeCDD	nd	0.378	1.0
1,2,3,4,7,8-HxCDD	nd	0.315	0.1
1,2,3,6,7,8-HxCDD	nd	0.286	0.1
1,2,3,7,8,9-HxCDD	nd	0.305	0.1
1,2,3,5,6,7,8-HpCDD	nd	0.919	0.01
OCDD	nd	2.694	0.0003
2,3,7,8-TCDF	nd	0.301	0.1
1,2,3,7,8-PeCDF	nd	0.197	0.03
23478-PeCDF	nd	0.192	0.3
1,2,3,4,7,8-HxCDF	nd	0.272	0.1
1,2,3,6,7,8-HxCDF	nd	0.254	0.1
1,2,3,7,8,9-HxCDF	nd	0.364	0.1
2,3,4,6,7,8-HxCDF	nd	0.298	0.1
1,2,3,3,4,6,7,8-HpCDF	nd	0.587	0.01
1,2,3,4,7,8,9-HpCDF	nd	0.827	0.01
OCDF	nd	3.951	0.0003
Total tera-dioxins	nd	0.301	--
Total penta-dioxins	nd	0.378	--
Total hexa-dioxins	nd	0.286	--
Total hepta-dioxins	nd	0.919	--
Total tetra-furans	nd	0.301	--
Total penta-furans	nd	0.192	--
Total hexa-furans	nd	0.254	--
Total hepta-furans	nd	0.587	--

[1] HRGC/HRMS Analyses performed according to EPA Method 8290 by Columbia Analytical Services, Kelso, WA.
[2] Method reporting limit (MRL)
[3] World Health Organization (WHO) adopted TEF's, taken from: Van den Berg et al.: Toxic Equivalency Factor (TEFs) for PCDDs, PCDFs for Humans and Wildlife (Environ. Health Perspect. 106:775-792 (1998)
[4] Not detected

Table 5. Metal toxicity characteristics leaching procedure (TCLP) analysis of char produced by gasification of Kentucky bluegrass (*Poa pratensis* L.) seed cleanings in a farm-scale gasification unit operated at temperatures ranging from 600 to 650°C.

Metal	TCLP extract	MRL[1]	Regulatory limit[2]
		------- ($mg\ L^{-1}$) -------	
Ag	nd[3]	0.02	5
As	nd	0.1	5
Ba	nd	1.0	100
Cd	nd	0.01	1
Cr	nd	0.01	5
Hg	nd	0.001	0.2
Pb	nd	0.05	5
Se	nd	0.1	1

[1] Method reporting limit
[2] From 40 CFR Part 261, et al., and Federal Register, March 29, 1990 and June 29, 1990
[3] Not detected

TIMING OF OCCURRENCE OF ERGOT ASCOSPORES IN NORTHEASTERN OREGON

S.C. Alderman, D.L. Walenta, and P.B. Hamm

Introduction
Ergot, caused by *Claviceps purpurea* (Fr.) Tul., is a persistent problem in Kentucky bluegrass in northeastern Oregon, with direct seed loss as great as 25%. Ascospores, produced during the spring about the time of flowering in grasses, infect the grass ovaries. Seed loss can occur directly from replacement of seed with sclerotia, or indirectly when the sugary, sticky "honeydew" stage, which precedes formation of sclerotia, clumps seeds and debris together and sticks to machinery during harvest. Additional seed loss occurs during seed cleaning when re-cleaning is required to remove ergot to meet certification standards.

Ergot severity can vary from year to year, but the cause of variation is not well understood. Understanding the nature of the variability is important in developing control strategies for ergot. The objectives of this study were to determine whether variation in the severity of ergot in Kentucky bluegrass among sites is related to the timing and/or number of airborne ascospores during flowering, when the unfertilized grass ovaries are susceptible to infection, and to evaluate the efficacy of timing fungicide sprays for ergot control.

Methods
Fungicide trials: Fungicide trials were established in fields of Kentucky bluegrass cv. "Midnight II" known to be infested with ergot at Site 1 (2008) and Site 3 (2009 and 2010). A commercial package mix of azoxystrobin (0.62 lb a.i./g) + propiconazole (1.04 lbs a.i./g), formulated as Quilt® and registered for use on grasses grown for seed in Oregon, was applied at label rate (14 oz/a) and included 1% v/v stylet oil. Treatments in 2008 included: a single application at early heading; an application at early heading and early flowering; an application at early heading, early flowering, and post flowering; and untreated control. Plot size was set at 90 ft. x 1000 ft. to accommodate a commercial field applicator (with 90 ft. boom), swather, and combine. Sprayer volume was 16 GPA at early heading and 18 GPA at early and post flowering, at 30 psi. Plot size restricted treatments to 3 replications.

Plot design in 2009 and 2010 was changed to include a single application at early flowering and a single application 14 days later (post flowering) among the treatments, utilize small plot equipment and include 4 replications in a randomized complete block design. Each plot was 5 ft. x 30 ft. Fungicide treatments were applied with a hand-held CO_2 sprayer with 5 ft. hand boom fitted with TeeFet TurboJet® 60-11003 nozzle tips, delivering a spray volume of 18 GPA at 30 psi. In all years, fertilization, weed/insect management, and irrigation were managed by the cooperating grower and followed common production practices for the area.

In 2008, 2009, and 2010, plots were swathed on July 12, July 15, and Jul 26, and harvested on August 1, July 31, and August 5, respectively. Samples collected during harvest were cleaned and seed yield and percent ergot contamination was determined by dividing weight of sclerotia by weight of cleaned seed + sclerotia and multiplying by 100. Grass seed yield and percentage ergot contamination were subject to ANOVA and means were separated by the LSD all pair-wise comparison test. Data were analyzed using Statistix 9 (www.statistix.com).

Ascospore and pollen trapping: In each year of the study, ascospores were monitored in two commercial fields of Kentucky bluegrass cv. "Midnight II" and "SR2100" (Site 2) using Burkard 7 day volumetric spore traps (Burkard, Rickmansworth, England). The traps were placed within fields in early May and removed before harvest. Spore tapes were prepared, processed, and examined as previously described. The number of *C. purpurea* ascospores and grass pollen were counted under a microscope at 100-400X and summed over 12:00 pm to 11:59 am each day to establish daily counts. Standard slides of *C. purpurea* ascospores and Kentucky bluegrass pollen were used during the examination process. Differentiation of pollen to grass species was not attempted.

Results and Discussion
Fungicide trial: Ergot was not detected in the fungicide trial plots in 2008. A low level of ergot (<0.51%) occurred in 2009 and 2010, but there was no significant difference in the level of ergot among the treatments.

Periodicity of ascospore and pollen release: Most ascospores of *C. purpurea* were trapped between 1:00 and 8:00 a.m. with few to no spores trapped between noon and 5:00 p.m. The occurrence of ascospores during the late evening through early morning hours is consistent with previously published data. Fewest grass pollen were trapped at about 5:00-6:00 a.m., followed by small peak between about 8:00 and 11:00 a.m. In *Poa pratensis* cultivars where the flowers open at night or early morning there would be a period when there are open flowers with unfertilized ovaries at about the same time as highest airborne ascospores numbers, increasing the chance of *C. purpurea* infection of Kentucky bluegrass. The scarcity or lack of spores during the afternoon suggests that in the Grande Ronde Valley, grass species that flower in the afternoon would be at less risk than Kentucky bluegrass, which typically flowers at night or morning, depending on cultivar. Resistance to ergot infection follows host fertilization, and consequently, flowers that escape infection and are pollinated later in the morning would develop resistance to infection.

Timing of ascospore and pollen release: Ascospores were trapped from mid-May through mid- to late-June (Figure 1). Total ascospores trapped at Site 1 in 2008, 2009 and 2010 were 7599, 181 and 1137, respectively. At Site 2 in 2008, 2009 and 2010 total ascospores trapped were 1332, 106 and 734, respectively. The long period of spore release is consistent with previous ergot spore trapping studies. The long spore release period is likely a reflection of variation in the timing of germination of sclerotia, and ascospore production from germinated sclerotia, which can extend for weeks.

The pattern of ascospore release was similar and ascospore numbers among the three sites were more or less parallel. This suggests that environmental conditions were similar among sites. The appearance of ascospores was several weeks in advance of flowering in Kentucky bluegrass occurring as early as May 14 in 2009 and 2010. The early appearance of ascospores suggests that early flowering grasses, including early flowering weed grasses, could be at greater risk of infection. Grasses such as annual bluegrass (*Poa annua* L.), which can flower weeks earlier than Kentucky bluegrass, could provide a potential source of secondary inoculum. The risk of infection from early flowering grasses in wheat has been demonstrated. Weed grasses common in Kentucky bluegrass fields in the Grand Ronda Valley that could potentially contribute sclerotia to the field including: cheatgrass (*Bromus tectorum* L.) and witchgrass (*Panicum capillare* L.).

In 2009, grass pollen was trapped about a week earlier than in 2008 and 2010 (Figure 2). Similarly, observed flowering in Kentucky bluegrass was earlier in 2009 and corresponded to a faster accumulation of degree days (Figure 3) relative to 2008 and 2010. Plant development, including the beginning and duration of flowering in Kentucky bluegrass is presumed to be a function of temperature.

Most of the ascospores were released before the start of flowering, resulting in the crop escaping infection. In 2009, a greater overlap between ascospores and pollen occurred, although few ascospores were present, and at numbers that were not likely sufficient to promote more than a low level of infection. Warm spring temperatures, which promote early flowering in Kentucky bluegrass could place the crop at greater risk for infection if there is greater overlap with ascospore occurrence. It may be possible to use a crop degree day model to predict the early flowering in Kentucky bluegrass.

It is not clear if the ascospores trapped at each site originated solely from within the fields included in the study, or from other fields or areas. The trapping of pollen in advance of flowering suggests immigration of pollen from surrounding fields. Ascospores are presumed to also be capable of immigrating into a field from sources outside the field. In an area such as the Grand Ronde Valley, where winds are common and wind direction variable, a single infested field could be a significant source of inoculum for surrounding fields. Additional studies would be needed to determine the relative contribution and significance of within field and outside field inoculum sources.

Susceptibility to ergot varies among cultivars, and ranges from highly susceptible to resistant. In a location such as the Grand Ronde Valley, in which many Kentucky bluegrass fields are within relatively close proximity, avoiding highly susceptible cultivars would be preferred. In highly susceptible cultivars, it is doubtful that fungicides alone would provide adequate control. Attempts to control ergot with fungicides have been met with mix results.

It is not clear to what extent secondary spread of ergot occurred in the plots as honeydew occurrence was not quantified. The potential for secondary spread depends on the period that seed heads emerge and the duration of flowering within seed heads. This can vary among cultivars. Cultivars in which most seed heads emerge about the same time and in which flowering duration is short will have the least risk for secondary spread, as there will be few newly opened and unfertilized flowers available for infection by the time that honeydew is produced. In cultivars with a longer flowering duration, secondary spread would depend on the number and movement of insects capable of transferring conidia from infected to uninfected, unfertilized flowers. It remains to be determined if irrigation washes honeydew off plants or contributes to secondary spread though rain splash.

Implications for control: From an ergot management perspective, cultivars highly susceptible to ergot should be avoided when possible, alternate hosts for *C. purpurea* should be strictly controlled both within and surrounding the field, and efficacious fungicides should be applied at the beginning of flowering. In addition, it may be possible to reduce the number of sclerotia in the field following harvest by post-harvest field burning. Currently, growers typically spray for powdery mildew in April to early May and for ergot early to mid June, depending on start of flowering, with a second application 14 days later. Study results suggest that monitoring the level of airborne ascospores prior to and during flowering in Kentucky bluegrass might provide a means to determine whether or not to apply up to two fungicide sprays for ergot control. On a broader level, a degree day model to predict early flowering in Kentucky bluegrass may have potential to predict years in which the crop may be at greater risk for ergot. Additional studies will be needed to establish the potential of these approaches as decision aides to eliminate one or both fungicide sprays for ergot control.

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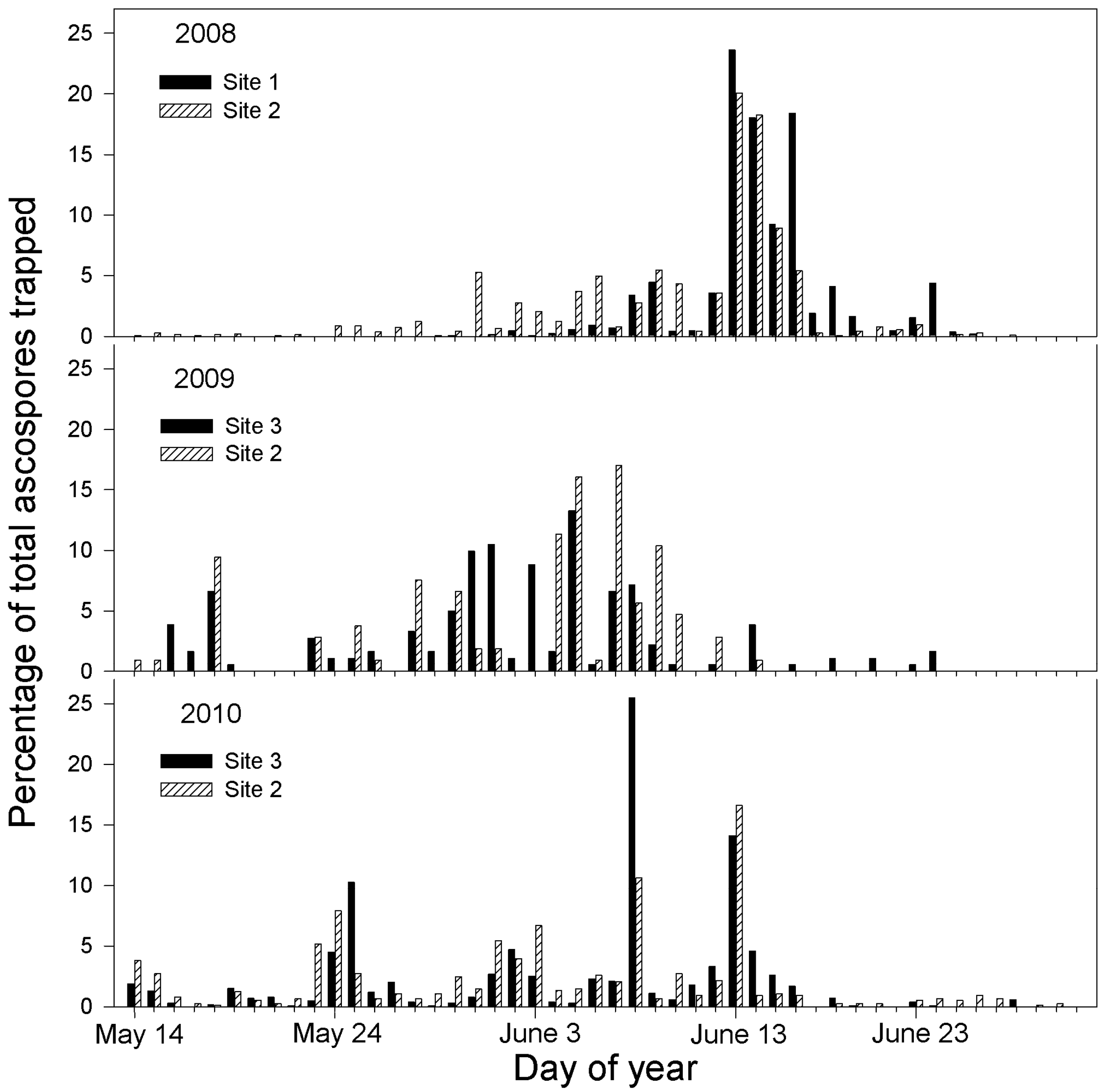

Figure 1. Daily percentage of total ascospores trapped in Kentucky bluegrass cv. "Midnight II" (Site 1 and 3) and "SR2100" (Site 2) in 2008-2010.

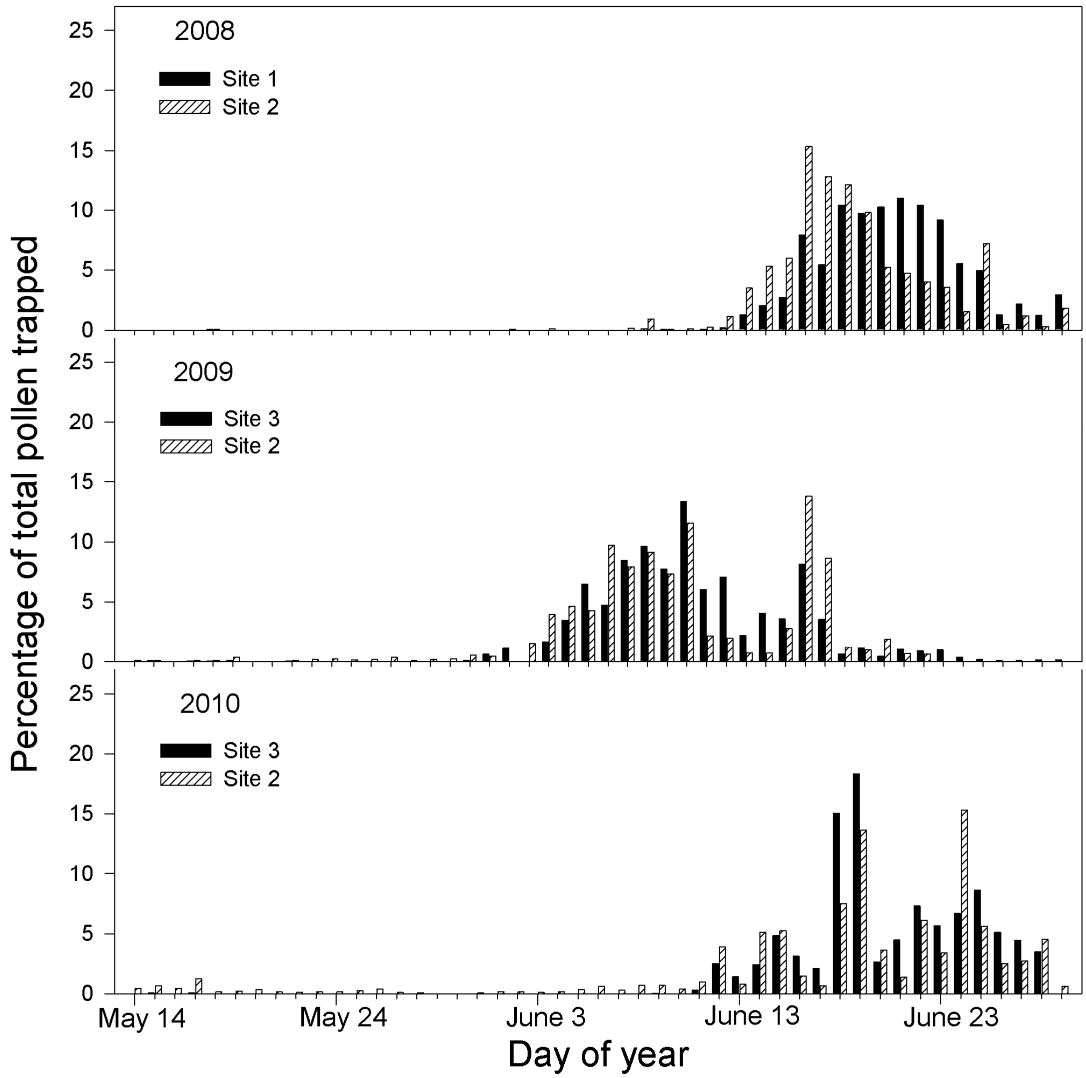

Figure 2. Daily percentage of total pollen trapped at in KBG cv. "Midnight II" (Site 1 and 3) and "SR2100" (Site 2) in 2008-2010.

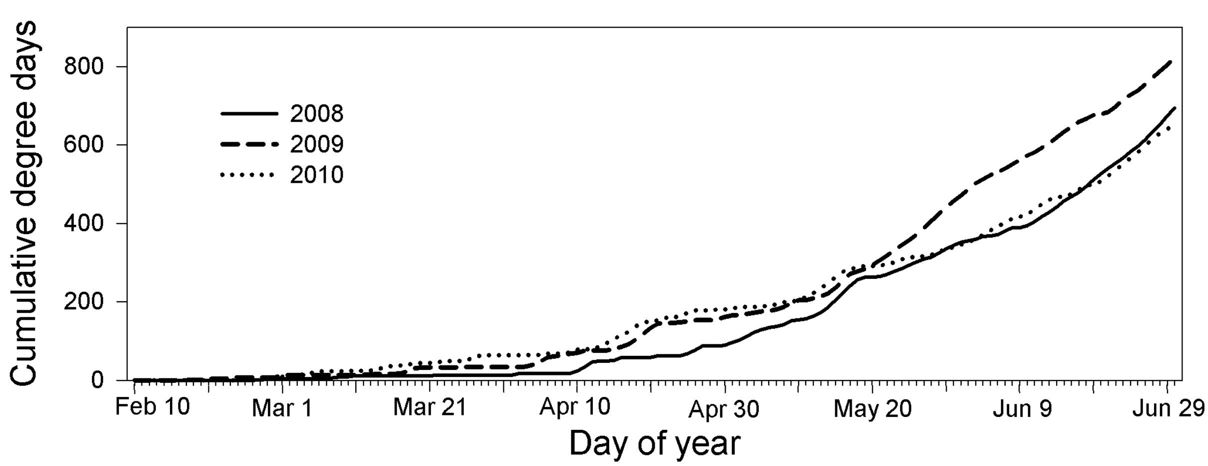

Figure 3. Cumulative degree days at Imbler, OR, 2008, 2009, and 2010, based on degree day data from Agrimet, Imbler, OR site.

IMPACT OF CEREAL LEAF BEETLE ON WINTER/SPRING WHEAT YIELD AND ECONOMIC THRESHOLD ASSESSMENT IN NE OREGON

D.L. Walenta and S. Rao

Introduction

Cereal leaf beetle (CLB), *Oulema melanopus* (Coleoptera, Chrysomelidae), is an invasive pest of economic concern to cereal grains, grass seed/forage crops and other grass-host species in the Pacific Northwest (PNW) region. CLB was first identified in Oregon in 1999 and has since been detected in 24 counties to date. ODA, USDA-APHIS and OSU collaborated and developed an integrated management program for CLB in the Willamette Valley and northeastern Oregon. The team implemented biological control with the introduction of *Tetrastichus julis* (Hymenoptera: Eulophidae), a tiny parasitoid wasp. CLB populations are largely kept in check by *T. julis* in areas with high parasitism rates but occasionally growers encounter CLB hot spots and insecticides are applied. In recent years, a nearly 30% reduction in harvested grass seed acreage in Oregon has occurred in the Willamette Valley while cereal grain acreage, particularly wheat, has increased. This is likely to increase insecticide use for CLB control. However, sustainability of biological control is dependent upon judicious use of insecticides. Hence, it is critical that economic threshold levels are adopted by growers when making decisions to spray their fields.

At the time CLB was first detected in the PNW, region-specific information related to host-crop preference, impact on host-crop yield, population monitoring techniques, economic threshold levels, and pest biology/management was non-existent. As a result, current economic threshold levels were adapted from the eastern U.S. which recommends insecticide application to cereal grain crops when CLB populations reach either: a) three eggs and/or larvae per plant up to the boot stage; or b) one larva per flag leaf during/after the boot stage. Field observations in northeastern Oregon suggest the boot stage threshold level was too high, therefore, prompting a field study to determine if adapted threshold levels were applicable to the area. Although the objectives of this study focused on northeastern Oregon wheat production in the Grand Ronde Valley, the information obtained from this effort could be of use to growers in the Willamette Valley given the increase in wheat production and the continued need to monitor pest populations and *T. julis* parasitism rates in all CLB-infested grass seed production areas.

Objective

The objective of this study was to determine the impact of CLB populations on winter and spring wheat crops grown in northeastern Oregon and to investigate the effectiveness of current economic threshold levels utilized for CLB management.

Methods and Materials

The study was conducted in 2004 and 2005 in established commercial production fields of soft white winter wheat, soft white spring wheat, and dark northern spring wheat located in Union and Wallowa County of northeastern Oregon. The experiment was setup as a randomized block design with 3 replications. Insecticide treatments consisted of: 1) insecticide applied, and 2) no insecticide applied. Replicated treatments were approximately 0.3 to 0.5 acres in size and designed to accommodate the use of commercial-sized equipment. Typical agronomic production practices for each study site were managed by the cooperating grower including the decision to treat CLB populations with an insecticide. Applications were made with either grower-owned or commercial spray equipment with the appropriate registered insecticide of choice for the respective crop.

The 2004 study consisted of a total of 7 sites including 3 winter wheat (2 dryland, 1 irrigated), 3 spring wheat (1 irrigated, 2 dryland), and 1 dark northern spring wheat (dryland) commercial production fields. The 2005 study consisted of a total of 4 sites including 1 soft white winter wheat (irrigated), 2 soft white spring wheat (1 irrigated, 1 dryland), and 1 dark northern spring wheat (irrigated) commercial production fields. Insecticide treatments were not replicated at each site in 2005.

<u>*CLB Population Sampling*</u>

At each study site, CLB egg and larvae populations were sampled 0 to 7 days prior to insecticide application and again approximately 14 days post-insecticide application. The decision to treat larval populations was determined by the cooperating grower and applied when larval feeding damage was evident and populations were in close proximity to or above current economic threshold levels. In the study, populations were determined by counting the total number of eggs and larvae per tiller from 10 tillers at 5 random locations, thus, yielding a total of 50 tillers sampled per replicated treatment. The number of larvae and eggs on each flag leaf were noted and included in the overall total for each tiller. Average numbers of egg, larvae, and egg + larvae *per tiller* and *per flag leaf* were calculated based on the results from inspecting 150 tillers total per treatment.

Flag Leaf Damage Assessments
Estimates of flag leaf defoliation by CLB larvae were determined by a digital image analysis technique (O'Neal et al, 2002) which utilized a flatbed scanner and imaging software to measure total leaf area and defoliated leaf area. The flag leaf and F-1 leaf were randomly collected from 20 tillers per replicated treatment (60 total tillers sampled per treatment) at each site. Time of leaf sample collection occurred when majority of larvae had moved to the soil to pupate. Leaf samples were prepared for analysis by being rinsed with tap water and blotted dry with paper towels, followed by placement in heat-sealed lamination pouches to preserve the leaves. In 2004, a total of 240 leaves from each site were collected and subjected to image analysis. Leaf defoliation measurements were not collected in 2005.

Grain Yield and Yield Loss Determination
Grain yield was determined by harvesting the center section of each replicated treatment with a commercial combine and the harvested grain was measured with a weigh wagon. Grain yield (bu/acre) and yield loss (for treatments not receiving an insecticide application) were then calculated for each replicated treatment.

Results
Winter Wheat
CLB adults usually emerge in late April to mid-May in NE Oregon and larvae are present when winter wheat crops are in the early boot to anthesis growth stages. Treatment decisions, therefore, were based upon the number of larva infesting the flag leaf. Current economic threshold levels after the boot stage (Feekes 9+) recommend insecticide application when larva populations reach an average of 1 larva/flag leaf.

In this study, CLB larva populations and level of flag leaf defoliation varied from between sites, but resulted in an average grain yield loss of -3 bu/a in 2004 and -14 bu/a in 2005 (Table 1). Winter wheat yield loss ranged from 0 to 18 bu/a, however, grain yield was negatively impacted at only two of the four sites (data not shown). Insecticide treatment at all sites prevented further leaf defoliation and significant yield loss. CLB impact on grain yield did not appear to be influenced by either dryland or irrigated production systems included in this study.

Interestingly, pre-treatment flag leaf populations of CLB larvae met current economic threshold levels at only one winter wheat site which resulted in no yield loss. At all other sites, flag leaf larvae populations collected prior to insecticide application were lower than current threshold levels with an average of 0.4 larvae/flag leaf (Table 1) and range from 0.2 to 0.6 larvae/flag leaf.

Spring Wheat
CLB larvae emerge and begin feeding on NE Oregon spring wheat typically when the crop is in the seedling to early boot growth stages. In this study, all spring wheat sites were in the early boot stage (flag leaf present) when pre-treatment CLB population data was collected. Data in Table 2 indicate flag leaf CLB larvae population averaged 0.6 and 1.0 larvae/flag leaf in 2004 and 2005, respectively, and was higher than in winter wheat. Yield loss occurred at all sites, regardless of irrigated or dryland production system, with an average yield loss of -13 bu/a in 2004 and -19 bu/a in 2005 (Table 2). Compared to winter wheat, these results are indicative of increased susceptibility of spring wheat to CLB damage. Flag leaf defoliation was more severe in spring wheat with damage levels reaching 29% in soft white spring and 36% in dark northern spring (data not shown). Insecticide treatment at these sites prevented further leaf defoliation and significant yield loss.

Discussion and Implications
This study suggests that for both spring and winter wheat, the pre-boot economic threshold of 3 eggs and/or larvae is applicable to northeastern Oregon production systems. However, once the flag leaf emerges (Feekes 9+), the economic threshold level for average # larvae/flag leaf may be less than 1 if two conditions are met: 1) overall health/vigor of the crop is low; and 2) if total # larvae per tiller >1. The overall health and vigor of a particular crop can influence crop tolerance to CLB feeding damage or other pest-related injury. Research from the eastern U.S. indicates effective CLB management techniques include sound cultural production practices that promote early planted, well-tillered wheat crops (Philips et al., 2011). Additional research is needed to further define economic thresholds for all market classes of small grains grown in both dryland and irrigated production systems.

In areas where turf grass and forage seed is produced, the new CLB adults that appear when pupation is complete in the summer and when small grains have matured may migrate to alternate host sites prior to dispersal to overwintering sites (Rao et al., 2004). New stands of annual and perennial ryegrass, orchardgrass and tall fescue (planted the previous spring) are at moderate to high risk for damage by the "summer" adults. It is recommended that seedling grass fields are monitored in late summer especially if in close proximity to small grain production fields.

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Table 1. CLB population and impact on commercial soft white winter wheat yield – Union County, Oregon (2004 and 2005, across all study sites).

Treatment	Number of larvae per tiller[1]	Number of larvae per flag leaf[1]	Percent flag leaf defoliation[2]	Percent yield loss
		2004		
No Insecticide	0.7	0.4	22	-3
Insecticide	0.1	0	6	0
		2005		
No Insecticide	1.5	0.4	na	-14
Insecticide	0.7	0.2	na	0

[1]Approximately 14 days after insecticide application.

[2]Flag leaf defoliation area determined when 90% of CLB larvae entered pupation.

Table 2. CLB population and impact on commercial soft white spring wheat yield – Union County, Oregon (2004 and 2005, across all study sites).

Treatment	Number of larvae per tiller[1]	Number of larvae per flag leaf[1]	Percent flag leaf defoliation[2]	Percent yield loss
		2004		
No Insecticide	0.7	0.6	25	13
Insecticide	0.1	0.1	1	0
		2005		
No Insecticide	3.1	1.0	na	19
Insecticide	0.1	0.1	na	0

[1]Approximately 14 days after insecticide application.

[2]Flag leaf defoliation area determined when 90% of CLB larvae initiated pupation.

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Business Address

Oregon Seed Council
494 State Street, Suite 220
Salem, OR 97301

Tel: (503) 585-1157
FAX: (503) 585-1292
E-mail: roger@rwbeyer.com
www.OregonSeedCouncil.org

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